and the currently accepted model for predicting the dielectric behavior of membranes, the Hodgkin-Huxley model, may be due to the possibility that effects at the level of biologic systems may not be predictable on the basis of the behavior of isolated molecular systems. The question of the energy difference between conformational states of biopolymers was raised; the effects of the shape and nature of experimental containers and depth of liquid on the actual field in studies of MW irradiation of biologic preparations were discussed; and the question of the existence of cumulative effects in cataractogenesis was discussed at some length. The problem of runaway heating in the MW heating of frozen tissues was also mentioned. The principal conclusions drawn from the six papers presented were set forth. Summing up the session, multidisciplinary research by a team of investigators comprising at least a doctor, biophysicist or physicist, and electrical engineer was strongly recommended.

0448 SESSION D. MEASUREMENTS OF MICROWAVE RADIATION. *(E.)* R. C. Baird, P. Czerski, A. W. Guy and M. Piotrowski. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 327-329.

Understanding of the biologic effects observed in specimens exposed to EM fields requires a complete quantitative description of the fields inside and outside the test subject. These fields are a complex function of the types of sources and the shape and size of the exposed subject. External fields have been specified in terms of power density, but the electric field or square of the electric field are more reliable indicators of possible biologic effects. Accurate instrument calibration is necessary for safety reasons and to provide interlaboratory comparisons of experimental results. Three approaches to calibration, all of which can be reasonably accurate, were discussed: the free-space standard field method, guided wave methods, and the standard probe or transfer standard method. Internal fields and power absorption may be directly measured *in vivo* by implanted electromagnetically transparent probes, though accurate and reliable probes still need to be developed. The problem of perielectrode energy observed in brain tissue was discussed as, in general, any time a sharp metal object is put in contact with tissue, field enhancement results at the point of contact. Diffraction patterns produced when a human subject is exposed to a MW field of 1-3 GHz were described, showing that the field is strongly perturbed by the subject. A simplified method for determining radiation hazards associated with radar antennas employing assumed radiation patterns based on selective measurements was described. The need for complete data on dielectric properties of biologic substances was discussed. The session made the following recommendations: (1) accurate internal dosimeters are needed; (2) standard methods for quantifying fields and detecting biologic signals should be established; (3) standardized exposure techniques should exist between laboratories; (4) researchers should describe all pertinent experimental conditions; (5) the development of magnetic field sensors should be promoted; (6) more complete information on EM and thermodynamic properties of biologic materials are needed; and (7) an interdisciplinary group should be established to translate and disseminate documents pertaining to biologic and engineering aspects of research on biologic effects of EM radiation.

0449 SESSION E. OCCUPATIONAL EXPOSURE AND PUBLIC HEALTH ASPECTS OF MICROWAVE RADIATION. *(E.)* Z. Edelwejn, R. L. Elder, E. Klimková-Deutschová and B. Tengroth. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 330-331.

The difficulties of rigidly controlled long-term clinical and epidemiologic studies were discussed. Environmental factors such as ambient temperature and exposure to x-rays, the lack of serious cardiovascular disturbances due to MW exposure, the fact that clinical findings in the case of longterm or overexposure are referable to the nervous systems, and "MW neurosis" were mentioned. Inclusive discussion concerned MW lens and eye injury. Biologic effects and health hazards to the general population and the methodological difficulties of large population research studies in the working environment were also discussed. The clinical studies presented led to recommendations for studies dealing with: suitable preventive measures for persons occupationally exposed to MW and for the general population, epidemiologic comparative and dynamic studies, and refinement of tests of motor system function as a diagnostic tool. Examination of the retina in all ophthalmologic examinations was also recommended.

0450 SESSION F. PRESENTATION AND DISCUSSION OF SESSION REPORTS, CONCLUSIONS (INCLUDING FUTURE RESEARCH NEEDS) AND RECOMMENDATIONS. *(E.)*

J. C. Gallagher, K. V. Nikonova, E. Shalmon and C. Susskind. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 332-335.

A single paper was presented on the use of microwaves as tools in biological research. Bound water in tissues was discussed. The second part of the session was devoted to session reports and recommendations, which included: (1) There should be continued international exchange of information, improved translation services, exchange visits, and closer international collaboration. (2) A program concerned with nonionizing radiation should be developed by an international health agency. (3) Internationally acceptable nomenclature and definitions and standardization of measurement techniques should be established. (4) Microwave intensities should be divided into three approximate ranges as suggested in Session A. (5) New electrode systems and integrated electrode/signal amplifying systems should be developed. (6) Further studies are needed to improve understanding of interaction of MW radiation with biologic systems in the following areas: cumu-

lative and delayed effects; low-intensity effects; determination of possible threshold values; combined effects of radiation and other environmental factors; investigation of differential radiation sensitivity; effects related to cellular transformation; effects at the molecular level; and determination of absorbed energy dose and its spatial distribution. Similar investigations in the RF range were emphasized.

