RADIATION HAZARDS

Are you considering purchasing a microwave oven, or a home located next to radio, TV, or other high power antenna installations? If your answer is "yes", you had better not read this section of *ITEM*, for it may give you cause to reconsider your decision.

We are, from the moment of conception, bathed in a sea of electromagnetic waves. Some of these waves are benign or even beneficial, while others are definitely harmful. Part of this radiation is natural and part is man-made. Natural radiation includes the light, radio-waves and cosmic rays from the Sun, Moon and stars; background radiation from the rocks, soil, water and atmosphere of our planets; and the internal radioactivity of our own bodies. Man-made radiation, which forms an increasingly large proportion of the whole, includes radio and radar waves.

It is obvious that we must be more or less immune to any kind of radiation which normally reaches us from outer space, yet earthworms are killed by sunlight even when kept damp and cool, and occasionally human children are born who are abnormally photosensitive and eventually die from the effects of sunlight. Moreover, sunlight can induce skin cancer as well as an attractive tan, and certain drugs have a strongly photosensitizing effect, which makes it necessary for patients who are taking them to use a barrier cream against the enhanced action of ultraviolet rays.

Within the last nine years there have been many reports concerning previously unnoticed effects of radio waves on animals.

The Canadian National Research Council has used radio waves of 1.8cm wavelength in experiments to clear airfields of birds which might endanger aircraft. The report refers to "dramatic nervous system disturbances" produced in birds by microwave fields. At intensities of only 10 to 30 milliwatts per sq. cm., chickens collapse within a few seconds, although apparently without permanent injury. Such fields are too weak for heating effects to be involved, and researchers in the department of physiology at the University of Ottawa, are trying to elucidate the physiological mechanism. In 1960, Dr. Swann at Rome Air Force Base (New York State) carried out experiments on Rhesus monkeys, irradiating their heads with weak 91 centimeter waves. The animals died in about two minutes. In 1966, Dr. Susan Korbel at the University of Arkansas, found that rats were rendered "lethargic, irritable, and more susceptible to seizures induced by noise or electric shock" when irradiated for prolonged periods with very weak (one to two milliwatts per sq. cm.) radiation at wavelengths between 86 and 94cm.

But the interaction of Man with his radiation evironment is not just a question of the presence of harmful waves: the absence of certain wavelengths can also be fatal in a larger dose.

Savages, who may go for long intervals without food, sometimes die from the effects of excessive meat eating when at last their hunting is successful. Others die from either an overall shortage of food or a lack of protective vitamins or mineral "trace" elements. The radiation equivalents of these nutritional diseases are not easy to define, but heavy doses of any very short wavelengths are fatal, and ill-health, if not death, will result from an insufficiency of visible light and also from lack of the near-infrared and near ultraviolet rays.

At present, the hazards due to sound or ultrasound have not been thoroughly investigated. Yet the risks may sometimes be serious, at least for people working in high noise-levels for prolonged periods, and to those subjected to sonic booms from aircraft. It is fairly well-known that protracted exposure to loud noises can produce both deafness and nervous disorders, but it is only recently that experiments on animals have shown that multilated children may be born as a result of the mother being exposed to sonic booms during pregnancy.

Magnetic Fields:

It has been known for many years that magnetic fields can magnetize watches, meters, and hypodermic needles. They can erase intelligence from magnetic tape but it is only within the past twenty-five years that the thesis that magnetic fields interact with biological organisms has become acceptable to most scientists. As magnetic fields are becoming more and more associated with telecommunication systems, and as humans are being brought into closer contact with them, an examination of the present state of the art might be of value.

Each magnetic field, as is well known, has certain characteristics which permit its classification; these are: strength, direction, variation with time, and field configuration (i.e. uniform or non-uniform pattern of force). All of these aspects must be considered in any possible biological interaction. While not the most important, field strength is generally the primary variable in any experiment and may be arbitrarily classified as follows: high (in excess of 100 gauss), medium (10 to 100 gauss), and low (1 to 10 gauss). The earth's normal magnetic field averages from 1/2 to 1 gauss. Added to these variables in the physical realm are certain biological variables such as: the spatial relationship of the organism to the magnetic field, the duration of exposure, the species of organism, etc. Considering all of these variables, it is easy to understand why confusing and at times contradictory reports have appeared in the literature.

