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SECTION I

INTRODUCTION

(U) The effects of radiowaves and microwaves on biological systems have traditionally been separated into two basic classifications, (1) thermal effects, and (2) nonthermal effects. The thermal effects are widely recognized and the mechanism of action reasonably well understood. Nonthermal effects, however, are controversial since the mechanisms involved are not clearly understood. Soviet and East European scientists believe that biological side-effects occur at power densities that are too low to produce obvious thermal effects. Such effects have been questioned in the West because experimental evidence, obtained largely in US laboratories, does not corroborate occurrence of nonthermal side-effects.

(U) Divergences in opinion between Bloc and Western researchers concerning the effects of microwave radiation are the result of nonstandardized research protocols and materials. In addition, mechanisms underlying observed biological effects are at present poorly understood by any of the world's scientists engaged in microwave research. The exchange of scientific information on microwave hazards has increased greatly since the active participation of Soviet, Czechoslovak, and Polish scientists in the International Symposium on Biological Effects and Health Hazards of Microwave Radiation in Warsaw in October 1973.

(U) It is now generally agreed that biological systems irradiated with electromagnetic waves in the radiowave and microwave frequency ranges (one kilohertz to more than 10^5 megahertz) absorb varying amounts of energy depending on the irradiation frequencies and the physical properties of the system. Typically, however, 40-50 percent of the incident energy is absorbed by the biological system and the remainder reflected. In reality, only the shorter wavelengths represent any appreciable hazard as a result of thermal heating. Radiation fields in the microwave range vary in wavelength from about one meter to very short wavelengths on the order of a millimeter. The depth of penetration of the waves is also variable and again depends on the frequency, wave polarization, and the physical properties of the system (i.e., dielectric and geometric), but typical penetrations are on the order of 1/10 of the wavelength. Therefore, very short waves are absorbed primarily by the skin, while long wavelengths penetrate to much greater depths.

(U) The degree of heating appears to be a function of the water content of the tissue and probably results from oscillations of water molecules or dipoles. Another possibility is a resonance absorption of energy by protein molecules of the cell. As might be expected, the actual damages resulting from a given exposure are functions of the thermal regulatory

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and active adaptation processes of the organ or animal. Less vascularized tissues are more susceptible to thermal damage because of a poorer ability to dissipate the heat, therefore, crystalline lens damage or cataract formation may be observed.

(U) Many techniques and indices have been employed to study the effects of irradiation on biological systems. These include:

Body weight.

Biochemical studies.

Cardiovascular studies.

CNS effects (including conditioned and unconditioned reflexes).

Electrophysiological measurements.

Fertility and mutation studies.

Histology and pathology studies.

Metabolic studies.

Temperature.

While these and other experimental studies have been conducted on animal and cellular models, knowledge regarding human exposure has been almost exclusively obtained retrospectively. Accordingly, information regarding the amount and/or portion of the body exposed, field intensities, and duration of exposure are usually ill defined.

(U) As can be seen from the above, quantitation of the biological responses to electromagnetic exposure is a very complex problem because of the wide frequency spectrum, the large number of physical and biological variables, and the interrelationships of those variables. Factors requiring consideration include the frequency, intensity, waveform, (pulsed, CW, or modulated) configuration of the body, its orientation with respect to the source, portion of the body irradiated, exposure time-intensity factors, environmental conditions (temperature, humidity, and air currents), and shielding. Other complicating factors include the subject's state of health and previous or concomitant medication. In addition to the above factors, the animal species used and its comparative relation to man is important. Accordingly, experimental results from animals cannot easily be extrapolated and assumed to apply to human exposure because of size differences relative to exposure wavelength which can markedly influence the system or organ being damaged.

(U) With these complicating factors in mind, the evaluation contained in this report was undertaken. The data presented were obtained from the sources outlined in the preface and sometimes contained insufficient information to make absolute decisions regarding their significance. The sources were, however, indicative of the types of effects being reported and suggested those areas of research being emphasized, thereby permitting assessment of recent Eurasian Communist attempts to define the biological effects of radiowaves and microwaves.