0451 EVALUATION OF THE INTERNATIONAL SYMPOSIUM ON BIOLOGICAL EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION - WARSAW, POLAND, 15-18 OCTOBER, 1973. *(E.)* Michaelson, S. M. (Univ. Rochester Sch. Med. Dent., N.Y.). *Univ. Rochester At. Energ. Proj. Rept.* No. UR-3420-457, 1973, 28p.

Following the 1973 Warsaw International Symposium on Biologic Effects and Health Hazards of Microwave Radiation, the World Health Organization's (WHO) Regional Office for Europe convened a group of experts to review the results of the symposium and to advise the Office on future plans for evaluation of the public health risks from MW radiation. Papers evaluated by the Group are summarized under the headings: Measurement of Electromagnetic Fields; Survey of Biological Effects, including Cellular and Molecular Effects, Thermal Effects, Cataracts; Central Nervous System Interactions; Occupational and Public Health Aspects; and Microwaves as a Tool in Medical and Biological Research. Recommendations for further action in some of these areas are presented along with a list of recommendations relating to the international exchange of data on the bioeffects of MWs and to other areas in which additional information is needed. The Group emphasizes that measurement of MW fields is complicated and still in a developmental state. A clear understanding of bioeffects in man, animals, and biological specimens exposed to EMF requires a complete quantitative description of the field both inside and outside the test subject. Accordingly, the Group recommends development of accurate internal dosimeters; increased efforts to quantify internal fields; and establishment of standard methods of quantifying internal and external fields and of detecting biological signals. The Group suggested the convening of a small working group of specialists to discuss and evaluate available instruments for measuring complex MW fields, and to provide a standardized description of their selection and use, including calibration and intercomparison of calibration. Further, the Group suggests convening a working group to discuss instrumentation for *in vivo* and *in vitro* measurements of MW fields in biological objects. Additionally, the Group suggests that available literature on the biological effects of MWs be analyzed by a small working group for evidence or rejection of threshold phenomena; if the data do not permit a definitive evaluation, recommendations should be made for appropriate biological investigations. In the area of epidemiologic studies, a working group should be convened to identify appropriate groups and risk and to determine study procedures. Carefully controlled epidemiologic studies are required to determine the biophysical mechanisms of microwave interaction with complex systems such as cellular and subcellular structures. The convening of working groups is also recommended to evaluate the compatibility between MW radiation and medical electronic equipment and to determine the risk from certain types of diathermy equipment. Other actions urged by the Group include a symposium on MW biophysics, biology, and potential health hazards; standardization of nomenclature used in discussing the effects of exposure to MW/RF energies; promotion of interaction between physical engineering and biological scientists; evaluation of ambient EM fields by a consultant and later, if a serious increase occurs, by a working group; a survey to establish consistency of product performance standards for MW-emitting devices with personal exposure standards; and a training program for health physicists and public health officials responsible for evaluating MW and RF radiation. (No references)

PREPRINTS

0452 A THEORETICAL ESTIMATION OF TISSUE ANISOTROPY EFFECTS ON ELECTROMAGNETIC POWER DEPOSITION -- 0.1 TO 100 MHz. *(E.)* Johnson, C. C. (Dep. Biophys. Bioeng., Univ. Utah, Salt Lake City) and C. H. Durney.

Muscle anisotropy has been demonstrated at ECG frequencies (below 100 Hz) by closing a battery-activated circuit for 0.1 sec to simulate the QRS complex. Greater than 15:1 changes in conductivity were measured as current flow was applied parallel to and then perpendicular to the direction of human skeletal muscle fibers. EM power deposition was studied theoretically by correlating the ECG anisotropy conductivity data with Schwan's data describing conductivity and permittivity variations with frequency in terms of a relaxation phenomenon associated with cell wall polarization. With E-fields perpendicular to the muscle fiber area, an estimate of σ variation with frequency was inferred. For E parallel to the fibers, no cell-wall polarization effects were assumed and thus no change in σ and ϵ in the range 0.1 MHz to less than 100 MHz. Expressions were derived for absorbed power distribution in a plane layered medium and for the case of a planewave in air striking an air-fat interface and then a fat-anisotropic muscle interface. With these expressions, variation in power deposited in muscle tissue can be calculated as a function of polarization, fat thickness, and frequency. (4 references)

0453 RAMAN SPECTROSCOPY OF MOLECULAR SPECIES DURING EXPOSURE TO 100 MHz RADIO FREQUENCY FIELDS. *(E.)* Klainer, S. M. (Block Eng., Inc., Cambridge, Mass.) and J. W. Frazer.