It would seem logical that the highest field strengths would be associated with the greatest detectable biological effects; however, the present literature does not support this thesis. While a host of relatively minor effects upon lower animals are reported, the most significant effect of high strength field exposure in mammals appears to be alterations in the electrical activity of the central nervous system, with possible associated pathological lesions in the brain. It would at this time, therefore, appear desirable to avoid exposure of humans (either total body or head alone) to field strengths in excess of 1,000 gauss, which might be found in the near vicinity of magnetohydrodynamic (MHD) equipment, in attempts to control atomic fusion reactions by intense magnetic fields, very large D.C. electrical transmissions, such as in the aluminum smelting industries, and in magmetic separation procedures, for anything other than short time periods. In particular, the suggestion to utilize magnetic shielding against radiation for space capsules, should also be most carefully evaluated before being put to use. Another caution would be in the application of high strength fields modulated at certain frequencies. Since certain definite effects seem to be associated with low strength, low frequency (0.1 - 0.2 Hz) fields, human exposure to high strength similarly modulated fields should definitely be avoided except under controlled experimental conditions.

To sum up, there are definite biological effects of magnetic fields. Of these, the most important to humans accidently exposed appear to be those related to central nervous system effects. It would appear desirable to limit human exposures to magnetic fields of very high strength (any configuration or frequency) to short periods of time only, and during such exposures to expect a possible deterioration in performance. Moderate strength fields of frequencies appropriate to produce magneto phosphenes should be avoided in any situation requiring the maximum performance relating to command or guidance decisions such as space craft cabins, supersonic transport pilot compartments, or hazardous experimental situations dealing with MHD power production. Any individual exposure to low strength fields modulated at very low frequency (0.1 Hz ect.) should be avoided for similar situations as well as inadvertent exposures of larger population groups to similar fields. While it is evident that certain elements of the population are more sensitive to these physical parameters, it is not known whether long term exposures could be cumulative and involve larger segments of the population. It should be emphasized that certain industrial or communications techniques could result in the exposure of relatively large population groups to such fields entirely without the knowledge of the exposed individuals.

Safe RF Fields:

The "magic" number for determining a radiation hazard condition is the field strength 10 milliwats per square meter. An explanation of how this value was derived can be found in the Handbook on *Radio Frequency Radiation Hazards* (T.O. 31-1-80) dated 15 April, 1958, published under authority of the Secretary of the Air Force. Two pertinent paragraphs are excerpted as follows:

"Based on evidence given in paragraph 1-7, that injury had been caused to experimental animals and could possibly be caused to personnel, all available information was researched in an effort to establish a safe exposure level to this form of possible injury. Many variables were considered, such as the frequency of the energy to which an individual may be exposed, the nature of the exposure, including time of exposure, field strength, and other aspects.

Sufficient factual data is not available to determine the safe exposure level for each frequency; therefore, it was decided to select one level satisfactory for all frequencies. Past research indicated that a power density of 0.2 watts/cm2 was required to produce damage. The accuracy of the methods and instrumentation used was somewhat questionable, and possibly some cases of reported damage might have been caused by power densities of approximately 0.1 watts/cm2. The expanded use of electronics has also resulted in adding minute amounts of microwave energy from incidental sources at many frequencies. Since it is impractical to measure the power density at each of these frequencies separately, and since the sum of all these assorted r-f sources would be extremely small, a safety factor of 10 was selected and the present USAF level of 0.01 watts/-cm2 was established.

NOTE

Incidental sources do *not* include other high power electronics equipment in the vicinity.

This level of 0.01 watts/cm2 is an *average* power level and not peak power, since available data indicates the only detrimental effects are thermal in nature, and these effects depend upon average and not peak power levels. Sufficient data is not available to furnish complete correlation between length of exposure and power density. The present level of 0.01 watts/cm2 is the maximum for either continuous or intermittent exposure, and precautions should be taken to avoid exposure of personnel to ambient power levels in excess of 0.01 watts/cm2 for any period of time."

In October of 1961, T.O. 31-1-80 was superceded by T.O. 31Z-10-4. The revised handbook went deeper into the problem, but maintained the 10ms/sq. meter magic value. One of the new aspects introduced was the relationship of man's physical size to wavelength. It states that when considering the biological effects produced by r-f radiation, the wavelength (frequency) of the energy and its relationship to the physical dimensions of objects exposed to radiation become important factors. It has been determined that for any significant effect to occur, the physical size of the object must be the equivalent of at least a tenth of wavelength at the frequency of radiation.