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SECTION II

BIOLOGICAL SIGNIFICANCE OF RADIOWAVES AND MICROWAVES

PART I - BLOOD

(U) Effects of electromagnetic irradiation on the blood include biochemical variations, effects on erythrocytes, changes in coagulation, and alterations in the blood forming system. As would be expected, most communist country reports originate from in vitro or in vivo animal experiments rather than from human data.

(U) Long-term ultrahigh frequency (UHF) exposure in rats reportedly reduced the iron and copper content in both the blood and muscle with a concomitant increase in iron content in the liver. Similar exposure in chicks caused an increase in total proteins and globulins, but decreased the albumin in the plasma. Rats exposed to 0.04 W/cm^2 for 25 days demonstrated similar shifts. In some studies with dogs, irradiation with microwaves significantly decreased the lifetime of erythrocytes, while other studies indicated no changes in the granulocytic system after exposure. In the lymphocytic system, however, mitotic disturbances and changes of nuclear structure occurred. Rabbits exposed to "an electromagnetic field" showed significant increases in the number of monocytes, basophils, and lymphocytes/mm. Although undesirable, these shifts are not significant enough to impair the functional performance of humans. However, they are significant enough to warrant further experimentation. Soviet researchers will emphasize more experiments with animals and they will continue to try and relate these experiments to data on human exposure to microwave environments. They will most likely work toward relating such changes in different species of animals to particular intensities or exposures.

(U) One study involved the observation of several thousand persons working in microwave-irradiated workshops, as well as animal experiments. In the human subjects, three kinds of damage were found:

- (1) Lymphocytosis and monocytosis.
- (2) Granulocytopenia, monocytosis, and eosinophilia frequently accompanied by absolute lymphocytosis.
- (3) Moderate neutrophilia.

The degree of changes in the blood could be correlated with exposure and/or duration of working period. This determination was based on the relative changes as a function of period of employment, which was felt to indicate a cumulative effect of microwaves in the human body. The type and intensity of the exposure was not documented.

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(U) Blood coagulation indices of dogs subjected to high intensity super-high frequency fields were studied at intervals of ten minutes to thirty days after irradiation. Initially the coagulation time was prolonged, but two hours after irradiation it was accelerated as a result of protective compensatory changes in neurohumoral factors. The protective reaction was, however, of short duration; the irradiation-induced prolongation of coagulation time reappeared and the animals' clotting times did not return to normal until at least fifteen days after exposure. Another study showed that long-term exposure to microwaves at a power density of $10\text{mW}/\text{cm}^2$ decreased the overall activity of butyrylcholinesterase in the blood serum of rats. Under conditions of whole-body exposure, the microwaves did not exert a consistent effect on the enzyme molecule. The decrease in the overall activity of butyrylcholinesterase was correlated with a decrease in its concentration in the blood of the irradiated animals.

(U) The action of microwaves on human erythrocyte permeability to potassium and sodium ions was also investigated. The mechanism of action appears to be an inhibition of active transport and an altered diffusion through the pores in the membrane. The latter may be caused by the influence of UHF energy on the membrane itself or on the hydrated sodium cation and potassium cation. The microwaves either change the membrane structure thereby increasing the passive sodium cation and potassium cation diffusion and reducing the concentration gradient, or somehow block the mechanism of active ion transport.

(U) The question of stability of microwave-induced changes in blood components was addressed in chronic and acute tests using dogs and rabbits. The irradiation was at a frequency of 2375 MHz with a field strength of thirty microwatts per square centimeter. The rabbits were subjected to between one and ten irradiations of sixty minutes duration each, and the dogs were subjected to repeated irradiations over a period of more than a year. The changes in the blood and marrow of rabbits were found to be unstable and to pass after a period of five to ten days. Changes observed in the chronically exposed dogs were more stable, but became normalized over a period of twenty-five days. Investigation of chronic microwave irradiation on the blood-forming system of guinea pigs and rabbits was also reviewed. Both continuous wave (CW) and pulsed microwaves were utilized at an intensity of $3.5\text{mW}/\text{cm}^2$ and a wavelength of 10 cm. Increases in absolute lymphocyte counts in peripheral blood, abnormalities in nuclear structure, and mitosis in the erythroblastic cell series in the bone marrow and in lymphoid cells in lymph nodes and spleen were observed. The changes appeared to be a cumulative result of repeated irradiations and were attributed to nonthermal effects. There is limited evidence to support the belief that these cumulative effects are reversible upon cessation of exposure. It is still not quite clear if similar results could be observed in humans since wide species-variations have been observed by Soviet researchers working with animals.

