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Report AMCA-71-004

ANNEX A to AHWG #3

Directed Energies for Military Applications (U)

BIOLOGICAL SENSITIVITIES TO VARIOUS ENERGY FORMS

(MATRIX)

July 1970

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U.S. ARMY
ADVANCED MATERIEL CONCEPTS AGENCY

ANNEX A to AHWG #3

Directed Energies for Military Applications (U)

BIOLOGICAL SENSITIVITIES
TO
VARIOUS ENERGY FORMS

(MATRIX)

July 1970

US Army Advanced Materiel Concepts Agency
Washington, D. C. 20315

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ABSTRACT

This report contains biological vulnerabilities to various energy forms such as electromagnetic radiations, ionizing particles, static electric and magnetic fields and acoustical energy forms. The vulnerabilities are given in Watt per cm^2 or Watt-Seconds per cm^2 for various body organs and body biological systems (blood circulation, lymphatic system, etc.).

This volume should be of interest to anyone who is concerned about health safety of individuals who would be potentially exposed to the above-mentioned energy forms.

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BIOLOGICAL SENSITIVITIES OF VARIOUS ENERGY FORMS

INTRODUCTION AND APPROACH:

The Ad Hoc Working Group 3A, consisting of Dr. Z. V. Harvalik, AMCA, COL C. McClure, ARO, Dr. L. Katchmar, HEL, and Mr. J. H. Mathews, AMCA, was convened on 31 July, 1 and 2 August 1968 to discuss biological sensitivities to various energy forms as an aid to assessment of concepts of unconventional weapons. The term "unconventional weapons" was quickly dispensed with as being solution-oriented without establishment of basic problems. The basic problem became one of establishing the scientifically derived biological sensitivities to various energy forms to provide a base for future ad hoc study groups to assess the existing and predicted technological capabilities of generating and delivering such energy forms to produce the biological effects desired. To establish the biological sensitivities to energy forms, a matrix approach was adopted. The energy forms were analyzed and broken out into five distinct areas. These were: (1) electromagnetic energies, (2) particle energies, (3) sonic energies, (4) static fields, and (5) electric currents and plasmoids. Following the establishment of the energy spectrum, discussion centered on the segmentation of biological systems in terms of their potential sensitivities to these energy classes. Seven areas were identified as follows:

1. The sensory mechanism of:
   a. Eye
   b. Ear
   c. Nose
   d. Skin
   e. Vestibular
   f. Kinesthetic (gamma motor system)
2. Other energy receptors were considered:
   a. Skin as covering
   b. Body organs
   c. Central nervous system
   d. Psychological phenomena

The compilation of these factors are shown in the matrix.

MATRIX:

The matrix was constructed in a manner to provide as complete coverage of the biological system as was deemed necessary without undue consideration of whether the data existed or were non-existent. The approach was merely to provide a framework within which most of the available knowledge about biological sensitivities could be incorporated.

The matrix provides for the inclusion of specific numerical energy levels where known and, additionally, provides for the effects of these numerical energy levels in terms of their possible anatomical, physiological, and psychological effects. A remarks section is included for qualification of the data within any given cell.

DATA REQUIREMENTS FOR THE MATRIX:

In its idealized form, the data required to complete the matrix would be in the unit of watt/cm^2 or watt-second/cm^2 (joule/cm^2) to produce a safe exposure level, degradation, incapacitation, and lethality. While watt/cm^2 or joule/cm^2 would be the desirable unit, it is recognized that the data may not exist in the desirable units of energy density; therefore, the specific instructions would be to provide data in their existing units for potential conversion into the desirable units. It should be kept in mind that the potential use of the data is for engineering design purposes and this should be the guiding principle. Wherever a numerical cell entry is made, the original source of the data should be identified in terms of author, publication, volume, page, and year.

RECOMMENDATION:

It is recommended that the completed matrix be reproduced and submitted to various organizations for their initial assessment of: (1) the availability of data required by the matrix, (2) the location of the information by individual and/or organization, and (3) a potential time requirement for extraction of data in the form required by the matrix. This initial assessment should be assigned an extremely high priority and answers requested within four weeks of receipt of the matrix.

CB agents are separate areas of investigation and are not included within this particular matrix.

The following individuals were asked to fill-in data as available into the respective matrices:

X-Rays, Gamma-Rays, and Particles

COL James B. Young, VC, Chief, NBC Sciences Division, US Army Medical Research and Development Command, Washington, D. C. 20315

Dr. Marylou Ingram, Department of Radiation Biology and Biophysics, School of Medicine and Dentistry, Rochester University, Rochester, N.Y. 14620

Dr. Aaron Wolfgant, Behavioral Sciences Laboratory, Walter Reed General Hospital, Washington, D. C. 20012

Columbia Research Corporation, Gaithersburg, Maryland 20760

Lasers and Optical Radiations

COL Robert W. Neidlinger, MC, Chief, Laser Section, Surgical Research Branch, US Army Medical Research and Development Command, Washington, D. C. 20315

Microwaves

Mr. William A. Palmisano, Chief, Laser and Microwave Division, US Army Environmental Health Agency, Edgewood Arsenal, Maryland 21010

Dr. Solomon Michaelson (DVM), Department of Radiation Biology School of Medicine and Dentistry, Rochester University, Rochester, N. Y. 14620

MAJ Joseph C. Sharp, Behavioral Radiation Laboratory, Forest Glen Section, Bldg 503, Department of Experimental Psychology, Walter Reed Army Medical Center, Washington, D. C. 20012

Magnetostatic and Electrostatic Fields and Plasmoids, Ions

MAJ Joseph C. Sharp, MSC, Behavioral Radiation Laboratory, Forest Glen Section, Walter Reed Army Medical Center, Washington, D. C. 20012

Ultrasonics

CPT Maurice B. Landers, MC, Surgical Research Branch, US Army Medical Research and Development Command, Washington, D. C. 20315

Dr. Gilbert Baum, Department of Ophthalmology, Albert Einstein College of Medicine, Yeshiva University, 1300 Morris Park Avenue, Bronx, N. Y. 10461

Sonics, Subsonics; and Barometrics

MAJ Daniel T. Sanders, MC, Aviation Medical Officer, US Army Medical Research and Development Command, Washington, D. C. 20315

The returned matrices, containing biological sensitivities to various energy forms, would be used by technical personnel to determine engineering parameters for the various devices utilizing the energy forms appearing in the matrices.

The following individuals and organizations contributed to the information contained in the subject matrices:

Columbia Research Corporation, Gaithersburg, Maryland 20760. Under Contract DAAB09-70-C-0033:

X-rays, Gamma rays
Particles (Electrons, Protons, Ions, Neutrons) and others

COL James B. Young, VC, Chief, NBC Sciences Division, US Army Medical Research and Development Command, Washington, D. C. 20315 and

COL Robert W. Neidlinger, MC Chief, Laser Section, Surgical Research Branch, US Army Medical Research and Development Command, Washington, D. C. 20314:

Electromagnetic (UV, Visible, IR)
Electromagnetic (Lasers and Masers)

Dr. Solomon Michaelson (DVM), Department of Radiation Biology, School of Medicine and Dentistry, University of Rochester, Rochester, N. Y. 14620:

Electromagnetic (Microwaves, RF etc)

AHWG #3 Participants:

Magnetostatic and Electrostatic Fields

Dr. Gilbert Baum, Department of Ophthalmology, Albert Einstein College of Medicine, Yeshiva University, 1300 Morris Park Avenue, Bronx, N. Y. 10461:

Ultrasonics

COL James B. Young, VC, Chief, NBC Sciences Division, US Army Medical Research and Development Command, Washington, D. C. 20315 and

COL Robert W. Neidlinger, MC, Chief, Laser Section, Surgical Research Branch, US Army Medical Research and Development Command, Washington, D. C. 20315 and

AHWG #3 Participants:

Sonics
Infrasonics and Barometrics

BIOLOGICAL SENSITIVITIES

TO

VARIOUS ENERGY FORMS

MATRIX

INCL: Instructions for Entries into the Matrix
Appendix A, B, C and D

Prepared at US Army, Advanced Materiel Concepts Agency, AMC
Washington, D. C. 20315

10 September 1968

INSTRUCTIONS FOR ENTRIES INTO THE MATRIX

The matrix consists of 10 sets, each of which relates to a portion of the energy spectrum. Each set consists of 11 sheets, each of which relates to a sense, body organ or part possibly damageable by a particular energy form.

Each sheet contains 14 columns:

1. ENERGY FORM: Already entered in the matrix, self-explanatory.
2. LEVEL OF INTERACTION: Arbitrarily defined as follows:

a. The "Safe Level" may be defined as the maximum level of energy that can be delivered without producing a degradation of function in the system.

b. The "Degradation of Function" level is defined as that range of values of delivered energy capable of producing discernible alteration in function of a system without producing total incapacitation of that system.

c. "Incapacitation" includes that range of values of delivered energy resulting in loss of function of a system in more than 30% exposed.

d. "Lethality" is that value of delivered energy that produces death in more than 30% exposed.

As a first approximation to levels of interaction the following example is given:

Energy Form Equivalent	Level of Interaction Equivalent
Blood loss: less than 500 ml	Safe
Blood loss: 500-1500 ml	Degradation
Blood loss: 1500-3000 ml	Incapacitation
Blood loss: greater than 3000 ml	Lethality

Note: These data are not to be construed as absolute.