Practically speaking, the human body is a three-dimensional mass having width and depth, as well as height. Therefore, when a man stands erect in an r-f field, he represents an object which not only has a height dimension, but also has width and depth dimensions that can be expressed in terms of wavelength. Again comparing the physical characteristics of the human body to those of a broadband receiving antenna, when the body is oriented so that any of these major body dimensions is parallel to the plane of polarization of the r-f energy, the effects produced are likely to be more pronounced than when the body is oriented to other positions.

The penetration of energy into the body and its absorption (loss of energy), and reflection will depend not only upon the physical dimensions and dielectric constant of the tissues, but also upon the frequency (wavelength) of the r-f radiation.

The handbook also discusses the frequency-dependent characteristices of whole body exposure. It states that the percentage of absorbed biologically effective energy approaches 40 percent of the incident energy for frequencies below 1000 mc (30 cm) and for frequencies above 3000 mc (10 cm).

The percentage of absorbed biologically effective energy is between 20 and 100 percent of the incident energy for frequencies between approximately 1000 and 3000 mc (30 to 10 cm wavelength).

The sensory elements of the body are located primarily in the skin tissues; for this reason radiation frequencies below 1000 mc are considered extremely hazardous because the presence of r-f radiation will not be detected by the human sensory system. Radiation at frequencies below 1000 mc causes heat to be developed primarily in the deep tissues as a result of the penetration of the energy. The energy absorbed in body tissues may be as high as 40 percent of the incident energy arriving at the body surface.

Frequencies greater than approximately 3000 mc cause heating of tissues in much the same manner as does infrared radiation or direct sunlight; therefore, the sensory reaction of the skin should normally provide adequate warning of the presence of r-f radiation. In general, the depth of energy penetration decreases rapidly with an increase in radiation frequency, and absorption occurs almost completely in the surface of the body where skin tissues and the sensory elements are located. Also, reflection of energy at the surface of the skin occurs at the higher frequencies. Thus, the percentage of energy abosrbed may approach 40 percent of the energy incident on the body surface, with a greater portion of energy being reflected.

Radiation at frequencies between 1000 and 3000 mc is subject to varying degrees of penetration and is abosrbed in both surface tissues and deeper tissues, depending upon the characteristics of the tissues themselves (thickness, dielectric constant, and conductivity) and the frequency of radiation. The percentage of incident energy absorbed varies from approximately 20 to 100 percent because of tissue factors governing impedance values, which range from complete mismatch, to a near perfect match, to the incident energy.

When electromagnetic energy is absorbed in tissues of the body, heat is produced in the tissues. If the organism cannot dissipate this heat energy as fast as it is produced, the internal temperature of the body will rise. This may result in damage to the tissue and if the rise is sufficiently high, in the death of the organism. The body's ability to dissipate heat successfully depends upon many related factors, such as environmental air circulation rate, humidity, air temperature, body metabolic rate, clothing, power density of the radiation field, amount of energy absorbed, and duration of exposure (time).

The limited ability of the body to dissipate heat when its temperature is elevated above normal is complicated by the fact that the basal metabolic rate increases as much as 14 percent for every degree of temperature rise above normal. The increase in temperature also causes abnormally rapid breathing, or fever hyperpnea. The lack of oxygen available in the blood for release to cells or tissues results in hemorrhages and damage to the brain cells, the central nervous system, and certain internal organs, and may also result in muscular irritability and sometimes convulsions. If these conditions persist, the results are usually coma and eventual death.

Certain organs of the body are considered to be more susceptible than others to the effects of r-f radiation. Organs such as the lungs, the eyes, the testicles, the gall bladder, the urinary bladder, and portions of the gastrointestinal tract are not cooled by an abundant flow of blood through the vascular system. Therefore, these organs are more likely to be damaged by heat resulting from excessive exposure to radiation. Of the organs just mentioned, presently available information and experience indicate that the eyes and testicles are the most vulnerable to microwave radiation.

The handbook concludes by discussing non-thermal effects. It states that another resonance,which is not dimensional, depends primarily upon the material irradiated and its molecular structure. The electrons orbiting about the nucleus can resonate; also, the nucleus itself can resonate and orient itself with respect to the energy field. These molecular resonances could result in movement of the constituents of the molecule in such a manner as to stretch and strain the bonds between them. It is therefore conceivable that breakage of the molecular bonds could occur if placed under extreme stress, as when exposed to pulsed energy at high peak power, and yet not be accompanied by sufficient rise in temperature to be considered a thermal effect. Thus, the molecule could be modified and broken up to form different molecules and result in denaturation of living tissues.