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(U) The primary concern of the present study was with electromagnetic field effects, but numerous reports regarding the effects of constant magnetic fields on the blood system were noted during the review. As with electromagnetic effects, effects on coagulation, biochemical properties, and formed elements were observed.

(U) To summarize the effects of electromagnetic radiation exposure on the blood, the following general changes emerge although conflicting reports are also present:

- (1) General decrease in hemoglobin content.
- (2) Generally reduced coagulation times.
- (3) Decrease in leucocyte count.

These findings are based largely on animal experimentation. While detrimental in themselves, the extent of these changes would not be expected to be great enough to materially affect an individual's performance or general health, especially under stress conditions, where other factors such as physiological protective responses would be far more important.

PART 2 - CARDIOVASCULAR SYSTEM

(U) Heavy emphasis has been placed on investigations involving electromagnetic radiation on the cardiovascular system. Effects on hemodynamics include blood pressure variations and cardiac arrhythmias. Also included are reports of a slowdown of intraventricular and intra-atrial conduction, diffuse cardiac muscular changes, and ventricular extrasystole. As with other effects, animal studies are frequently reported and human reports are typically retrospective in nature. Many of the variations noted on the cardiovascular system result from central nervous system effects.

(U) Several reports concerning human cardiovascular effects from super-high frequency exposure were reviewed. Functional changes were noted, including a slight increase in the asynchronous contraction phase, a tension period, as well as other data indicative of moderate dystrophic changes of the myocardium accompanied by a disruption of its contractive capacity.

(U) Comparison of a group of engineers and administrative officials who were exposed to microwaves for a period of years and an unexposed control group revealed a significantly higher incidence of coronary disease, hypertension, and disturbances of lipid metabolism among the exposed individuals. Hereditary predisposition to heart disease was approximately the same in both groups, but overt disorders developed much more frequently in the previously exposed group. It was concluded that microwaves may act as a nonspecific factor which, under certain conditions, interferes with adaptation to unfavorable influences. Exposure may, therefore, promote an earlier onset of cardiovascular disease in susceptible individuals.

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PART 3 - CELLS

(U) Histological techniques have been used extensively for evaluating the effects of electromagnetic radiation on cellular systems. Such studies have included in vivo investigations of the cellular effects resulting from whole body irradiation and in vitro studies employing cell cultures.

(U) The most popular cells for study appear to be those of rat or mouse liver. Nonthermal effects on subcellular structures include the formation of binuclear cells and irregular thickening of the nuclear membrane. Invagination of cytoplasm into the nucleus has also been observed, frequently accompanied by breaks in the nuclear membrane. Marked changes in the endoplasmic reticulum and the mitochondria have also been noted. The available data, although still insufficient and inconclusive, seem to indicate that the magnitude of these effects is frequency dependent.

(U) The liver cells of rats exposed for three hours to a 1.625 MHz field showed damage to the protein synthesizing structures. Distinct changes were seen in the nucleoli or ribosome synthesizing apparatus. The ultrastructure of mouse liver cells was investigated after exposure to the same frequency. The mitochondria became swollen and underwent lysis. Some giant mitochondria also appeared. The cellular reactions observed were largely the same as those observed after the action of many other environmental factors.

(U) Phagocytic function has reportedly been increased by exposure to an electromagnetic radiation field and induction of colicin synthesis has been observed in E. coli irradiated with a nonthermal intensity.