3. to 9. DAMAGE TO (SENSE, BODY ORGAN OR PART)

Columns 3-9 contain the constituent elements of a sense or receptor mechanism. In some cases there will be more than seven, in some cases less. The data required and entered in column nos. 3-9 should be a specific number preferably stated in terms of dose rate, Watt/cm^2, or where energy (dose) is of interest or primary concern, in terms of Watt-second/cm^2 or J/cm^2, to produce that effect requested in column 2 for the energy form in column 1. The requested information should be filled in these cells with reference to the appendices pertaining to that ta.

10., 11., 12. SPECIFIC ADVERSE EFFECTS TO TRANSMIS ON

In many cases of interaction of energy with pa s of senses or body organs adverse or beneficial effects are observed due transmission of a signal by the sense or body organ. For example, flickering visible light may cause discomfort to the individual perhaps climaxing in confusion and panic, or pseudo-epileptic seizure, or vomiting.

In addition to the specific number if it is available, columns 10, 11, and 12 should describe in very cogent terms the specific adverse effect of the number entered into the cell. Any appropriate remarks required to qualify the number entered into the specific cells should be inserted in column 14 (Remarks).

13. COUNTERMEASURES

Give an indication of whether the effects presented in columns 3 to 12 could be easily protected against, difficult to protect against or impossible to protect against. Protection here should be couched in terms of protection without adversely affecting the performance capabilities of the individual. For example, it would be easy to protect an individual against any form of radiation by incapsulating him in a lead box. However, the lead box essentially reduces his performance capability to zero and hence is an impossible solution. Included in countermeasures are immunization and therapeutic techniques. Specific information as to the nature of countermeasures should be amplified in Appendix B with appropriate reference. If expansion of easy, difficult or impossible is required, this also should be addressed in Appendix B.

14. REMARKS: Short remarks pertaining to the particular row. If more space is needed, reference in column 14 and enter remarks in Appendix B.

There are four appendices required to support the matrix.

APPENDIX A - BIBLIOGRAPHIC SOURCES. Should contain all relevant literature used to support matrix-entered data.

APPENDIX B - AMPLIFICATION OF REMARKS. Shall contain amplification of the Remarks section of the matrix, if necessary.

APPENDIX C - OTHER POSSIBLE INFORMATION SOURCES. Because the matrix will be filled in by specific people who may not have all sources of information available to them, this appendix should contain all other sources of information which could be explored, if necessary.

APPENDIX D - CATCH-ALL. This appendix is designed to permit the individual respondent to provide his thoughts and/or speculations on the subject area.

Identify Appendix references in cells related to columns 3 to 14 by entering in appropriate cells for:

Bibliography (APPENDIX A): A-1,2,.....

Amplification of Remarks (APPENDIX B): B-1,2.....

Other Possible Information Sources (APPENDIX C): C-1,2,3....

Catch-All (APPENDIX D): D-1,2,3....

APPENDIX A - Bibliographic Sources

Add pages if necessary.

APPENDIX B - Amplification of Remarks

Add pages if necessary.

APPENDIX C - Other Possible Information Sources

Add pages if necessary.

APPENDIX D - Catch-all

Add pages if necessary.

INTRODUCTION TO MATRICES ON IONIZING RADIATIONS

This work is the result of a major search of the available world literature on the biological effects of both ionizing electromagnetic and particulate radiation.

Findings are noted for each organ or system on the forms supplied. All doses are expressed in rads (where 1 rad = 10^{-5} Joule of deposited energy per gram of matter.) A discussion of units commonly used in radiation biology can be found in Appendix D. When a specific dose for a specified amount of damage to the organ or system was found, it is stated as such in the appropriate box in the matrix along with the reference to the study. When a range of doses was found, meaning that different investigators described the same effect for different doses, the lowest and highest doses that produced the effect are noted along with the particular references. It should come as no surprise that different investigators noted the same effect for different doses when one realizes the great difficulty experienced in reproducing results in biological material even under the best of circumstances. In many of these studies quoted the only common factor was the dose. As would be expected in a field that is relatively new to investigation, there are many organs and systems for which no dose rates have been determined or no specific study can be quoted. These spaces have been either filled with just a reference or left blank. Because electromagnetic ionizing radiation has been the choice until quite recently for the therapy of human disease which lends itself to treatment with ionizing radiation and because the production of particulate ionizing radiation for therapy, other than those few radioisotopes which are useful in medical therapy, is expensive and cumbersome, the literature is disproportionately concerned with the effects of electromagnetic ionizing radiation, at least as it is concerned with the purpose of this study. The obvious result of this state of affairs is the dearth of references to be found in the matrices dealing with the biological effects of particulate radiation. What literature is available and pertinent to this study is quoted, usually in the form of remarks in Appendix B. The bibliography of sources used for this report comprises Appendix A. Sources that promise possible dose levels but are unavailable either because physically inaccessible or because they are written in a foreign language are in Appendix C.

No attempt has been made to extrapolate data from animal studies to human beings in terms of doses for the reason that such extrapolation is more than likely to be in serious error, e.g., the dose of ionizing radiation to the ovaries of mice which produces a significant increase in congenital abnormalities cannot be extrapolated to the human ovary with any meaningfulness because of a significant difference in the biological development of ova in the two species. When some degree of speculation enters into the dose noted in a box, a footnote to that effect is appended.

Taken in toto, this study points out the large hiatus in our knowledge of the biological effects of ionizing radiation on specific organs and systems in the human being.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Reference 4 is a general reference to the effects of ionizing radiation on ocular structures.
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	<1,000 A1,B1		<15 $ <200 # A7,A9,B3	B2	B2	B2	B2					$ for fast neutrons # for beta-rays
	DEGRADATION	1,000-20,000 A1,A17,B1		15-100 $ 200-2,000# *									* A1,A9,A11,A16,A17,A19, A20,A22,B3
	INCAPACITATION	>25,000 A1,A26,B1		>100 $ >2000 # A9,A26,B3									
	LETHALITY	No dose confined to the orbit will cause whole animal lethality.											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	DRUM	OSSICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	*	*	*	*								*No literature on dosage levels of particulate radiation causing damage to the ear has been found.
	DEGRADATION												
	INCAPACITATION												
	LETHALITY	No dose localized in the ear will cause whole animal lethality.											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
18. PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	*	*	*									*No literature on dosage levels of particulate radiation causing damage to the nose has been found.
	DEGRADATION												
	INCAPACITATION												
	LETHALITY	No dose confined to the nasopharynx will cause whole animal lethality.											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	*	*	*									*The anatomical makeup of the skin has nerve endings located either in the dermis or in the epidermis. Certainly degradation or incapacitation of either the dermis or epidermis would degrade or incapacitate the sensor faculties of the skin. There are indications[90], however, that lower doses than those required to cause even epidermal damage have led to sensory changes in touch, pain, and/or thermal sensitivity. Unfortunately, no doses are reported.
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	<170 A11, A24, *	B4										*dosage for beta-rays
	DEGRADATION	170-635 A11, A24, *											
	INCAPACITATION	>635 A11, A24, *											
	LETHALITY	#											#Dosage sufficient to destroy the epidermal layer over a large percentage of the body would kill in a manner analogous to burns (75% of the epidermis destroyed would kill for burns, probably a lesser percentage for radiation).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	*	*										*No literature on dosage levels of particulate radiation causing damage to either the labyrinth or gamma motor system has been found
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
PARTICLES (ELECTRONICS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	<25 All	*	*	*	*	*	*					*Excepting long term effects of deposited radionuclides, such as Sr^{90} in bone, no literature on damaging dosage levels from particulate radiation has been found for the anatomical features on this page. This lack of information is perhaps a result of the limited penetration depth of the commonly used low energy beta-rays and thermal neutrons in human or animal tissue. The more deeply penetrating high energy particulate radiation is not yet readily available.
	DEGRADATION	25-100 All											
	INCAPACITATION	>100 All											
	LETHALITY												

1	2	3	4	5	6	7	3	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	B5,*	B4,*	B7,*	10,000 A24	*							*Excepting the thyroid, where internally deposited radionuclides and high energy particulate radiation have been used to regulate function, no literature on damaging dosage levels from particulate radiation has been found on the organs or systems on this page.
	DEGRADATION				10,000-20,000 A21,A24								
	INCAPACITATION				>20,000 A21,A24								#Irradiation localized to the thyroid or gonads will not cause whole animal lethality.
	LETHALITY				#	#							