A Raman spectrometer with an argon ion laser was used to observe the effects of 100 MHz RF fields on glycine, ATP, *Escherichia coli* tRNA, and chymotrypsin molecules. No perturbations of glycine or ATP spectra were found in carefully stirred solutions where thermal gradients were avoided. *E. coli* tRNA, conversely, lost several of the peaks associated with intramolecular hydrogen bonding that appear in the region 800 cm^{-1} to 2000 cm^{-1}. The most pronounced loss was in the adenine-guanosine cross bonding; this effect was produced with a power feed of 8 W, corresponding to a field of about 400 V/cm. At input powers of 3 W ($\sim$150 V/cm) and 4 W ($\sim$200 V/cm), chymotrypsin showed a progressive loss of several prominent peaks in the 209 cm^{-1} to 600 cm^{-1} region. When power was increased to 5 W, the entire solution became very turbid. These results suggest that alterations in the Raman spectra may show effects of applied fields on the tertiary structure of large molecules in addition to providing information usually contained in dielectric dispersion spectra. (5 references)

0454 ELECTROMAGNETIC POWER ABSORPTION IN ANISOTROPIC TISSUE MEDIA. *(E.)* Johnson, C. C. (Dep. Biophys. Bioeng., Univ. Utah, Salt Lake City), C. H. Durney and H. Massoudi.

Strong dielectric constant anisotropy exists in muscle tissue at the lower MW frequencies. Based on a model derived from tissue measurements at 0.001-100 MHz, an analysis is carried out for single and multiple tissue layers. The model assumes an idealized anisotropic tissue medium consisting of infinitely long, perfectly parallel muscle fibers generating relaxation effects only where there are E field components perpendicular to the fibers. Calculated effects of tissue anisotropy on MW fields and power absorption in tissues at two frequencies are presented. The effect of polarization on power absorption is significant at 0.01 MHz but not at 100 MHz. Further research on anisotropic effects must involve models more representative of human- or animal-sized bodies. (3 references)

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0100 EFFECTS OF ELECTROMAGNETIC FIELDS ON GENETIC PHENOMENA. Brever, G. (Dep. Zool., Univ. Oklahoma, Norman).

See CR 0015, Volume I(1), for description of this research. (Renewed 7/73-6/74)

SUPPORTING AGENCY:EPA, Off. Res. Dev.

0101 TREATMENT OF TRICEP'S SURAE CONTRACTURES. Lehmann, J. F. (Univ. Washington Sch. Med., Seattle).

The objective of this study is to develop a more efficient nonsurgical method of combating equinus deformity that occurs as a result of gastrocneumius and soleus contractures. Loading--with and without diathermy--is added at a prescribed rate with simultaneous readout of the strain produced. The gain was approximately one degree of dorsiflexion per day at the ankle in patients with recent (as opposed to long standing) contractures, in patients with lower motor neuron disease, and in young muscular dystrophy patients. Patients with upper motor neuron lesions immediately gained full range of motion, but it is uncertain whether true contractures or muscle tone problems were present in these cases. Optimal conditions for selectively heating the calf musculature have been developed by using a specially designed microwave applicator, but investigations are still preliminary. (7/72-6/73)

SUPPORTING AGENCY:HEW, Soc. Rehab. Serv.

0102 INVESTIGATION OF OCULAR EFFECTS OF CHRONIC EXPOSURE OF PRIMATES TO MICROWAVE RADIATION AT 2.45 GHz. Polson, P. (Stanford Res. Inst., Menlo Park, Calif.).

The objective of the initial phase of this study will be the design, development, calibration, and testing of exposure cavities. The cavities developed will be utilized to study MW effects to determine safe exposures for military personnel. The exposure cage will be designed as a "stirred," multimode resonant cavity so that animals will constitute virtually the entire power absorption load within the cavity. It will be designed so that animals will have free movement with capabilities to control and monitor ambient temperature and humidity, and to view and feed exposed animals. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Army

0103 ANALYSIS AND PREPARATION OF AVAILABLE WORLD LITERATURE ON BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION. Lindberg, R.; Larrimore, J. (Technol. Labs., Mead Corp., Dayton, Ohio).

Literature selected and included in the *Biological Effects of Electromagnetic Radiation Digest* produced by the Science Information Services Department of the Franklin Institute Research Laboratories, under another contract with the Army, will be entered into a computerized file in full text and in a manner to provide rapid review and retrieval. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Army

0104 PROGRAM ON THE QUANTITATION OF THE EFFECTS OF ELECTROMAGNETIC ENERGY ON HUMAN TISSUE. Guy, A. W. (Med. Rehab. Res. Train. Cent., Univ. Washington, Seattle).

A renewal of the contract reported in CR 0044, Volume I (2), is being conducted to advance the existing knowledge on the quantitative effects of electromagnetic radiation on the human body and to provide realistic guidelines for safety standards of human exposure. The progress and findings of this on-going project include: (1) The minimum cataractogenic threshold in the eyes of a rabbit exposed to EM energy was determined. (2) The threshold for human auditory perception of incident MW pulses was found to correspond to a specific pulse energy density regardless of average or peak power. (3) Calculated peak pressures induced in mammalian tissues by the incident electric field energy were found to be above the cone-conduction threshold. (4) The behavior of the spinal cord exposed to high level microwaves indicates that this CNS structure is subject to functional alteration by the impingement of radiation. (7/74-6/75)

Supporting Agency:HEW, Soc. Rehab. Serv.