(U) In many cases, electromagnetic radiation effects occur at the cellular level, therefore tissue culture techniques provide a well controlled and accurate method for study of those effects. Ultrahigh frequency exposure of cultures of rat fibroblasts, monkey kidney cells, and human embryo fibroblasts led to degeneration of the culture in four to six days. The earliest degeneration occurred in primary cell cultures. Studies are now under way on cell permeability, cell interfaces, cell stimulation, and the electrical characteristics of nerve cells. Other Bior research will include study of microwave effects on mitosis, cell differentiation, and subcellular deoxidation potentials. The data obtained from these studies of cellular and subcellular responses to electromagnetic stimulation will be highly significant, since they may lead to the eventual understanding of basic mechanisms underlying biological changes which occur during and after microwave radiation.

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PART 4 - CENTRAL NERVOUS SYSTEM

(U) Research on the effects of radiowaves and microwaves on the central nervous system of humans was relatively widespread. A number of reports are discussed in this section, as well as research results regarding central nervous system effects on animal models and isolated nerves.

(U) Subjects exposed to microwave radiation exhibited a variety of neuroathenic disorders against a background of angiodystonia (abnormal changes in tonicity of the blood vessels). The most common subjective complaints were headache, fatigue, perspiring, dizziness, menstrual disorders, irritability, agitation, tension, drowsiness, sleeplessness, depression, anxiety, forgetfulness, and lack of concentration.

(U) Various neurological disorders were investigated by studying the vestibular and visual analyzer functions in persons exposed to radio waves of varying types for various periods. Elevation of the threshold of excitability was also accompanied by a lengthening of the time required for dark adaptation. The magnitude and intensity of the changes tended to increase with length of exposure. Similar studies showed increases in the threshold of olfactory sensitivity. EEG automatic frequency analysis was performed on 80 persons exposed to one meter wavelength radiation and 80 healthy controls. No differences were found between the exposed group and the controls regardless of length of the exposure, intensity of the field, or frequency. Presumably, all of these exposures were of a nonthermal nature. Conversely, thirty-seven persons occupationally exposed to a superhigh frequency microwave field ($10 \mu\text{W}/\text{cm}^2$) over periods of two to eight years, were studied; symptoms of asthenic and autonomic vascular disturbances, endocrine shifts, and abnormal EEG's were observed in half of the patients. Their reflexes in response to light and sound were weak, distorted, or nonexistent and their skin galvanic reaction to flashing light was abnormally intense and prolonged. Additional data will be required in order to assess the significance of these human studies.

(U) Long-term experiments conducted on rabbits demonstrated that irradiation with intermittent or continuous low intensity microwave fields elicits qualitatively and quantitatively different changes in the EEG. Intermittent radiation had a more pronounced effect on the recovery time. It has also been observed that long-term exposure of humans to microwave radiation results in extremely flattened EEG patterns.

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during microwave irradiation were also characterized by a much faster increase, followed by a sharp drop to below the original level after irradiation and essential recovery in three minutes. In a series where the temperature increased to 31°C, the microwave effect at first was the same as the thermal effect; after thirty seconds the BA value was even lower than for the thermal effect alone, possibly due to overlap of ionic currents at such high temperature. This was followed by a substantial drop after irradiation, and very little recovery in three minutes. The differences in results in this series were attributed to different initial conditions of the preparations.

(U) These experiments indicate that microwaves may have a specific effect of a nonthermal nature on EC and BA, causing sharp and reversible changes in these functional parameters of nerve impulse. Further experimentation will be needed before extrapolations of similar functional changes to in vivo conditions, or to humans, are attempted. It is expected that Soviet research on these and other CNS responses will continue during the next five years.

PART 5 - DIGESTIVE SYSTEM

(U) A number of alterations in the function of the gastrointestinal system were observed. Reportedly, exposures of subjects working for long periods of time in the presence of low intensity centimeter and decimeter waves resulted in numerous disorders. These included dyspeptic disorders, edema of the gums, bleeding gums, alteration of the gastric acidity, and a reduction of the tonus and evacuator functions of the stomach.

(U) Numerous animal studies have been conducted on the motor function of the gastrointestinal tract and the secretory function of the stomach. Non-thermal intensities were reportedly used. In general, suppression of the stomach's evacuatory function, with signs of adaptation upon repeated exposure, was found. After partial denervation of the stomach, the opposite occurred. It was concluded that the waves have a dual effect - a mediated action through changes in the function of the CNS and a direct effect on the organ or its local innervation. In general, gastric juices increased and little change in acidity was noted. This work tends to support observations of functional changes in humans and indicates that they may actually result from a CNS interaction. Other animal results are discussed below, but do not relate to the human observations.