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS AND OTHERS)	SAFE	*	*	*	*								*No literature giving damaging dosage levels for external or internal particulate radiation to the gastrointestinal, urinary, respiratory, and liver and gall bladder systems has been found.
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS, AND OTHERS)	SAFE	*	*	*	*								*No literature reporting damaging dosage levels for external radiation to the central nervous system has been found. Harmful effects of beta-emitting radionuclides on the central nervous system were also not found. Although high energy particulate sources of radiation do exist, and have been used to treat intracranial tumors, no literature giving doses has been found.
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
PARTICLES (ELECTRONS, PROTONS, IONS, NEUTRONS, AND OTHERS)	SAFE	*	*										*No literature on the effects of particulate radiation on psychological processes was found.
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Reference 4 is a general reference to the effects of ionizing radiation on ocular structures.
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	<1,000 A1,A19		<200 A1,A19,A15		<2,000 A15,*	<1000 A90,B9	<1200 A103,**					
	DEGRA-DATION	1000-3000 A1,A19		200-1400 $		>2000 A15 *		1200-5000 A#,A103**					# A9,A10,A16,A19,A20,A25 $ A1,A6,A19,A25,A49,A60
	INCAPA-CITATION	>3000 A1,A19		>4000 *	5000-7000 A1	>30,000 A15,*	>2,000 A15,*	19000-49000 A#,A99,**					*Experiments conducted on animals, not man. **Dosage levels are general values for muscle tissue.
	LETHA-LITY	No dose confined to the orbit will cause whole animal lethality.											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	DRUM	OSCICLES	ROUND WINDOW	COCHLEA	TEMPORAL BONE			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	<4,000 A90	<4,000 A62,A90										
	DEGRADATION	>6,000 A90	>6,000 A90		1900-72,000 A90,*								*Experiments conducted on guinea pigs resulted in hearing loss at high frequencies.
	INCAPACITATION					4000-6,000 A64							
	LETHALITY	No dose localized in the ear will cause whole animal lethality.											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATONIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	B11											
	DEGRA-DATION	B11	2000 A90; B12	4000 A103									
	INCAPA-CITATION												
	LETHA-LITY	No dose confined to the nasopharynx will cause whole animal lethality.											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE		<4,000 A1,*										*Since there are no nerve endings in the epidermis and dermis, damage to either will degrade or destroy the sensory faculties of the skin. The dosage levels reported are
	DEGRA-DATION		1000-3,500 A1,AN,*										therefore identical to those found from the literature for the dermis. There are indications[90], however, that lower doses than those required to cause even epidermal damage
	INCAPA-CITATION		>5000 A99,*										have led to sensory changes in touch, pain, and/or thermal sensitivity.
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	<35 A1,A28,A99	<1,000 A1										
	DEGRADATION	2,000-3,000 *	1000-2500 A1,A14										* A1,A3,A14,A28,A74
	INCAPACITATION	>3,000 A1,A14	>5,000 A99										#Dosage sufficient to destroy the epidermal layer over a large percentage of the body would kill in a manner analogous to a burn (approximately 75% epidermal destruction will kill for burns, probably less for radiation because of slowed epidermal regrowth.)
	LETHALITY	#											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	<2,000 A1,*	<6,000 A90,*										
	DEGRA-DATION	>2,000 A1,*	>6,000 A90,*										*In 50% of rats exposed to x-rays.
	INCAPA-CITATION	5,000-32,000 A90											*In the burro, which has a much lower central nervous system syndrome threshold than man.
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	<100 A1,A97	<350 A1,A96	<1,200 A97,A103	<2,000 A1,A74	B13	<400 A1	B16					
	DEGRA-DATION	100-150 A1, B15	2,000-3,000 A1	1,200-5,000 A74,A103	2,000-5,000 A1,A74	B13	1,000-2,500 A1						
	INCAPA-CITATION	>350 A1	>4,500 A1	10,000-77,000 A74,A99	>4,000 A88,B14	B13	>3,000 A1						
	LETHA-LITY	>350 A1											

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	<4,000 A74	<10,000 A1			B17							
	DEGRADATION	>4,000 A74	>10,000 A1	2,000 A74,#	30,000-50,000 A74	B17							
	INCAPACITATION			8,000 A74,#	>90,000 A74	B17							#Experiments conducted on rats.
	LETHALITY					*							*No dose localized to ovaries or testes could cause whole animal lethality.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	<200 A1	<500 A1,A30,B23	<1,000 A1,A5,A65*	<1,100 A1,A46,A63,B24			B25					
	DEGRADATION	>1,500 A1,*	500-2,000 A1,A30	>1,500 A1,A51,A65	>2,000 A44								
	INCAPACITATION	5,000-200,000 A1,A2,A32	>3,000 A30	>5,000 A65*	>3,000 A30,A75								*Animal experiments on monkeys
	LETHALITY	5,000-200,000 A1,A2,A32,B22	3,000-5,000 A2,A30	>5,000 A65*	**								**In most severe cases, quadraplegia is the eventual result. Death follows, but from secondary causes.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (X-RAYS, GAMMA RAYS)	SAFE	B26	*										*No literature on radiation produced illusions was found.
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE FROM WHOLE BODY RADIATION							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		Hematopoietic System	Gastrointestinal System	Central Nervous System					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
IONIZING RADIATION	SAFE	<400 A2, A11	<50 A2, A11, A50	<1,000 A29									LD^{30}_{50} for man = 360 rads[75]
	DEGRADATION	100-200 A11, A99	100-2,000 A2, A11, A50	>1,000 A29									Whole body dose in rads / % fatalities: 200 few; 400-450 50; 700-800 100
	INCAPACITATION	200-1,000 A11	>2,000 A2	>5,000 A2, A11, A29									
	LETHALITY	200-600 A11	>1,000 A2, A11	>5,000 A2, A11									

APPENDIX A

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APPENDIX B

AMPLIFICATION OF REMARKS

Damage From Particulate Radiation to the Eye (A1)

1. Approximately 1000 rads will produce a superficial keratitis (inflammation of the cornea) which, appearing after a latent period of several weeks, will generally subside without serious sequelae. Moderate doses (on the order of 5000 rads or less) produce punctate keratitis. Doses as high as 20,000-30,000 rads will produce ulceration followed by keratinization and telangiectasis.[1] Corneal scarring will appear in a certain number of cases after a latent period inversely proportional to the dose.[26]

2. Because beta-rays and thermal neutrons are absorbed within a thickness of several millimeters of living tissue, the chief ocular structures damaged by such external particulate radiation will be the lens and cornea. Deeper lying structures will not be significantly effected by low energy external particulate radiation. A possible source of damaging dosage levels for the retinal elements, muscles, and vitreous humor would be studies of Beta-emitting radionuclides introduced to the posterior region of the eye or high energy electron, proton, deuteron radiation, capable of deep penetration into human tissue. No such studies have been found in the literature.

3. Radiation causes opacification of the lens or "radiation cataract". Neutrons, especially fast neutrons, have a very high RBE. Consequently, a low dose (approximately 15 rads) can lead to opacities in the lens.

Damage From Particulate Radiation to the Skin as a Covering (A-5)

4. Most of the energy from incident beta-rays or neutrons is absorbed by the epidermis. The dosage levels for epidermal degradation and incapacitation are therefore well known, while dosage levels of particulate radiation sufficient to cause dermal destruction seem to be unknown.

Damage from Particulate Radiation to Adrenals, Pituitary, and Pancreas (A-8)

5. Irradiation may alter adrenal function but this alteration appears to be the result of stress of illness rather than a primary effect of radiation.

6. Pituitary gland irradiation with high energy electrons increases the ACTH content of the blood within one hour of the time of irradiation. The increase lasts for at least 24 hours. Experiments with rats has lead to the conclusion by at least one author that the gonadotropia, somatotropia and thyrotropic activities of the pituitary are either unaffected or slightly stimulated by irradiation if the adrenals are intact.[33]

7. The pancreas of the irradiated rat loses its ability to form citrate.[33]

Damage from Electromagnetic Radiation to the Eye (B-1)

8. Possible sequelae of X-ray irradiation of orbit:[53]

punctate staining of cornea
atrophy of iris
glaucoma
cataract
choiroido-retinal changes

9. The dark adapted human retina is sensitive to low levels of X and gamma radiation. Brief exposures to approximately 1 Mev of X-rays produce perception of an unsaturated bluish light and allows the discrimination of a shadow of a radio-opaque object. Beta and gamma-rays cause the perception of a greenish formless glow.[90]

Damage from Electromagnetic Radiation to the Ear (B-2)

10. Immediate sequelae of a therapeutic dose of X or gamma-radiation are a transient radiation otitis media and vasculitis of the vessels of the inner ear resulting in hearing loss, tinnitus, temporary recruitment, a painful feeling of fullness, and possible obstruction of the eustachian tube caused by swelling of mucosa. Possible late changes include impairment of blood supply to cochlea and auditory ossicles, necrosis of the incus, and acute radionecrosis of temporal bone.[61]

Damage from Electromagnetic Radiation to the Nose (B-3)

11. The nasal cavaties show little sensitivity to radiation. In the period immediately following irradiation, there may be alteration or temporary suppression of the sense of smell and hypersecretion of mucus. As a late reaction, many patients complain of dryness of the mucosa with a tendency toward formation of crusts, which is probably due to a transitory atrophy of the mucus secreting glands at the level of the nostril vestibule, the transitional epithelium shows severe radiation reactions which resemble in their development that of other mucocutaneous orifices. (No doses given)[14]

12. 20% of patients receiving localized irradiation to the oral-nasal-pharyngeal regions report experiencing unusual tastes and smells.[90]

Damage from Electromagnetic Radiation to Blood, Skeleton, Cardiovascular System, and Spleen (B-7)

13. Cardiovascular:[1,28]

heart <6,000 rads in 6 weeks - safe
>6,000 rads in 6 weeks - degrading

vessels <1500 rads - safe (1200 rads lead to reversible changes)
>1500 - 2000 rads - degrading

14. Skeleton:[87,99]

Osteoradionecrosis (of the mandible) is caused primarily by loss of circulation to the bone, periosteum, and mucosal tissues and may proceed to osteomyelitis with greater destruction anterior and posterior to the irradiated area. Radiation of formed bone may result in a derangement of the synchronization of resorption and new bone deposition, producing either excessive absorption or overgrowth of bone.

15. Blood: Countermeasures for irradiation effects

1. Pre-irradiation erythropoietic stimulation (by placing experimental animal in a high altitude chamber) enhanced post-irradiation recovery in Swiss mice.[31]

2. Vitamin C administered to patients undergoing therapeutic radiation eliminates or moderates leukopenia.[39]

16. Spleen:

Shielding of the spleen during whole-body irradiation has in some species resulted in markedly improved survival rates.[33] An attempt to assess the effects of splenic shielding on survivors of the Japanese atomic bomb explosions,[93] did not prove that a healthy spleen helps in recovery from radiation in humans. The findings of the study were, however, not inconsistent with that hypothesis.