0105 OCULAR EFFECTS OF MICROWAVE RADIATION. Carpenter, R. L. (Northeast Radiol. Hlth. Lab, Winchester, Mass.).

The objective of the research is to determine the threshold conditions for the production of microwave induced cataracts and to characterize these cataracts uniquely. The effect of frequency, dose regimen and pulsing on the threshold for cataract formation in rabbits will be investigated. Biochemical and histopathological examinations of microwave irradiated lenses will be performed in order to determine if microwave induced cataracts differ in any characterizable manner from cataracts of other etiologies. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0106 THE EFFECTS OF MICROWAVE RADIATION ON THE CENTRAL NERVOUS SYSTEM. Albert, E. N. (George Washington Univ. Sch. Med., Washington, D.C.).

The project will investigate, using light and electron microscopy, the existence of morphological alterations in animals exposed to microwave irradiation. Chinese hamsters are being irradiated with microwaves at 12.5 cm and power levels of 10, 25, and 50 mW/cm^2. Brain nuclei will be examined for radiation-induced changes using both light and electron microscopy. Special emphasis will be placed on the mitochondria, nucleolus, rough endoplasmic reticulum, golgi apparatus, and lysosomes. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0107 INVESTIGATION OF BIOMOLECULAR FUNCTIONS BY MICROWAVE RADIATION. Eisenbud, M.; Rabinowitz, J. R. ((New York Univ. Sch. Med., New York City).

Work is being conducted to describe the mechanisms by which the absorption of microwave energy can interfere with the function of the absorbing biological molecule; and to attempt experimentally to demonstrate these mechanisms in biological systems and identify the specific biomolecules involved. Tranquilized rabbits will be irradiated at 2450 MHz to determine the cause of the decrease in ascorbic acid concentration of the lens. Irradiated and control lenses will be cultured in a media containing C^{14} ascorbic acid, then C^{14} activity of the lenses determined after removal from the media. If it is transport that is affected, and the element changed is in the transport system of the lens, then the study will determine if ascorbic acid transport is stereo-specific in the lens. Research will also aim at determining if microwave irradiation increases the concentration of acetylcholine when an animal is irradiated at 2450 MHZ using a power density of 40 mW/cm^2, and if the hydrolysis of acetylcholine by acetylcholine esterase is affected by irradiation. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0108 NAVY ENVIRONMENT: MUTAGENIC EFFECTS DUE TO MICROWAVE RADIATION GENERATED BY NAVAL OPERATIONS. Varma, M. M.; Joshi, S. R. (Sch. Eng., Howard Univ., Washington, D.C.).

See CR 0046, Volume I (2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0109 NAVY ENVIRONMENT: EFFECTS ON BIOLOGICAL SYSTEMS DUE TO MICROWAVE IRRADIATION. Durney, C. H.; Lords, J. L. (Sch. Engr., Univ. Utah, Salt Lake City).

This research continues study of the response of isolated turtle and rat hearts to low power MW radiation. Hearts from freshly killed turtles are placed in Ringers solution and a record of physical and electrical activity is taken until stabilization occurs. Microwave power is then delivered to the heart and the activities of the heart recorded. Chemical stimulants and depressants are added to determine which of the two parts of the autonomic nervous system are most affected by the microwave field. The microwave field parameters will be varied and mammalian (rat) hearts will also be studied. See CR 0037, Volume I (2), for earlier work in this project. (Renewed 7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0000 PERSONNEL TECHNOLOGY: OCEAN ENGINEERING AND BIOMEDICAL RESEARCH. Wheeler, E. J. (Wheeler Industries, Inc., Washington, D.C.).

See CR 0067, Volume I (2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0111 NAVY ENVIRONMENT: QUANTITATION OF MICROWAVE RADIATION EFFECTS ON THE HEAD AND EYES OF RABBITS, PRIMATES AND MAN. Guy, A. W.; Piroska, D. (Univ. Washington Sch. Med., Seattle).

See CR 0029, Volume I (1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0112 INFLUENCES OF VERY WEAK EXTRA-PHOTIC ELECTROMAGNETIC FIELDS. Brown, F. A. (Dep. Biol. Sci., Northwestern Univ., Evanston, Ill.).