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(U) The effects of high frequency radiowaves on the content of nucleic acids in the digestive organs of rabbits were studied. The total nucleic acid content and the individual levels of DNA and RNA were assayed in the liver, pancreas, stomach, small intestines, and blood. It was found that the content of nucleic acids in the organs was a function of the power and duration of exposure. Low doses were found to considerably stimulate the nucleic acids, while higher doses reduced their content. Significant shifts in DNA content required very high level exposures. In a similar study on frogs exposed to microwaves (2307 MHz), the highest nucleic acid content was found in the pancreas and the lowest in the stomach. Again, low doses increased the total nucleic acid content while higher doses induced insignificant increases or reductions in their content.

(U) The effects of microwaves (2307 MHz) on radiophosphorus resorption in the stomach, duodenum, ileum, and colon were studied in rabbits. Simultaneously, absorbed radiophosphorus distribution in the liver, lungs, kidney, and spleen was investigated. It was found that rates of radio-active phosphorus resorption by sections of the alimentary canal differ. Under microwave exposure, resorptive activity of the stomach is somewhat decreased, while in the small and large intestines, it is increased. Lower intensity exposure accelerated the intestine resorptive function to a greater extent than large doses of lower frequency waves. Radiophosphorus deposition in the viscera is also a function of the dosage.

PART 6 - GLANDS

(U) Investigations of the effects of radiowaves and microwaves on the glandular system have been concentrated mainly on the adrenal, pituitary, and the thyroid. The glandular effects, however, do not appear to be a high priority area when compared to other systems currently under investigation.

(U) The functional status of the adrenal cortex in shipboard specialists subjected to the effects of a UHF field was reviewed. Thirty-eight men were exposed to the field for periods of 24 to 1800 hours and ketosteroids and oxycorticosteroids (which reflect androgenic function) were monitored. The results indicated that androgenic, glucocorticoid, and mineral corticoid functions of the adrenal gland cortex do not deviate from the normal. Microwave exposure also increased thyroid function in these subjects. The increase was attributed to secondary effects of the radiation and was felt to result from disturbances of the sympathetic nervous system in the hypothalamic region. In guinea pigs, the weight of the adrenal glands increased after continuous exposure at low levels for fourteen days, but decreased in animals exposed to interrupted exposures. Modification of lipid metabolism appears to be the mechanism of action. Similar exposure

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using chicks resulted in increased ascorbic acid content in the cytoplasm of the adrenal cortex, but other work has produced conflicting results regarding the effects on the adrenal cortex.

(U) A quantitative assay of the gonadotropic hormones and growth hormones in the pituitary body of rats exposed to microwave radiation indicated that for a certain time after exposure, blocking or inactivation of gonadotropin-releasing agents occurs in the hypothalamus. Both neural-hormonal and pituitary gonadotropic hypofunctional effects resulted from whole-body microwave irradiation.

(U) The general conclusion that can be drawn from various (both animal and human) studies of the anterior pituitary and adrenal cortex is that exposure to radiowaves and microwaves of thermal intensities results in suppression of the hormone producing functions but exposure to nonthermal intensities tends to enhance production.

(U) An increase of the thyroid function indices was found in animals undergoing microwave irradiation for four months at a power density of 5 mW/cm^2 . In histological sections of the cylindric epithelium covering the thyroid, follicles were seen and electron microscopy revealed reticulum.

PART 7 - METABOLISM

(U) Electromagnetic radiation exposure has been found to produce disturbances in carbohydrate energy and nitrogen metabolism in the brain, liver, and muscles. It appears that under electromagnetic exposure, macroergic compounds become deficient due to disjunction of the oxidative phosphorylation processes and deranged metabolism of carbohydrates. With respect to nitrogen metabolism, radiation causes an intensification of the ammonia formation processes in the absence of correspondingly more vigorous processes for its elimination.