Damage from Electromagnetic Radiation to the Gonads (B-8)

17. Gonads: man

< 50-200 rads - safe[1,75]
236-365 rads - transient sterility (degradation)[1,75]
>400-600 rads - incapacitating[75]

woman

< 100-200 rads - safe[1,5]
200-500 rads - degrading[1,2,5]
>500-2000 rads - incapacitating[1,5,8]

Damage from Electromagnetic Radiation to Gastrointestinal and Urinary Systems and Liver and Gall Bladder (B-9)

18. Gastrointestinal[1]:

esophagus -	< 5,000 rads-safe 5-6,000 rads-degrading > 6,000 rads-incapacitating
stomach -	< 250-350-safe 350-1,000-degrading > 1,000-incapacitating
small intestine -	< 500-safe 500-1,000-degrading
large intestine -	< 7,000-safe > 7,000-degrading

19. Urinary:[2,99]

kidney -	< 400 rads-safe 500-2,000 rads-degrading > 3,500-4000-incapacitating & lethal
bladder -	< 3,000-safe 3,000-9,000-degrading > 9,000 rads-incapacitating

20. Nausea resulting from irradiation can be controlled by doses of Vitamin B_1.[39]

21. The liver appears to be a radiosensitive organ from studies on mice, rats, and pigeons. The hepatic vascular system must remain intact for some radiation effects to become radiation apparent. A compendium of effects on the liver observed in various species includes

   1. increased oxygen consumption
   2. no change in liver protein synthesis
   3. decreased activity of choline oxidase
   4. decreased acetylating capacity
   5. increased permeability to phosphate ions.[33]

Damage from Electromagnetic Radiation to the Central Nervous System (B-10)

22. The period until death ensues is inversely proportional to the size of the dose, above a lethal dosage.

23. Cortex and immediate sub-cortical medullary regions are less radiosensitive than deep-seated white matter.[36]

24. Irradiating a shorter length of spinal cord allows a higher dose to be used safely.[58]

25. Effects of irradiation of the head of animals and humans on the EEG are summarized in reference 90. However, no human dosage levels for significant changes in the alpha rhythm have been established.

Psychological Effects from Electromagnetic Radiation (B-11)

26. Chapter 7 and 8 of reference 90 discuss the effects on psychological processes and behavior of animals exposed to varying levels of ionizing radiation. Extrapolation to the human species is hazardous at the present level of understanding of the phenomena.

APPENDIX C

OTHER POSSIBLE INFORMATION SOURCES

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APPENDIX D

CATCH-ALL

D-1 Radiation Units (74, 99)

rad = absorption of 100 ergs of energy/gm of irradiated material, regardless of the type of ionizing radiation or of the absorbing material.

roentgen = amount of radiation which produces, as a consequence of ionization, one esu of charge in 1 cm^3 (0.001293g) of dry air at 0^oC/760 mm(Hg). This is equivalent to the production of 2.1 x 10^9 ion pairs and represents an energy deposition of 87.6 ergs/gm of air. This unit can be used for exposure to x- or gamma-radiations of less than 3 Mev. (One rad is approximately equal to 1 roentgen when soft tissue is exposed to medium voltage x-radiation.)

rem (roentgen equivalent man or mammal) = a unit of dose equivalent which is numerically equal to the dose in rads multiplied by appropriate modifying factors such as RBE (or QE) or DF.

RBE (Relative Biological Effectiveness) = factor expressing the relative effectiveness of radiations with differing linear energy transfer (L.E.T.)

QF (Quality Factor) = another name for a linear energy transfer (L.E.T.) dependent factor by which absorbed doses are to be multiplied to account for the varying effectiveness of different radiations.

DF (Dose Distribution Factor) = a factor expressing the modification of biological effect due to nonuniform distribution of internally deposited radionuclides.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS Energy Levels of Interaction expressed in watts/cm^2. MICROWAVE: two effects--(1) at ~0.8 W/cm^2 for 5 min = hydrops of the lens, followed by cataract in months; (2) at ~0.3 W/cm^2 for 5 min = slow cataract formation. No military value to either.
		CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE	?	?	?	?	< 4	4						White light (sunlight) in a 1mm spot image; may be less for larger images.
	DEGRADATION					> 4	> 4						
	INCAPACITATION												Not known to contributor
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	DRUM	OSCICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	Not known to contributor
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Not known to contributor
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS Not known to contributor
		PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS Nct known to contributor
		POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Not known to contributor
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Not known to contributor
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Not known to contributor
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Not known to contributor
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		Not known to contributor
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		10Hz flicker white light seems to influence the alpha rhythm of the brain.
ELECTROMAGNETIC (UV, VISIBLE, IR)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

APPENDIX A - Bibliographic Sources

Add pages if necessary.

APPENDIX B - Amplification of Remarks

Add pages if necessary.

APPENDIX C - Other Possible Information Sources

Add pages if necessary.

APPENDIX D - Catch-all

Add pages if necessary.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS Energy Levels of Interaction expressed in joules/cm^2.
ENERGY FORM	LEVEL OF INTERACTION	CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE	?	?	?	?	<0.07	<0.07	?	+	+	?	filter	OPTICAL MASER
		<0.1	<0.1	<	<	<<	<<	?	+	+	+	filter	(CO_2) INFRARED MASER
	DEGRADATION	$>10^{-7}$				>0.07	>0.07	?	+	+	+	"	OPTICAL MASER
		>0.1	>	>	>	>>	>>	?	+	+	+	"	(CO_2) INFRARED MASER
	INCAPACITATION												OPTICAL MASER: not dependably predictable because of variability of target factors-- position, etc. INFRARED: effects much more dependably predictable, but as yet not known.
	LETHALITY												OPTICAL MASER: no lethal effect likely. INFRARED: lethality from ignition predictable.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS No effects known to contributor.
		DRUM	OSCICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		No effects known to contributor.
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS Energy Levels of Interaction expressed in joules/cm^2.
		PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE	?	<0.1	<1.0					?	+	+	fil-ter	Applies to CO_2 infrared only.
	DEGRA-DATION		>0.1	>1.0									
	INCAPA-CITATION												Not known to contributor
	LETHA-LITY												Not known to contributor

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		No effects known to contributor
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS Energy levels of interaction expressed in joules/cm^2.
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE	<0.1							-	+	+		Applies only to CO_2
	DEGRADATION	>1.0							+	+	+		
	INCAPACITATION												Not known to contributor
	LETHALITY												Not known to contributor

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS No credible results known to reporter.
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		No effects known to reporter.
ELECTROMAGNETIC (LASERS AND MASERS)	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

APPENDIX A - Bibliographic Sources

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Add pages if necessary.

APPENDIX B - Amplification of Remarks

Add pages if necessary.

APPENDIX C - Other Possible Information Sources

Add pages if necessary.

APPENDIX D - Catch-all

Add pages if necessary.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE	0.2-5.5 / <150 A1	→	→	→	→	→	→	→	→			
	DEGRADATION	1-30 / 170 A2	2.8 / X A3	1.8-10 / 170 A4	1.8-3.3 / X A5				10 / 10 A6	.07-3.0 / 170 A7		E A8	
	INCAPACITATION				2.5-10 / >200 A4							E A8	
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	DRUM	OSCICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE		$\frac{9.5}{5}$ A9										
	DEGRADATION		$\frac{0.2-6.5}{0.4}$ A10							$\frac{3-10}{1}$ A11		D-I A12	
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE												
	DEGRADATION									.003-.3 A13		D-I A12	
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE		$\frac{0.1-10}{<10}$ A14										
	DEGRADATION		$\frac{0.75-10}{101}$ A15						$\frac{3-10}{1}$ A16	$\frac{3-10}{1}$ A17		D A18	
	INCAPACITATION		$\frac{3-10}{100}$ A19									D A18	
	LETHALITY		$\frac{3}{165}$ A20									D A18	

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE												
	DEGRA-DATION	2.8-10 / 10-165 A21	.003-24 / 10-165 A22						0.2-28 / 165 A23			E A8	
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE												
	DEGRA-DATION	$\frac{2.5\text{-}10}{40}$ A24							$\frac{0.2}{165}$ A25			D A18	
	INCAPA-CITATION	$\frac{3}{165}$ A26										D A18	
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE				0.8-3/43 A27	10/1 A28	0.4-24/43 A29			3/1 A30			
	DEGRADATION	.003-24/10 A31	015/350 A32	10-24/10 A33	10/20 A34	.003-30/10 A35	.003-30/10 A36	3-24/8 A37	3-24/8 A38	.003-30/10 A39		D A18	
	INCAPACITATION					2.5/70 A40						D A18	
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE					0.4-24 / 8 A41							
	DEGRADATION	2-3 / X A42	0.3-300 / 10 A43		003-300 / 10 A44	2.5-24 / >10 A45				2-300 / 10 A46		D A18	
	INCAPACITATION									3 / 60 A47		DI A12	
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE								3 / 10 A48				
	DEGRADATION	0.2-24 / 15 A49	24 / 50 A50	.003 / X A51	24 / 50 A52				.001-3 / 20 A53	.003-30 / 10 A54		E A8	
	INCAPACITATION	0.3-300 / 70 A55	2.5-10 / 70 A56	2.5-24 / 70 A56	2.5-10 / 70 A56							E A8	
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO CENTRAL NERVOUS SYSTEM							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD			ALPHA RHYTHM	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE							C P 3-10 / 5 A57	C P 2.5-10 / 5 A58	C 2.5 / 5 A58			
	DEGRADATION				10-24 / 200 A59			C P .003-300 / 0.02 A60	0.14-300 / 10 A61	.003-300 / 10 A62	.003-300 / 10 A63	D-I A12	
	INCAPACITATION								1.4-10 / 10 A64			D-I A12	
	LETHALITY			0.2-24 / 50 A65					A64			D-I A12	

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS-DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	
ELECTROMAGNETIC (MICROWAVES, UHF, VHF, RF, AF, AC)	SAFE												
	DEGRA-DATION	.05-25 / 10 A66								0.2-24 / 30 A67	.003-300 / 30 A68	DI A12	
	INCAPA-CITATION												
	LETHA-LITY												

Compendium of Pathophysiologic Sensitivities to Microwave Exposure

Directions for Reading Entries in Matrices

Entries have been made in the box of each matrix where information appropriate to the subject is available. Where a box is left empty, it indicates that no information was available at this time. The three entries in each box include:

Upper figure - frequency (the highest and lowest frequency under which a particular physiologic parameter was studied). The entry for frequency designation is 1×10^{-3} i.e., if the frequency range designation such as in A 2 is 1-30 this is in reality 1000-30000MHz. In some entries for frequency designation the letters P or C may be noted. In these particular instances where differences between pulsed (P) or continuous waves (C) is noted, these are so designated.