Systematic variations in living systems in constancy of obvious environmental factors are reported to include such phenomena as geographic directional preference, spontaneous activity and standard metabolism, seed germination and growth, response to light, and gas and water uptake by seeds. Correlations with weather parameters, with solar activity and geomagnetic changes, with major geophysical periodicities, and between organisms simultaneously investigated at separated sites have been described. These, together with recent experimental demonstrations of an apparently highly specialized organismic responsiveness to diverse parameters of the extremely weak geoelectromagnetic fields, suggest the organismic variations reflect responsiveness to their varying ambient subtle physical fields and the fields have roles for biological clocks and orientation. Recent discoveries of organismic in-

teractions through biologically generated electromagnetic fields and discovery of plus and minus response states now emphasize further potential significances of the phenomenon. Objectives of this investigation include further searches for subtle geophysical influences for selected plants, invertebrates, and vertebrates and include such processes as directional preferences, light responses, spontaneous activity, growth rates, and water uptake by seeds. Common denominators will be sought, experimental manipulation and regulation of the phenomenon will be attempted, and efforts made toward disclosure of effective atmospheric parameters. (11/74-10/75)

Supporting Agency:U.S. Natl. Sci. Found., Div. Biol. Med. Sci.

0113 NAVY ENVIRONMENT: NONTHERMAL HAZARDS OF EXPOSURE TO RADIOFREQUENCY AND MICROWAVE FIELDS. Mickey, G. H. (New England Inst., Ridgefield, Conn.).

These experiments test for chromosome damage or malformation in live animals and cultured cells following microwave treatment in the X and K bands and radio frequency (RF) exposure between 15 and 40 MHz. Cytologic assays are being carried out to determine chromosome aberrations in cultures of Chinese hamster lung cells and lymphocytes irradiated *in vitro* and in bone marrow cells, cells of the testes, and lymphocytes irradiated *in vivo*. Studies will be done using *Drosophila* to determine if RF and microwaves at the above frequencies will have genetic effects as evidenced by nondisjunction, chromosome abnormalities and mutations. See CR 0012, Volume I (1), for further information on this research. (Renewed 7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0114 EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION ON SUBCELLULAR PREPARATIONS. Straub, K. D. (Univ. Arkansas Sch. Med., Little Rock).

The project will explore the effect of ELF and microwave radiations on the subcellular preparations responsible for active transport and oxidative phosphorylation. The work involves exposing microsomal cell membrane and (Na^+ and K^+) ATPase from several sources (ox brain, rat brain, gar olfactory nerves, and invertebrate peripheral neurons) to both ELF-ULF (10 Hz - 30 kHz), VHF-UHF (30-300 MHz) and microwave radiation (1-12 GHz) in especially constructed cells. Measurement of the various parameters of this membrane preparation will be made including K_m and V_{max} for Na^+, K^+, and Mg^{++} and ATP, ouabain sensitivity and lipase activation. Fluorescent probes of membrane structures will be used to assess the extent of change in membrane conformation. Simultaneously rat liver and rat brain mitochondria will be exposed to these frequencies using the same exposure cells. The O_2 consumption, ADP/O ratios, state 3-4 transition, control ratios, swelling and shrinking, and state of electron carriers will be measured. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0115 A PRELIMINARY SURVEY OF VETERANS WHO MAY HAVE BEEN EXPOSED TO CATARACT PRODUCING RADIATION. McAfee, R. D.; Cazenavette, L. L.; Holland, M. G.; Robinett, C. D. (Tulane Univ., New Orleans, La.).

A pilot program was reported in CR 0030, Volume I (1). The National Academy of Sciences, National Research Council, Medical Followup Agency, is cooperating in enlarging the original pilot study to a full scale investigation of electronic technicians who may have been exposed to microwave radiation (as well as controls). It will be their task to obtain the names and addresses of selected groups of veterans to whom the shadowgraph device will be mailed. Medical Followup people will also participate in the statistical interpretation of the data obtained. (Renewed 7/74-6/75)

Supporting Agency:U.S. Vet. Adm.

0116 SEQUENTIAL CHEMOTHERAPY AND HYPERTHERMIA IN THE TREATMENT OF EXPERIMENTAL GLIOMAS. Sutton, C. H.; Popoff, N.; Carroll, F. B. (Neurosurg. Sect., VA Hosp., Miami, Fla.).

In order to explore the antineoplastic effects of moderate hyperthermia alone and as an adjuvant in the chemotherapy of malignant gliomas of the brain, a method, employing MW radiation at 2,450 MHz, has been devised for heating rat brain, murine gliomas and cell cultures. The gliomas can be implanted either intracranially or subcutaneously. Lipid crystal was used to map the MW field. It was possible to heat both normal and neoplastic tissues uniformly and reproducibly at sublethal dosages. In one series of experiments, mice with bilateral flank implants of experimental glioma were subjected to MW heating of one implant at increasing increments of temperature and time from 37 C to 45 C. Tumor blood flow, as measured with intratumoral 133 Xenon clearance, increased in normothermic mice with implant heating up to 42 C for decreasing periods of time, followed by a rapid diminution in flow. Histochemical studies on heated implants showed that the secondary rapid decrease in blood flow was produced by vessel coagulation secondary to excessive heating. Increased flow had resulted from vascular dilatation. In hypothermic mice, increased tumor blood flow persisted for prolonged periods. This temperature gradient may serve to achieve greater concentrations of intravenous agent in gliomas. When rat brain was heated selectively, the blood-brain barrier, as studied with horseradish peroxidase, was resistant to MW radiation at lower dosages, but could be disrupted by excessive heating. Systemic hypothermia increased its tolerance. The barrier was disrupted in the white matter of

cerebellum before that in cerebrum. Studies have been initiated to determine the cell cycle kinetics of both lines of hyperthermia and individual antineoplastic agents. Studies of the uptake of these agents with isotopic labels in heated and unheated implants is also in progress. (7/74-6/75)

Supporting Agency:U.S. Vet. Adm.