(U) Exposure of rats to various intensities of electromagnetic fields with a frequency of 48 KHz produced an increase of lactic and pyruvic acids and a decrease in glycogen content in brain tissue. The changes depended on the field intensity and exposure duration and one month after cessation of the exposure the titer of lactic acid in the rat brain had not returned to normal.

(U) The role of metabolic disturbances of the heart in development of functional and structural changes under the influence of low frequency impulse electromagnetic fields was studied. Test animals were rats and it was found that exposure decreased ATP and creatinphosphate by

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causing disturbances of the oxidative changes of carbohydrates and divergence of conjugation of oxidation and phosphorylation processes. It was concluded that changes in carbohydrate energy and nitrogen metabolism preceded the inception of structural changes in the myocardium.

(U) While these animal studies indicated an upset of some metabolic pathways, the degree of functional impairment was relatively small and probably not a significant factor. No human metabolic variations were noted and meaningful extension of these animal studies to the human is not possible. Research in this area is likely to remain low key and will be conducted mostly on animals.

PART 8 - REPRODUCTION

(U) The effects of electromagnetic radiation on reproductive systems have been the subject of numerous animal studies. Experiments with female white mice revealed changes in the estrus cycle. During the five-month study, the mice were irradiated twice daily for one hour, using a 10 cm wavelength of low intensity (10 mW/cm^2). Although the average number of normal cycles was unchanged, normal cycle duration increased. Prolonged diestrus and metestrus, along with a shortened estrus period, resulted in a decrease in the reproductive function of the ovaries. A weight loss was found to occur starting at about two weeks, reaching a maximum loss after four months.

(U) The fertility of female white mice was also investigated. The animals, irradiated as above, were mated during proestrus or early estrus with nonirradiated males. Conception in fifty-eight control animals was 94 percent, but only 75 percent in irradiated animals. Long-term non-thermal microwave irradiation of male mice evoked diffuse changes in the testes. Subsequent mating of the animals resulted in reduction in the size of litters.

(U) Microwave radiation at 10 and 50 mW/cm^2 intensity was administered for twenty and fifteen minutes respectively at various stages of the twenty day gestation periods. The progeny showed reduced viability, poor development, and anomalies. Changes in rate of postnatal development and disturbances of higher nervous system activity were also observed.

(U) Female white mice were irradiated twice daily for one hour with 10 cm waves of low intensity (10 mW/cm^2) up to the eighteenth day of pregnancy. There were stillbirths, a significant number of weak newborn, and a general retardation of body weight gain and growth. Other researchers found similar effects in litters from females which had been exposed twice daily for one hour to a 10 cm wavelength at an intensity of 10 mW/cm^2 for five months prior to mating.

(U) Genetic effects of electromagnetic radiation were observed in other studies. Male rats, irradiated with microwaves at 50-55 mW/cm², were mated with nonirradiated females. Litters displayed reduced viability and abnormal development, reduced rate of development and nervous disorders.

(U) Although researchers noted a certain degree of specificity in the pathological changes induced by microwave irradiation of mice, they concluded that the pathological processes occurring in male or female animals resulted from different mechanisms of action.

(U) Both sexes of the fruit fly, Drosophila melanogaster, were exposed to microwaves to study the effects of radiation-induced mutation. Group A, exposed for five seconds to 38 MHz, showed an increased frequency of mutation when bred five to nine days after irradiation. The results were not statistically conclusive, however. Group B, exposed for ten minutes to 2375 MHz, showed no effect on frequency of mutations.

(U) A strain of Staphylococcus aureus, known to be resistant to penicillin, was exposed to an electromagnetic field. A mutant was found to be sensitive to penicillin, probably due to a change in lipid content.

(U) In summary, a large amount of research has been done on the reproductive effects of EMR. However, effects on human reproduction, especially on male fertility, have not been demonstrated.