A phenomenon known as the "pearl-chain formation" has been observed in milk and human blood. The phenomenon can be demonstrated by passing an alternating current through water in which droplets of oil are floating. Before the alternating current is applied, the droplets assume random positions on the surface, but when current is applied, the oil droplets move into groups and align themselves to form "chains". These chain-like groups resemble short strings of pearls, from which the name of the phenomenon is derived. When the current is turned off, the droplets break up the formation and return to random positions. If the current is interrupted as though pulsed, the chain formation starts to break up, but quickly reforms when the current is again applied. The effect observed is as though a string of pearls were pulled taut, relaxed, and then pulled taut again.

Russian Regulation:

Report number AD 278 172 is based on a translation of a book by Professor A.A. Letavet and Decent Z.V. Gordon of the Institute of Labor Hygiene and Occupational Diseases of the Academy of Medical Sciences, U.S.S.R. The book is dated, Moscow, 1960 and bears the title, "The Biological Action of Ultrahigh Frequencies."

The publication contains many conclusions apparently based upon actual case histories of humans exposed to microwave energy and is in sharp contrast to most of the experimental data available in the United States which has, in general, been obtained from experiments performed with animals.

The following general effects of chronic exposure of humans to microwave energy were reported:

a. Bradycardia, or an inhibiting effect on the rhythm of heart contractions.
b. A disruption of the endocrine-humeral processes.
c. Hypotension, or low blood pressure.
d. Intensification of activity of the thyroid gland.
e. An exhausting influence on the central nervous system.
f. A decrease in sensitivity of the sense of smell.
g. An increase in the histamine content of the blood.

The general effects listed above were established on the basis of a considerable amount of clinical data accumulated by the Institute of Labor Hygiene over a period of years. The data concerned the state of health of employees in both industrial plants and research laboratories where microwave generating equipment was fabricated, tested or operated.

In chronic exposure experiments at low power density (10 milliwatts per cm^2 and below), the central nervous system proved to be most sensitive to the action of microwave energy and reacted earliest.

The report goes on to state that U.S. Army Regulation AR 40-583, dated 12 July 1961 specifies 10 milliwatts per square centimeter as a permissible limit for exposure of humans to microwave energy. The Russian safety regulations for exposure of humans to microwave energy are so much more stringent than those specified in AR 40-583 that the permissible limits are here reproduced for emphasis:

"The microwave radiation intensity in areas where personnel are required to be present should not exceed the following maximum permissible values:
a. In the case of irradiation during the entire working day - no more than 0.01 milliwatts/cm^2.
b. In the case of irradiation for no more than two hours per working day - no more than 0.1 milliwatts/cm^2.
c. In the case of irradiation for no more than 15 to 20 minutes per working day - no more than 1.0 milliwatt/cm^2. (In this case the use of protective goggles is mandatory.)"

What Are We Doing About It?

In the ten years preceding the last Tri-Service Symposium (1960) on the "Biological Effects of Microwaves," a considerable community of researchers participated in the study of interaction of microwaves with biological systems, particularly animals and man. Military standards were confirmed at 10 mw/cm^2 maximum permissible exposure levels based on the conclusion that all significant effects were thermal in nature.

There has been little activity in this field until this year. If the recent symposium held in Richmond, Virginia, on September 17-19 is any indicator, however, there is a revival of interest despite little new knowledge. This conference was sponsored by the Bureau of Radiological Health (BRH of the Department of HEW) and the Medical College of Virginia partly with the aim of providing new information for BRH in its new safety standards work in the field of microwaves.

At the present time, there is no agreement on what should be done. The Russian work appears to concern itself primarily with effects on the central nervous system. They report that certain people working in a microwave environment have headaches, nervousness, dizziness, falling hair, etc. We have reports of individuals in the U.S. who suffer from "microwave headaches." The capability of the Russians in this type of work is such that we should not ignore their results. On the other hand, to suddenly jump to a specification which is substantially more stringent on the users of microwave energy than has been the case in the recent past, might be an unnecessary, expensive, and restrictive precaution. The meeting in Richmond was a small, but important step in the right direction.

Is This Interference Control?

Radiation hazards are directly related to interference control. This relationship does not necessarily include the biological effects, but can be found in the design of equipment and the measurement of the environment. It is the Interference Technology which will lead to the design of safe microwave ovens, the inclusion of shielding properties in homes and buildings, and the development of instrumentation and test techniques to measure the environment in which we live.