Middle figure is the power density or field intensity which is the lowest one reported to produce an effect on the particular system under study, in the degradation, incapacitation, or lethality levels. For entries in the safe level, the highest field density recorded in which no effect was observable, has been used. The power level entry is in mW/cm^2. In other words under, A 2, 170 indicates 170 mW/cm^2. In reviewing the field density designations an inconsistency between various levels of safe, degradation or incapacitation may be noted. This is due to the fact that various physiologic parameters were studied at certain frequencies and power levels and not at others. Also, in order to prevent bias of available information a large number of papers from the Soviet Union have been included in these entries. Inasmuch as the Soviet research in microwave effects is based on "conditional response" or "higher nervous activity" approaches, effects at field densities lower than those in the U.S.A. are reported. Where an X is noted for the power density measurement it indicates that such information was not given in the report.

Lower Figure - i.e. A 1; A 2; A 3 are specific notations for Appendix A; this should be referred to for amplification of remarks.

Designations of the countermeasures include:

E.- for easily accomplished countermeasures
D - indicates countermeasures are difficult to establish
I - in the opinion of the reviewer, countermeasures may be impossible in the present state of the art.

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APPENDIX B

Amplification of Remarks

A 1. Most of these exposures were whole-body. It must be realized that in such exposures the eye is not constantly in the microwave field and as the individual or animal moves about there are variable periods during which the eye is not exposed. (1,28,46,68,117,135,136,189).

A 2. These findings include keratoconjunctivitis, iridocyclitis, temporary eye distrubance, photophobia, hyperemia, clouding of the cornea, conjunctivitis. (6,116,121,155,164).

A 3. Miosis (121,164).

A 4. These changes include clouding, opacities, haziness of the lens, broadening and arborization of the lens suture, roughening of the anterior capsule and cataract production after variable periods of exposure ranging from 20 minutes to one hour. (12,17-23,27,31,41,67,71, 95,121,122,143,154,155,164,187,189,190,191,).

A 5. Opacities in vitreous fluid. (31,67).

A 6. Temporary eye disturbance, photophobia, hyperemia. (90).

A 7. Biochemical changes consisting of decreased ascorbic acid in the lens within 18 hours post irradiation, decreased glutathione 24 to 48 hours post irradiation, reduced enzyme systems, in experimental animals. Among individuals working in radiofrequency fields of 67 to 230 MHz, a study of speech and visual motor reactions showed that reaction speed was significantly decreased. In other observations increased and subsequent decrease in vision threshold as measured from the edge of the retina were noted when the back or abdomen of experimental subjects completely adapted to darkenss were exposed to 3 to 300 MHz. Patients who were dark adapted showed increased sensitivity of marginal vision when their heads were exposed to 1 to 10 cm waves (3×10^3 - 3×10^5). Accidental exposure of the head and upper-trunk of man to 10,000 MHz 10mW/cm^2 for 15 minutes produced visual disturbances. (19,20,32,56,75,86,90,115,121,183).

A 8. Countermeasures for this level include the wearing of protective goggles, operation within the 10 mW/cm^2 maximum permissible exposure. Periodic medical examination such as slit lamp examination of the lens and complete cardiovascular and endocrine examination; visual and aural fatigue can be eliminated by rest. (13,159,164).

A 9. Exposure of man to 9,500 MHz (pulsed) 5 mW/cm^2 did not result in hearing sensation for audio-modulated waves. (29).

A 10. Humans in a radiofrequency field of 216 to 6,500 MHz with an average intensity as low as 0.4 mW/cm^2 have hearing sensations produced by audio-modulated waves (29,52).

A 11. Exposure of the auditory region of the cortex to 3 to 300 MHz produces changes in auditory threshold. Exposure of rats to 3,000 to 10,000 MHz 1 to 10 mW/cm^2 produces an initial increase in excitibility followed by subthreshold inhibitions manifested as a lowered sensitivity to auditory stimuli. (87,165).

A 12. Countermeasures are difficult because these changes occur within the maximum permissible exposure of 10 mW/cm^2. Screening by RF absorbing materials is indicated. (140,151).

A 13. In occupationally exposed individuals in fields between 3 and 300 MHz an increase in olfactory thresholds were found which could be indicative of sympathetic and parasympathetic inhibition. (56,102).

A 14. No physiologic decrements were observed in individuals working in radiofrequency fields of 0.3 to 0.5 MHz (47,57,81,110,118,126, 146,184).

A 15. Individuals working in a 75 MHz field showed considerably higher skin temperature on the forehead and fingers than controls. Localized exposure of the skin of rats to 10,000 MHz, 350 mW/cm^2 showed a linear temperature rise during the initial 3 to 4 minutes at a depth of 1 to 2 mm. During exposures at 350, 220, and 100 mW/cm^2 for 5 to 20 minutes thermal equilibrum was established (81,126,137,146).

A 16. Animals exposed to 3 to 10 MHz, 1 mW/cm^2 showed morphological and histochemical signs of irritation of receptor and interoreceptor apparatus after one hour daily exposures for 5 to 9 months. (168,179).

A 17. Local irradiation with 3,000 MHz, 350 mW/cm^2 to the ventral body area of rabbits reduced cardiac rhythm; radiation of the same body area while the skin was anesthetized did not alter cardiac rhythm. This suggests that reduced cardiac rhythm is a function of skin receptor reaction to microwaves. Rats exposed to 10,000 MHz pulsed, 100 mW/cm^2 for six minutes showed changes in nucleic acid metabolism in the skin. (78,99,179).

A 18. Protective metallic woven suits which, however, are quite cumbersome has been recommended (140,151).

A 19 . Animals exposed to 3000 to 10,000 MHz, 100 mW/cm^2, for several hours developed severe burns in selected body areas, mainly over bony prominences. (121,126).

A 20. Dogs exposed to 3,000 MHz, 165 mW/cm^2 for periods ranging from 2 to 3 hours developed severe skin burns and ulceration; this exposure is in the lethal range for this species. (12).

A 21. Accidental exposure of the head and upper trunk of man to 10,000 MHz, 10 mW/cm^2 for 15 minutes resulted in asthenia. Dogs exposed to 2880 MHz, 165 mW/cm^2 developed akinesia. (90,121).

A 22. Rats exposed to 3 to 300 MHz, 10 mW/cm^2 showed decreased swimming ability. Chickens, pigeons, and sea gulls exposed to 9,300 and 16,000 MHz (pulsed), 10 mW/cm^2 showed sustained extensor activity of wings and legs commencing within a few seconds. These birds showed distress and unsteady gait. Whole-body exposure of chicks to 24,000 MHz produced staggering gait and muscular weakness. (68,104,116,176).

A 23. Dogs exposed to 200 or 2800 MHz (CW or pulsed), 165 mW/cm^2 show disturbed equilibrium and ataxia. (2,121).

A 24. Animals exposed to 2450 to 10,000 MHz, 100 mW/cm^2 developed severe skin burns. (121,179).

A 25. Rats and rabbits exposed to 3000 MHz, 40 mW/cm^2 for 30 minutes show injury to skin receptors, which is greater than to the receptors of internal organs. (179).

A 26. Same as A 23.

A 27. Mice exposed to 3000 MHz or 800 MHz, 43 mW/cm^2 did not show any effect on growth. Exposure of the hind limb of rats to 2720 MHz did not produce any disturbance in bone growth. (11,135).

A 28. In rats exposed to 10,000 MHz, 1 mW/cm^2 there was no appreciable change in blood pressure after several weeks of exposure for 30 minutes daily. (58).

A 29. Mice or rats exposed to 800 MHz or 24,000 MHz at field densities up to 43 mW/cm^2 did not show any evidence of bone marrow alteration. (8,145).

A 30. Rabbits exposed to 3000 MHz, 1 mW/cm^2 showed no changes in cholinesterase activity in the blood after multiple 90 minute exposures. (130).

A 31. In both animals and man exposed to various frequencies ranging from 3 to 24,000 MHz at field densities as low as 10 mW/cm^2 blood changes have been reported including increased temperature of jugular blood, decrease in lymphocytes, increase in Cx reactive protein, alteration in electrolyte content and blood protein ratios, and increased blood coagulation time. Human lymphocytes cultured under 3000 MHz at 7 mW/cm^2 showed numerous transformations. (25,97,116,126,131,153,167,171,182).

A 32. At 500 MHz, 350 mW/cm^2 there was evidence of increased phagocytosis of intravenously injected colloidal carbon. (142,177).