PART 9 - VISUAL SYSTEMS

(U) The role of microwaves in cataract formation and visual damage has been studied extensively in the past and is reasonably well understood. Primary attention in many studies has been directed at the biological effects of superhigh frequency electromagnetic radiation on the crystalline lens of the eye. Biomicroscopic techniques have been used to study cataract development in persons regularly exposed to microwave fields. A four-year study involving 600 workers and 300 controls revealed no significant difference between the two groups. Cataracts were discovered in only one percent of those persons exposed to such radiation; most of these cases resulted from safety violations. Cataracts which occurred were characterized in their early stages by turbidity of the lens and changes in form and color.

(U) In another study, thirty-five workers regularly exposed to microwave fields and having pronounced congenital lenticular cataracts were examined over a one to three year period; the results of their examinations were compared to those of twelve persons with similar cataracts who had no history of exposure to radiation. No progression was noted in any of the exposed individuals; changes were slow and probably attributable solely to natural aging of the lens.

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(U) Combined wavelengths over the range of the millimetric spectrum were used in an animal study involving nine rabbits exposed for 35-70 minutes. Although the radiation used was of considerable intensity (120-495 mW/cm²), no damage occurred in the deeper media of the eye, in particular the lens, during the 2 to 2½ months observation period. However, erosion of the epithelium of the cornea did occur along with damage to the conjunctiva and its vessels. Multiple tiny hemorrhages in the mucosa and submucous tissue were also evident.

(U) The Soviets have reported the occurrence of "acute attacks" (sic) of glaucoma (1304 cases) which were correlated with geomagnetic disturbances. Moreover, recurring "acute attacks" came primarily on days when the mean value of the horizontal component of the geomagnetic field varied significantly. The significance of this report is questionable, but it indicates that the Soviets are examining all aspects of magnetic and electromagnetic radiation which might cause changes in vision.

(U) Although a growing body of evidence suggests that the microwave power density required to produce cataracts is incompatible with life, the Soviets will continue to investigate the visual effects of EMR but their effort will be reduced from its previous level.

PART 10 - INTERNAL SOUND PERCEPTION

(U) Perception of modulated microwave signals which seem to be originating intracranially as characteristic sounds is a phenomenon which was first reported in the US open literature more than thirteen years ago. To produce sounds, peak power densities of up to 80 mW/cm² may be required, but the average power density usually is 5 µW/cm². The Soviets have studied this phenomenon in order to determine the underlying physiological mechanism(s) and to define the optimum irradiation parameters needed to evoke the response. They found that when the fundamental frequency of the electromagnetic stimulus was raised from 2050 to 2500 MHz, the reaction threshold rose significantly, but at a frequency of 3000 MHz there was no reaction in the auditory centers. The average intensity of electromagnetic radiation required to evoke the response was less than 10 mW/cm²; it was concluded that the fundamental signal frequency rather than the amount of energy constituted the primary stimulus and that the observed phenomenon was sensory in nature.

(U) The Soviets will continue to investigate the nature of internal sound perception. Their research will include studies on perceptual distortion and other psychophysiological effects. The results of these investigations could have military applications if the Soviets develop methods for disrupting or disturbing human behavior.

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SECTION III

MISCELLANEOUS OBSERVATIONS

(U) Most of the reported biological effects from radiowaves and microwaves result from exposure to the higher frequency ranges. Many of the observed physiological changes probably occur as a result of thermal effects arising from the vibration of ions and dipoles of water molecules in tissues; the vibrations are set into motion more efficiently by the shorter wavelength (high frequency) waves. For example, a radiowave of ten centimeters wavelength converts about fifty percent of its energy into heat in this manner, whereas a three-centimeter wave converts nearly ninety-eight percent of its energy into heat. A study of the biological activity of low frequency (seven KHz) impulse electromagnetic radiation of different intensities and durations was done on rats. It was found that the pathological changes were a function of dose; susceptibility to radiation was governed by metabolic processes and morphology and the organs and systems could be classified as to sensitivity in the following order: testicles, liver, kidneys, heart, and central nervous system. Another study indicated that relatively low frequency electromagnetic fields generated sonic and ultrasonic oscillations in living organisms which in turn produced elastic deformations. If the frequency of the source field corresponded to the oscillation frequency of the cells (the resonance frequency most likely), the cells deteriorated as a result of the mechanical resonance.