0117 BIOLOGICAL EFFECTS AND HAZARDS OF MICROWAVE RADIATION. Sharp, J. C.; Grove, H. M. (Walter Reed Army Inst. Res., Washington, D.C.).

Research has been undertaken to establish meaningful criteria to delimit human operations in an EM environment and to determine maximum combat effectiveness at minimum personnel risk from the environment. The study will delineate the interaction of RF and MW radiation 100 MHz to 100 GHz with biological systems, survey and evaluate all known methods and techniques of MW dosimetry and develop improved techniques and instrumentation where appropriate and necessary. Each major organ system and biological process will be investigated where there is reason to believe microwave effects may occur at reasonable power intensities. Where indicated, the military significance of the effects and the measures necessary to obviate them will be determined. A data bank of the world literature on the biological effects and hazards of EM radiation is to be established and maintained. Initial scientific efforts will use evaluative methods from experimental psychology, electrophysiology and neurochemistry. Exposure parameters will be chosen for relevance to army radiating equipment and operational requirements. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Army

0118 PERSONNEL EXPOSURE CRITERIA FOR OPERATIONAL RADIOFREQUENCY RADIATION ENVIRONMENTS. Frazer, J. W.; Gass, A. H. (Sch. Aerospace Med., Brooks Air Force Base, San Antonio, Tex.).

The primary objective is to establish appropriate personnel exposure criteria for operational RF radiation environments. Current exposure guidelines are not adequate for many operational situations. The results of this work will be used as the biomedical data base to establish both normal and emergency exposure limits for specific operational situations. These data are needed to support site selections and site layout and to establish shielding requirements and operational maintenance procedures for systems such as the Over-The-Horizon (OTH) radar for CONUS defense. A series of exploratory tests will be conducted to establish power absorption/energy deposition parameters as a function of frequency, field intensity, sample configuration, and environmental stress. Initial studies will be conducted at HF band frequencies of 10.5, 19.27, or 26.6 MHz using a 50 kW pulse transmitter. These studies will include irradiation and measurement of resulting temperature changes in sensing implants, and evaluation of the RF radiation induced effect on the growth rate in mice. Subsequent studies will be conducted using the new 40 kW (AN/FRT-6B) CW transmitter. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Air Force

0119 MIXED RF/IONIZING RADIATION EFFECTS. Krupp, J. H.; Barnes, D. J. (Sch. Aerospace Med., Brooks Air Force Base, San Antonio, Tex.).

See CR 0039, Volume I (2), for description of this research. (Renewal 7/74-6/75)

Supporting Agency:U.S. Dep. Defense, Air Force

0120 RADIOFREQUENCY RADIATION INTERFERENCE (RFI) OF MEDICAL PROSTHETIC DEVICES. Mitchell, J. C.; Hart, W. D. (Sch. Aerospace Med., Brooks Air Force Base, San Antonio, Tex.).

This research is being conducted to develop test data on the interaction of Air Force RF radiation emitters and medical prosthetic devices. The initial objective is to assess manufacturers' progress in developing cardiac pacemakers to operate properly in pulsed RF fields of 200 volts per meter. The overall purpose of this R & D effort is to resolve the potential hazard to cardiac pacemaker users in the vicinity of RF radiation emitters. A state-of-the-art test sample of cardiac pacemakers including approximately 20 types made by 10 different manufacturers will be tested to a variety of RF radiation sources. Tests will be conducted in both "free-field" and "simulated-implant" configurations, in the laboratory, and at radar and communication sites remote from Brooks AFB. Test plans include studies using the AWACS radar, AN/FPS-24 and 35 research radar, AN/MPS-T1 ECM threat simulators, AN/FRT-49 ground to air telemetry system, and a Loran system. The AN/FPS-85 and an AN/TPS-44 may also be studied. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Air Force

0121 RADIOFREQUENCY EFFECTS ON BIOCHEMICAL SYSTEMS IN THE CENTRAL NERVOUS SYSTEM. Merritt, J. H.; Frazer, J. W. (Sch. Aerospace Med., Brooks Air Force Base, San Antonio, Tex.).