A 33. Exposure of sciatic and radial nerves of cats to 10,000 MHz results in contraction of leg muscles. Sixteen thousand MHz exposure at less than 10 mW/cm^2 causes neuromuscular responses in birds. Twenty-four thousand MHz produced neuromuscular effects in chicks. (36,111,175).

A 34. Exposure of mice to 10,000 MHz, 20 mW/cm^2 causes increased growth rate after initial suppression. (128).

A 35. Individuals working in radiofrequency fields of 3 to 30,000 MHz show various cardiovascular effects such as arterial hypotension, bradycardia, sinus arrhythmia, reduction of ECG spikes, ventricular extrasystole, disruption in intrauricular conduction, tachycardia, coronary spasms. Similar results more or less have been reported in animals such as rabbits and dogs exposed to 100 to 200 mW/cm^2. When the head of the dog is exposed to 2450 MHz, there was evidence of increased heart rate and diastolic pressure. In rats vascular alteration in the brain and internal organs are seen after 3,000 MHz, 40 mW/cm^2. Accidental exposure of man to 10,000 MHz 15 mW/cm^2 for 45 minutes produced tachycardia (10,16, 30,39,54,55,58,60,62,76,89,92,95,107,109,116,127,134,138,139,148,162,172, 173,180,184,186).

A 36. Accidental exposure of man to 10,000 MHz, 15 mW/cm^2 for 45 minutes produced a neutrophil leucocytosis. In man and animals at exposures ranging from 300 to 24,000 MHz at 10 to 40 mW/cm^2 alteration in various bone marrow functions and blood cell components, such as, granulocytes, leukocytes, red blood cells, reticulocytes, hemoglobin, and red cell life span. (35,38,62,88,96,100,109,118,120,170,178,182).

A 37. Whole-body exposure of rats to 24,000 MHz pulsed at 15 mW/cm^2 resulted in a 5° C temperature rise in 27 minutes. Mice and rats exposed to 3,000 MHz at 8 mW/cm^2 showed slight hyperplasia of the reticulohistiocyte system of the spleen. (37,125).

A 38. Exposure of rabbits and rats in the lumbar region to 24,000 MHz resulted in vascular dilation and subcutaneous hemmorhage. Rabbits and rats subjected to 3000 MHz, 10 mW/cm^2 showed changes in the protein fraction of blood serum, residual nitrogen in the blood, amino acid in urine and decrease in RNA content in the liver, brain, and spleen. (77,131).

A 39. Workers exposed to 3,000 to 30,000 MHz under industrial conditions showed increase in blood sugar level and fluctuation in creatinine, lactic acid, and pyruvic acid levels. Workers exposed to 3 to 300 MHz showed increase in blood histamine content. Decreased cholinesterase activity has been noted in the liver, heart, and brain stem in rabbits and rats. At 100 to 2450 MHz, effects on dielectric constant of blood decreased as frequency decreased. Forty-eight MHz, 3.5 watts for 5 minutes evokes changes in the gastrocnemius and sartorious muscles of the frog. In humans exposed to 3 to 30 MHz significant deviation in glucose tolerance occurs and an increase in gamma-globulin was noted. (3,10,39, 69,128,130,159,160,167,180,185).

A 40. In rabbits or mice exposed to 2450 MHz, 70 mW/cm^2 right auricular pressure increased for 2 to 10 minutes then decreased precipitously before death; 10,000 MHz, 400 mW/cm^2 produced myocardial necrosis. (152).

A 41. Whole-body exposure of dogs to 24,000 MHz produced no effect on female reproductive organs. Whole-body exposure of guinea pigs to 3000 MHz did not effect reproduction. Exposure to 3000 MHz, 8 mW/cm^2

did not effect mating of mice or rats. (8,34,45,50,125).

A 42. In animals and man exposed to 2000 to 3000 MHz, adrenal cortical changes, increased blood sugar, and alteration in creatinine, lactic, pyruvic, and blood ascorbic acid levels are noted. (10,98a).

A 43. Exposure of dogs to 3000 MHz, 100 mW/cm^2 results in hypophysial-hypothalamic-adrenal response. In man chronically subjecte to 300 to 3000 MHz during routine operational procedures, functional activity of the hypophysial adrenal cortex system is lowered. (91,121,181).

A 44. In individuals occupationally exposed to microwave fields ranging from 3 to 300,000 MHz, thyroid activity is increased. Increased I-131 uptake and alteration in thyroid function is noted in dogs after exposure to 1280 MHz and 2800 MHz, 50 mW/cm^2. (39,40,49,91,119,121,157,169).

A 45. Exposure of the scrotal area results in varying degrees of testicular damage such as edema, enlargement of the testis, atrophy, fibrosis, and coagulation necrosis of seminiferous tubules in rats, rabbits, or dogs exposed to 2450, 3000, 10,000 or 24,000 MHz at field intensities of 250 mW/cm^2. Minimal changes have been noted in dogs at field intensities of about 10 to 15 mW/cm^2; these, however, were simply temperature increases rather than pathological changes. Exposure of 2 to 3 month old mice to 10,000 MHz, 400 mW/cm^2 for 5 minutes causes a decrease in the number of estral cycles with increase in duration of individual cycles. (26,46,61,62,66,71,72).

A 46. Individuals occupationally exposed in 3 to 300,000 MHz fields had lower 17-hydroxycorticosteroid levels in blood, plasma, and urine in comparison with controls indicating depressed functional activity of the hypophysial-adrenal-cortical system. Rats exposed to 2450 or 24,000 MHz, 250 mW/cm^2 showed decreased androgen output. Exposure of pancreatic amylase of swine to frequencies of 10 to 40 MHz resulted in deactivation. (4,10,19,63,91,98a).

A 47. Testicular biopsy in a radar operator revealed tubular atrophy with focal necrosis and interstitial edema; hypospermia continued for a period of at least a year after the patients last exposure. Exposure of rats to 2816 MHz, 60 mW/cm^2, 2 minutes daily over a period of time resulted in severe damage to the testes. (123,156).

A 48. The epigastric region of humans was exposed to 13.56, 40 and 2375 MHz without evident disturbance in the periodic motor activity of the stomach. In rats exposed to 3,000 MHz, 10 mW/cm^2, no appreciable morphologic changes in internal organs were noted after 30 minutes of exposure. (149,180).

A 49. Accidental exposure of man to 10,000 MHz for 45 to 47 minutes, 15 mW/cm^2 resulted in nausea. Whole-body exposure of rats to 24,000 MHz (pulsed), 15 mW/cm^2 for 27 minutes resulted in a 5° C temperature rise in the stomach and rectum. (2,37,90,150).

A 50. Whole-body exposure of rats to 24,000 MHz pulsed, 50 mW/cm^2 for 27 minutes resulted in a 5° C temperature rise in the kidneys. (37).

A 51. Whole-body exposure of mice to 27.2 MHz produced an increase in respiratory rate. (33).

A 52. Whole-body exposure of rats to 24,000 MHz (pulsed), 50 mW/cm^2, 27 minutes resulted in a 5° C temperature rise in the liver. (37).

A 53. Rats exposed to 3000 MHz, 20 mW/cm^2 for 30 minutes showed negligible overheating symptoms without reversible morphologic changes in internal organs. Mice were exposed to 39 and 1.6 MHz; a number of changes in subcellular structures were found after exposure; these included many binuclear cells in the liver, irregular thickening, and breaks in the nuclear membrane. (166,180).

A 54. Radiation with 2450 MHz over the kidney in man resulted in decreased glomerular and renal plasma flow. Exposure of rats to 3000 MHz, 10 mW/cm^2 produced changes in appetite patterns. Whole-body exposure of mice to 27.2. MHz resulted in decreased oxygen consumption.

Whole-body exposure of rats to 2450 MHz resulted in increased rate of glucose absorption and transfer of glucose in the small intestine. Local irradiation of a portion of the stomach in dogs with 3 to 300 MHz results in stimulation of gastric juice secretion. (2,33,48,55,93,98,113,130).

A 55. Gastric ulcers have been produced in rabbits following exposure of the epigastric region to 300 to 300,000 MHz at 70 to 160 mW/cm^2. (141).

A 56. Exposure of mice, rabbits, or rats either whole-body or head alone to fields between 2450 and 24,000 MHz, 70 mW/cm^2 may produce variable damage to organs, such as, liver and kidney abscesses, hemorrhage and progressive fibrosis of the brain, lungs, liver, and kidneys, lung congestion, and thrombic emboli. (60,77,141,144).

A 57. Rabbits exposed to 3000 MHz (CW) or 10,000 MHz (pulsed) at 5 mW/cm^2 showed no changes in EEG tracings. (7).

A 58. Rabbits exposed to 10,000 MHz (pulsed) 5 mW/cm^2 showed no evidence of morphologic damage to the brain. Exposure of the head of the dog to 2450 MHz (CW) produced no effect on brain or cerebrospinal fluid. (7,161).

A 59. A nociceptive reflex in cats occurs after 10,000 MHz, 200 mW/cm^2 focal irradiation. Whole-body exposure of rabbits and rats to 24,000 MHz results in muscle spasms, tremors, convulsions, stimulation and depression of activity. (77,112).

A 60. EEG tracings in rabbits exposed to 3000 MHz (pulsed) 5 mW/cm^2 showed slight desynchronization from the motor region; at 20 mW/cm^2 variations in the amplitude were observed. Rabbits irradiated with 300 to 3000 MHz showed changes in the EEG; 300 MHz had the greatest biologic effect while 3000 MHz had proportionately less pronounced effects. Pulsed microwaves produced a greater effect than CW microwaves. Rabbits exposed to

40 MHz, 0.1 mW/cm^2, show EEG changes in the cortical and subcortical brain structures produced by a 3 minute exposure. Exposure of rabbits to 300, 577, or 2400 MHz (CW) for 5 minutes at power levels as low as 0.02 mW/cm^2 resulted in EEG changes in more than 50% of the animals studied. In individuals occupationally exposed in microwave fields of 3 to 300 MHz, lowering of the alpha index and slower waves are noted. An individual exposed to 10,000 MHz, 15 to 20 mW/cm^2 for 10 to 15 minutes showed lowered voltage, a rapid beta rhythm and a slow theta rhythm. (7, 24,43,44,64,83,85,91,167,182,192).