(U) Clinical studies were done on thirty subjects, aged 25 to 40 years, exposed to industrial ultrahigh frequency centimeter waves at power densities of 10 to 500 mW/cm² for periods of time ranging from 4 to 13 years. Subjective complaints included generalized weakness, afternoon and evening apathy, fatigue, headache, sleep disorders, and nonradiating precordial pain suggestive of asthenia or neurasthenia with autonomic dystonia. Electroencephalography revealed periods of absence of alpha wave activity alternating with low R waves, increased frequency of potentials, dysrhythmia, periodic low peak potentials, and reactions to afferent stimuli. Peripheral blood studies revealed lymphocytosis or monocytosis in eight subjects; increased alpha and gamma globulins were found in 18 subjects. Erythrocyte potassium was within the lower limits of normal, while urine potassium was within the upper limits of normal. Adrenal cortex function was evaluated by urine levels of 17-ketosteroids, which were elevated to 22 to 40 mg in 11 subjects; average levels were 20.5 mg. Urine levels of epinephrine and norepinephrine were elevated in some subjects. Thyroid function was evaluated by rate of radioiodine uptake. Average uptake within two hours was 11.3 percent, and in four hours 16.9 percent. The 24 hour uptake did not differ from normal values. Electrocardiography revealed changes in the heart conduction system in six subjects; the T_{V1}>V₆ syndrome was found in ten

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subjects and a U wave was registered in lead V₃ in eight subjects. Hemodynamic and myocardial function parameters were studied by tachoscillography and polysphygmography. Arterial pressure was usually within normal limits, although it was of a labile nature. Bradycardia was present in 14 subjects and decreased minute volume was observed in eight; increased peripheral resistance was found "in a significant number" of subjects. Autonomic-vascular changes and emotional lability and reactivity were attributed to CNS changes and increased pituitary-adrenal gland function. It was also noted that such shifts in neuroendocrine function could lead to circulatory disorders manifested by changes in the hemodynamic indices and electrical activity of the heart.

(U) A second study was done on two groups of workers occupationally exposed in the radio industry. The first group consisted of 100 subjects who had worked for several years under conditions of periodic exposure to microwaves of considerable intensity (up to several mW/cm²). The second group consisted of 115 subjects who had begun work after the introduction of protective measures and had been exposed to microwave intensity levels approximately the same as those to which the first group was exposed. A control group of 100 subjects not exposed to the action of microwaves was also continuously examined. The study showed adverse effects, primarily on the nervous and cardiovascular systems, in both exposed groups. These effects were more pronounced in the first group. They were manifested by more frequent complaints of asthenic syndrome and vegetative vascular dysfunction.

(U) A lack of standards for measuring power levels represents a problem which probably accounts for conflicting reports regarding the effects of a given frequency and intensity. Other problems with dosimetry and experimental technique also exist. Such differences make comparison of results from one investigator to another, as well as from one country to another, extremely difficult.

(U) Only a few studies involving electromagnetic interaction with the immunological system have been reported. In one, rabbits were employed to study the body immunological reactivity under long-term irradiation. The rabbits were immunized with typhoid antigen and divided into two groups. One group was exposed to waves of 50 and 10 mW/cm² intensity for four hours a day over a four-month period. Analysis of the data obtained indicated that chronic exposure to the effects of low intensity high frequency radio-waves can influence the immunoreactive state of the body as evidenced by differences in phagocytic activity of neutrophils, blood serum complement level, and specific antibody titers.

(U) Soviet investigators have conducted studies on the effects of microwave frequencies in combination with ionizing radiation, magnetic fields, drugs, and nonionizing electromagnetic radiation of other wavelengths. Generally, synergistic effects have been observed. Continued work in this area is expected, and possibly new safety standards for these combined effects will be developed.

(U) In summary, this section shows the rather broad front on which Soviet researchers are investigating the biological effects of EMR. It is apparent that their interest covers all body systems which could reasonably be expected to display responses to such radiation. As with Western researchers, they have concentrated their efforts on the higher frequency spectrum which would be expected to produce more thermal responses. However, they also continue to be interested in nonthermal effects, which, by Western standards, they have yet to conclusively demonstrate.