The USAF has an on-going R & D effort to evaluate the biological effects of RF radiation associated with planned or operational radar systems. This effort will evaluate "near field" exposures representative of those associated with the 414L OTH radar system. Data will be applied to USAF safety criteria for this and other systems. The study will evaluate the effects of RF radiation on those biochemical events subserving and associated with neural impulse transmissions in the central nervous system. Simultaneous estimations of 5-hydroxyindole-

acetic acid, homovanillic acid, norepinephrine, dopamine, and 5-hydroxytryptamine will be made in discrete brain areas of rats exposed to RF fields. Preliminary studies of the effect of a defined electrical stimulus and hyperthermia on the levels of these transmitters will be made. After preliminary data have been obtained, the effect of "far field" conditions (19 MHz) at both CW and pulsed modes on the neurotransmitters will be determined. The same studies will be done using animals exposed on the SAM "near-field" simulator. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Air Force

0122 IMPACT OF RF BIOEFFECTS ON AF OPERATIONS. Mitchell, J. C. (Sch. Aerospace Med., Brooks Air Force Base, San Antonio, Tex.).

Specific Air Force systems RF emission and bioeffects studies will be conducted and a state-of-technology data base maintained to support environmental impact positions and operational RF safety criteria for future and ongoing systems such as AN/FPS-85, AWACS, 487L, 414L, Pave-paws, and Seeksail. RF radiation effects data applicable to AF RF safety criteria and systems' operations will be compiled as background information. Systems' studies will be undertaken in accordance with mission direction. The RF biomedical data base generated under this effort will be used in support of the AF petition for a change in OSHA standards, Title 29, CFR 1910.97 and in the revision of AFM 161-7. Initial state-of-the-art data will be obtained through a multi-agency contract with the Franklin Institute to provide a quarterly *Biological Effects of Electromagnetic Radiation Digest*.

Supporting Agency:U.S. Dep. Def., Air Force

0123 EFFECTS OF LOW FREQUENCY A-C FIELDS ON BIOLOGICAL SYSTEMS. McKinney, H. E. (U.S. Navy, Crew Syst. Dep., Warminster, Pa.).

CR 0103, this issue, describes this project. H. E. McKinney replaces K. D. Straub as principal investigator during this contract period. (Renewed 7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0124 BIOCHEMICAL MEASURES OF MICROWAVE INDUCED STRESS. Polis, B. D.; Cope, F. (U.S. Navy, Crew Syst. Dep., Warminster, Pa.).

The stress induced by microwave radiation using chemical and physiological changes to determine possible health hazards will be measured. The direct relation of the rise in plasma phospholipids to stress of various kinds has been established by the biochemistry laboratory of NAVAIRDEVCEN. Phospholipid changes have been correlated with CNS excitation caused by injection of free radical structures discovered at NAVAIRDEVCEN. The levels of MW power which cause biochemical and EEG indication of stress will be investigated. Alteration with frequency, pulse light, duty cycle will also be studied. From the results, information will become available to establish safety standards. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy

0125 EFFECTS OF MICROWAVE IRRADIATION ON EMBRYONIC BRAIN TISSUE. Rioch, D. M. (Inst. Behav. Res., Silver Spring, Md.).

Preliminary studies have indicated that moderate to low level exposure to microwaves causes increasing mitotic activity of primordial neuroblasts. A study will be made of those effects and their implications on brain development and behavior factors of rats so exposed. The Army is a major developer and user of ground located devices using MW beams. The effects on man or animals accidentally irradiated are of considerable concern. Adequate knowledge will allow establishment of improved safety criteria and avoid establishment of excessive restrictions on their use by other governmental agencies. Phase I of the project will study neuroanatomic alterations during fetal and subsequent development. Gestational stage, exposure mode (cavity vs free space), and variations in MW parameters (frequencies, power densities, exposure rates) will be included. Phases II and III will depend on the success of Phase I. Phase II will study behavioral consequences of alterations found in Phase I, the biophysical properties operative, and the nature of mechanisms causing alterations. The objectives of Phase III are to provide a detailed description of neuroanatomical alterations in the developing brain resulting from fetal brain MW insult. An operational explanation of the biophysical parameter important to the alterations will be developed and the behavioral and physiological effects of brains so altered "in utero" will be assessed. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Army

Biological Effects Electromagnetic Radiation II(1), March 1975

TECHNICAL NOTES

PRELIMINARY INVESTIGATION OF THE RF EXPOSURE OF CLINICAL PERSONNEL USING 13.56 MHz DIATHERMY EQUIPMENT

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Introduction

Constant vigilance is maintained throughout the USAF laboratories to minimize personnel radiofrequency (RF) radiation exposures. In response to a recent question concerning potential hazards with the use and control of RF diathermy machines, a survey was performed on two Birtcher Model 800 diathermy units (13.56 MHz) at Wilford Hall Medical Center, Lackland AFB, Texas.