A 61. Rabbits exposed to 3000 MHz (pulsed or CW), 5 to 20 mW/cm^2 showed evidence of brain injury; cells of the cortex, cerebellum and subcortical structures had deficient tigroid content, vacuolization was observed in some cells, proliferation of glial cells, congestion of the meninges and superficial cerebral cortex vessels was frequently observed at 30 mW/cm^2; some red cell effusion and enlarged perivascular spaces, was noted. There were more pronounced morphologic changes in the nervous system of rats following 3000 MHz than 10,000 MHz at 1 to 10 mW/cm^2. Pulsed waves are more effective than CW. Exposure of cats for 1 hour to 10,000 MHz 400 mW/cm^2 resulted in injury to cerebral and spinal cord nerve cells. Changes occurred in the tigroid substance and in other components of nerve cells in the cerebrum and spinal cord of cats subjected to 300 to 300,000 MHz, 400 mW/cm^2. In animals exposed to 14 to 88 MHz damage to neural structures consisting of thickening of neural fibers, swelling and vacuolization of cell protoplasm in the hypothalamic area and the medulla oblongata and local karyocytolysis of individual neurons are noted. (7,14,53,180).

A 62. Rabbits whose heads were exposed for 30 minutes to 3 to 300 MHz show increased excitation of cortical and other visual analyzers.

Exposure of the head of monkeys to 390 MHz results in alternation of arousal and drowsy periods. Alteration in cellular protein metabolism of the nervous system is seen in experimental animals following 3000 to 30,000 MHz at 10 mW/cm^2. Increase in brain cholinesterase is noted after 3000 to 30,000 MHz. In individuals occupationally exposed to frequencies ranging from 3 to 10,000 MHz at levels as low as 1 mW/cm^2 nervous system effect is noted i.e. decrease in speech and visual motor reaction, increase in olfactory thresholds, general weakness, lower working capacity, increased irritability, headaches, dizziness, lowered emotional status, apathy, hypokinesia, loss of memory, and or insomnia. (5,36,44,56,74,84, 109,130,132,139,157,158,181,182).

A 63. In individuals occupationally exposed to frequencies ranging from 3 to 300,000 MHz symptoms of a neurosis like complex, or a quasi neurotic reaction has been noted. (42,43,44).

A 64. Degeneration of neurons in the cerebral cortex and retograde changes in the kidney and myocardium of rabbits have been produced by exposure to 200 MHz. Head exposure of rabbits to 2450 MHz results in focal lesions in the cerebral cortex. Whole-body exposures of rats to 1430 MHz produced lesions of the brain (133,163,180).

A 65. Death has occured in various species after exposure to CW or pulsed 200 to 24,000 MHz at power levels ranging from 50 to 800 mW/cm^2 for periods of time varying from several minutes to several hours. (2,15, 16,36,108,121,126,157).

A 66. In conditional response studies in dogs irradiated with 50 MHz to specific zones of the cerebral cortex exposure at 20 to 25 watts caused defensive reactions and deterioration of discrimination. At fields of 3 to 300 MHz, rats exposed at 10 mW/cm^2 showed changes in conditional response activity after several one hour daily exposures.

Exposure of a pigeons head to a frequency field produced by a 35 watt generator for a period of 3 to 5 minutes caused latent periods of conditioned food reflexes to extend to more than twice normal time. Rats exposed at 10 mW/cm^2 showed changes in some conditional activity after several one hour daily exposures. Exposure of rats to 2860 MHz, 30 mW/cm^2, for more than two minutes produced changes in conditional responses. At 3000 MHz 10 mW/cm^2 30 minutes daily changes in conditional responses which are more pronounced in pulsed than continuous microwaves such as, changes characterized by increased excitibility and decrease in inhibitory processes are noted. Rats given head irradiation at 24,500 MHz try to avoid the microwave field suggesting awareness of a stimulus. In mice exposed to 10,000 MHz, 450 mW/cm^2 for 5 minutes a partial decrease in conditional response is noted up to three days after exposure. Brief exposure of rabbits to 3 MHz at 10 mW/cm^2 intensifies conditional responses to different stimuli whereas prolonged exposure produced an inhibitory effect. In rats exposed to 300,000 MHz, 40 mW/cm^2 for 15 minutes for a total of 99 times shifts in reflex activity were found with pulsed and continuous microwaves characterized by disinhibition and a depression of reflex activity. However, the effects of the pulsed microwaves were more pronounced and occurred earlier during the first to 19th exposure. Reflex shifts in animals exposed to continuous wave microwaves occurred considerably later in the 81st to 99th exposure. (9,40,62,65,77,80,82,101,102,103,105,106,107, 109,123,124,147,157).

A 67. Whole-body exposure of man to 200 to 300 MHz produces a buzzing or knocking sound which was heard no matter where radiation was aimed; source was identified as a short distance behind the head. Whole-body exposure of animals to 3000 MHz results in movement to positions where irradiation makes them less uncomfortable, dogs show agitation and apprehension. Occupationaly employed individuals who have been exposed to 6000 to 10,000 MHz exhibit functional disorders of the nervous system characterized by dystonia, insomnia, and amnesia. Chickens exposed to 10,000 MHz, 30 mW/cm^2 for 15 minutes show a tendency to move away from the radar beam. Twenty-four thousand MHz (pulsed) 109 mW/cm^2 produces changes in behavioral patterns in rats. (51,68,73,79,116,129,174).

A 68. Individuals occupationaly exposed to fields ranging from 3 to 300,000 MHz show a variety of subjective symptoms which include neural disturbances and neurasthenia. Rats exposed to 300 to 900 MHz, CW show behavioral changes. (41,44,70).

APPENDIX C

Critique

Quantitation of the biological response to microwaves is a complex problem because of the wide frequency spectrum, the large number of physical and biological variables and the interrelationships of these variables.

The factors which have to be considered include: frequency, intensity, waveform (continuous wave, pulsed, and modulation), animal orientation with respect to source, size of animal with respect to wavelength, portion of the body irradiated, exposure time-intensity factors, environmental conditions (temperature, humidity), and shielding. The condition of the subject such as state of health, restraint, medication, etc. has to be considered. These variables, individually and in combination, affect the biological response to microwaves. An effect observed at a particular frequency should not be attributed to the frequency alone without consideration of the many variables noted above and their interrelationships.

Since radiation in the millimeter range tends to penetrate only a few millimeters into the body, while radiation of longer wavelengths penetrates progressively deeper, the internal structures of smaller animals, being closer to the body surface, may be more strongly affected by certain wavelengths of electromagnetic radiation than those of larger animals, thus producing discrepancies in any comparative evaluation. The inherent thermal regulation ability of the animal is also a factor in such biological responses. The intensity of radiation required to produce a given biological effect can vary considerably with frequency. When a particular biological effect is reported at a specific frequency it does not mean that the effect occurs only at that frequency; the effect may be produced at other frequencies, but the particular parameter may not have been studied.

Interpretation of the relationship of frequency to a particular biological response should be approached with caution since not all investigators look for all responses at all frequencies. Acquisition of data are determined by the particular type of generating equipment available and the interests of the investigator.

APPENDIX D

ABSTRACTS FROM ARTICLES ON BIOLOGICAL EFFECTS OF MICROWAVE RADIATION

Schwan, H. P., and Li, K., "Hazards Due to Total Body Irradiation by Radar", Proc. IRE, Vol 44, p 1572.

At 10-cm wavelength irreversible damage to the eye occurs if the energy flux is in excess of about 0.2 watt/cm^2. Intolerable temperature rise, due to total body irradiation may be anticipated for flux values in excess of 0.02 watt/cm^2. Hence a discussion of hazards due to total body irradiation is of primary interest. This paper presents data which analyze the mode of propagation of electromagnetic radiation into the human body and resultant heat development.

(1) The amount of absorbed energy is near 40 percent at frequencies much smaller than 1000 and higher than 3000 Mc. In the range from about 1000 to 3000 Mc the coefficient of absorption may vary from 20 to 100 percent.

(2) Radiation of a frequency below 1000 Mc will cause deep heating, not well indicated by the sensory elements in the skin and, therefore, considered especially dangerous. Radiation of a frequency between 1000 and 3000 Mc will be absorbed in both body surface and in the deeper tissues, the ratio being dependent on parameters involved.

(3) Arguments are advanced in support of tolerance values for total body irradiation near 0.01 watt/cm^2.

Conclusions of practical value are: (1) Since sensory elements are located primarily in the skin, low-frequency radiation ($f < 1000$ Mc) is much more dangerous than high-frequency radiation. (2) Radiation of very high frequency ($f > 3000$ Mc) causes only superficial heating with much the same effects as infrared and sunlight. The sensory reaction of the skin should provide adequate warning.

Kulberg, M. E., "Radar Can be Tamed", Natl. Safety News, Vol 81, pp 22-23, 56, 70 (May 1960).