Procedure

The survey was performed with NBS built and calibrated E-field (dipole) and H-field (loop) probes and a Narda Model 8310 electromagnetic radiation monitor with a Model 8321 broad-band isotropic probe. The first survey (Birtcher Model 800, Serial #B115E7201) was performed with the patient reclined on a treatment table with the applicator in the region of the knees. Three orthogonal readings were made with the NBS dipole and these readings converted to incident power density. Three orthogonal readings were also made with the H-field probe and these readings converted to incident power density. The field measurements were applied as follows:

$$\text{Incident Power Density in mW/cm}^2 = \frac{E_1^{\,2} + E_2^{\,2} + E_3^{\,2}}{3770}$$

Where E is in V/m

$$\text{Incident Power Density in mW/cm}^2 = 37.7(H_1^{\,2} + H_2^{\,2} + H_3^{\,2})$$

Where H is in A/m

A second series of measurements was made using the Birtcher Model 800, Serial #3108E7664 with another patient seated in a chair and the applicator on the left arm. The 10 mW/cm^2 isodose lines were located using the E-field probes.

Results

For 13.56 MHz CW the NBS dipole and Narda instrument agree within 10%. It should be cautioned that if the Narda probe is used in a pulsed field in this frequency range, large errors can result; the instrument being designed for 0.3 to 18 GHz operation. The E-field devices indicated the 10 mW/cm^2 isodose line extended from 2 to 3 feet from the applicator for either exposure geometry. Treatment tables were approximately 5 feet apart and survey of adjacent treatment tables indicated the field to be less than 1 mW/cm^2. The incident power in the area where the therapist stood to tune the diathermy was less than 1 mW/cm^2 and the therapist was only in the immediate area for 2-3 minutes during the treatment. H-field measurements made at several locations indicated a field strength which was about a factor of 2 higher than would be indicated by the E-field measurements, that is E/H = 200. For the second exposure geometry the loop was inserted between the applicator and the patient's arm, and the field density was determined to be 3770 mW/cm^2. Although the measurement in this geometry is of questionable absolute accuracy, it does indicate the magnitude of the power density and the patient reported only a slight sensation of heating in the treated area. For the second exposure, measurements above the patient's head indicated fields which were less than 1 mW/cm^2.

Conclusions

Extremely high fields are generated near the applicator of these specific devices; however, the untreated areas of the patient, as well as the surrounding area occupied by the therapist and other patients, are well below 10 mW/cm^2. The patients reported little if any sensation of heating for 20 minute treatments. The results of these measurements show no exposure problem for the therapist or patients in this specific clinical situation. Several other AF diathermy clinics will be surveyed to cover the other diathermy frequencies and ascertain if any potential personnel hazards exist.

LETTERS TO THE EDITOR

Extending the Parameters of the Digest

Dear Sir: I have received your letter regarding informal exchange program in biological effects of non-ionizing EM radiation. I have also received a letter from Dr. Kleinstein of the Franklin Institute which is apparently relevant to the same topic.

I am very interested in this field and am pleased to see that an informal exchange is being set up. I note from Dr. Kleinstein's letter that the electrical EM parameters are to be microwave and RF's; all of our work is in static or low frequency fields, and I would have nothing to contribute to the present bibliography. I suggest that you consider extending the scope of the parameters to include this additional area; we have found certain specific effects and there are collaborative reports in the literature in this area.

Robert O. Becker, M.D.
Medical Investigator
Veterans Administration Hospital
Syracuse, New York 13210

Ed.'s Note: A special section or special report could be devoted to static and low frequency fields in an issue later this year. Those interested should complete the General Information form, or suggest other sources of work in this area.

Low-level High Frequency Current Flows

Dear Sir: I would be most interested in receiving your current awareness bulletin on the biological effects of non-ionizing radiation, since I am involved with several committees of the NFPA and IEEE in this area.

Could I suggest a subject for early discussion? The effects on infants (or neo-natal animals) of the application of low-level high frequency currents for long periods of time. Low-level would be 10 to 500 microamperes. We are usually concerned with currents flowing through the body rather than radiation fields. Frequency range is 10 KHz to 10MHz. Duration is one hour to one week.

While this is probably not your area of prime concern, it is a significant problem in patient monitoring. If there is nothing much in the literature about it now, perhaps it could go out as a question.

Saul Aronow, Ph.D.
Department of Radiology
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Boston, Massachusetts 02114

Ed.'s Note: Send suggested sources or references directly to Dr. Aronow or the digest

Gordon Conference of EM Radiation Suggested

Dear Sir: I was most pleased to learn from your letter of July 1, of the Science Information Services effort to produce a current awareness bulletin on the biological effects of non-ionizing electromagnetic radiation. I am currently doing research in this area, as you may know, and would like to be on your mailing list and assist you in any way possible.

It occurred to me that your quarterly publication might serve as a vehicle to present the idea of organizing a Gordon Research Conference on the Biological Effects of Non-Ionizing Electromagnetic Radiation. The readers of your bulletin would appear to be the individuals who would benefit from such a meeting and if the idea is presented I feel it might serve as the impetus leading to the organization of a much needed meeting of this type. I hope you will consider this further and contact me if it appears feasible to pursue.

Stephen F. Cleary, Ph.D.
Medical College of Virginia
Richmond, Virginia 23298

Ed.'s Note: The digest is exploring this possibility; reader's comments would be appreciated.

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