Major hazards associated with radar include: (1) material handling hazards, particularly with portable equipment and during its installation or removal; (2) falls from towers or in or around the radar unit; (3) electrical hazards connected with use and servicing of high-voltage electrical equipment, (4) flammable oil fire hazard in certain transformers and condensers of high-voltage electrical equipment (in addition, a fire hazard may exist when flammable gases, fumes, vapors, or explosives or other highly combustible materials are present in the radar beam; (5) toxicity of gas fills in certain wave guides; (6) hazardous x-radiation from high-voltage tubes; (7) hazardous radioactivity from radioactive activators in certain radar switching tubes; (8) harmful effect of electromagnetic radiation on the body or its parts. The hazard of greatest interest seems to be that of electromagnetic radiations. When placed in a radar beam, the body will be warmed, as will any other conductive object. If the temperature rise exceeds the capacity of the body to dissipate the energy applied, the condition aggravates itself, and it is possible that damage could occur. In the event of low-power radar sets, such as used in radar speed-measuring devices or weather-mapping radar on aircraft, the amount of power available is too low to cause difficulty. A possible exception is made in the case of the eyes, if a direct observation is made of the output of the unit. The eyes and other parts of the body not provided with many blood vessels tend to rise in temperature more rapidly than the rest of the body. Studies indicate that harmful body heating cannot possibly result if the incident energy level does not exceed 1 mw/cm^2 at the eyes, kidney, and liver.

Morgan, W. E., "Microwave Radiation Hazards, A.M.A. Arch. Ind. Health, Vol 21, pp 570-573 (June 1960).

The author offers the following suggestions for the control of possible radiation hazards: (1) avoid any exposure to radio-frequency energy having a power density of 0.01 w/cm^2 or greater. Areas accessible to transit personnel and having a power density equal to or greater than 0.01 w/cm^2 should be posted with a caution sign and flashing light, and should not be occupied for any length of time; (2) do not make detailed visual examination of any microwave radiator, reflector, wave guide horn, or magnetron during periods of transmission; (3) limit the number of personnel having access to areas immediately adjacent to test stands or benches containing equipment radiation energy of hazardous power. (only those required to perform specific tests should be present); (4) use dummy loads, water loads, or other absorbent materials whenever possible to absorb the energy output of the transmitter while it is being operated or tested; (5) when Item No. 4 cannot be complied with; provide absorbent screening to isolate test stands from each other or from adjacent administrative areas which may be affected by the microwave radiation. It is believed that repeated exposure to radar waves while observing proper precaution does not lead to any cumulative or chronic effects on the body. This seems to be proven by the lack of evidence showing that anyone has been seriously injured from working with radar equipment. There have been some reports in the past concerning alleged injuries, but it is the opinion of most medical scientists that the reported disorders were not caused by radar.

Lubin, M., et al., "Effects of Ultra-High-Frequency Radiation on Animals", A.M.A. Arch. Ind. Health, Vol 21, pp 555-558 (June 1960).

Twenty-nine rabbits and 44 rats were subjected to repeated whole-body exposure with ultrahigh-frequency radiation at about 400 Mc. About an equal number of animals served as controls. No pathological damage was found which could be attributed to the effects of radiation.

Goldman, D. E., "Short Wave Electromagnetic Radiation as a Hazard to Personnel", NP-9992, Lecture and Review Series No. 60-6. (Naval Research Institute, Bethesda, Md.) 8 pp (Sept. 17, 1960). Obtainable from: Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

The radiation hazards of short-wave electromagnetic radiation are discussed. It is pointed out that electromagnetic radiation produces electrical and magnetic forces and generates heat upon contact with biological systems. Reactions are induced which are potentially dangerous to animals. Reported cases of eye damage and other serious injuries to personnel working with high-powered radar generators are discussed. Results are reported from studies with monkeys in which a number of neurological disturbances were induced by exposure to radio frequencies in the 300 to 400-Mc range. Results of other animal studies are discussed briefly, and reaction mechanisms involved in the biological effects of primary radiations in the range 100 to 30,000 Mc are summarized. [illegible] from measurements of the conductivity and dielectric constant of skin; the dielectric constant of selected tissues; the percent energy absorption by whole rats, rabbits, and dogs; and the cooling time constant for mice, rats, rabbits, dogs, and humans exposed to radiation in this energy range. Data are also included on the heat input and output of the body at various temperatures under steady-state conditions.

Weiss, M. M., and Mumford, W. W., "Microwave Radiation Hazards", Health Physics (London), Vol 5, pp 160-168 (June 1961).

A review of the published literature on the exposure of animals to microwave radiation indicates that the principal hazard results from the heating effect as the energy in the microwave radiation is absorbed in the body. The interpretation of extensive experimental data on small fur-bearing animals has led to the establishment of recommended exposure limits. These limits are discussed from the standpoint of the probable safety factor involved for total immersion of the human being in the microwave radiation field and for localized exposure confined to particular portions of the anatomy. Precautionary measures are discussed and a method of estimating the distance from a radiating antenna is presented. Some presently available microwave radiation-intensity measuring devices are described.

Minecki, L., "Critical Evaluation of Maximum Permissible Levels of Microwave Radiation", Arhiv hig. Rada, Vol 15, pp 47-55 (1964).

The biological effect of microwaves and electromagnetic radiation of lower frequency is reviewed, with particular reference to the problem of the so-called extrathermal effect, which -- in the author's opinion -- should be given due consideration. The assumption that the biological effect of microwaves is only based on thermal effect, unduly simplifies the whole problem, especially in connection with the determination of maximum permissible doses. Results are presented of the clinical observations of a larger group of persons occupationally exposed to microwaves ranging from 750 to 200 MHz. These results indicate that in the group with prolonged exposure the occurrence of some symptoms was considerably higher than in the control group. The results of some experimental work on the effect of microwaves, with special reference to the so-called thermal effect, are also discussed.

Pelis, L., Jr., "The Hazards of Low Voltage Radiation", Ind. Med. & Surg., Vol. 33, pp 866-868 (Dec. 1964).

In the absence of a foolproof standard and to minimize the hazards of radio-frequency radiation the following recommendations should be considered: unauthorized persons should be prohibited from entering microwave areas. Those areas which may exceed the maximum permissible level should be posted with caution signs and other warning devices including visible or audible signals. Equipment power should be shut off whenever wave guides are open for the purpose of making changes during the experimental work. Exposure of whole body to microwave radiation should be avoided. Dummy loads such as water loads or other absorbent material should be used to absorb the energy output of the transmitter while it is being operated or tested. Absorbent screening should be installed to isolate test stands from one another and from adjacent workers. Calculations should be made to determine areas of probable unsafe exposure. Where it is known or suspected that workers will be exposed to microwave radiation in excess of 10 mw/cm^2, a preplacement medical examination should be given the worker.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	Visual sensations produced by pulses of 100K gauss fields were observed in close vicinity of high field-strength magnets (1m to 5m from poleshoes). See Appendix A 1 and 2. No symptoms were reported when subjects were exposed to high field-strength electric fields (10,000V/m)
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		DRUM	OSCICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION-			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												Electric fields (10,000V/m) produce sensations of standing-up of hair, and corona discharges have been observed.
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							GENETIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES.	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
MAGNETO STATIC AND ELECTROSTATIC FIELDS	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

APPENDIX A - Bibliographic Sources

1. A. Kolin: "Magnetic Fields in Biology," Physics Today, Vol. 21, page 42 ff (1968).

2. M. F. Barnothy, Editor: Biological Effects of Magnetic Fields, Plenum Press, New York, N. Y. (1964)

Add pages if necessary.

APPENDIX B - Amplification of Remarks

Add pages if necessary.

APPENDIX C - Other Possible Information Sources

Add pages if necessary.

APPENDIX D - Catch-all

Add pages if necessary.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS See Appendices A(1,2), B, C. * Reported by J. W. Condex, rabbit in waterbath (See Appendix A-2)
		CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE	$0.5W \cdot cm^{-2}$ $*1\ W\ cm^{-2}$ 3 min							U N	K N O	W N	none	
	DEGRA-DATION	$1.0W \cdot cm^{-2}$ $*\ 3W\ cm^{-2}$ 3 min		none		none		none	U N	K N O	W N		
	INCAPA-CITATION	$1\text{-}2W\ cm^{-2}$ $*3W\ cm^{-2}$ 5 min		See note (1)		See note (2)		See note (2)	U N	K N O	W N		Note (1): Reversible lens changes depending upon duration of exposure amd omdiued temperature rise.
	LETHA-LITY	$3.0W\ cm^{-2}$		See note (1)		See note (2)		See note (2)	U N	K N O	W N		Note (2): Dependent upon temperature rise induced.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		DRUM	OSCICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-L TY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
ULTRASONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS Direct application of transducer to skin. See Appendix A-2
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE	1W cm^{-2} 1 min	1W cm^{-2} 1 min										None
	DEGRADATION	1W cm^{-2} 5 min	1 W cm^{-2} 5 min										Erythema and light burn
	INCAPACITATION	2 W cm^{-2} 5 min	2 W cm^{-2} 5 min										Burn with charring of tissue
	LETHALITY	2 W cm^{-2} 10 min	2 W cm^{-2} 3 min										Complete necrosis
		3 W cm^{-2} 3 min	3 W cm^{-2} 3 min										2nd degree burn

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS See Appendix A-2 *Underwater bath; Wistar rats were used as experimental animals.
		BLOOD	LYMPH	MUSCULES*	SKELETON*	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE			?	?								
	DEGRA-DATION												
	INCAPA-CITATION			3 W cm^{-2} 5 min	cm^{-2} 5 min				**	**			*** Paralysis of hind quarters Necrosis of skin and muscle
	LETHA-LITY			3 W cm^{-2} 5 min	cm^{-2} 5 min				***	***			*** Necrosis of bone and muscle, with tail falling off, hind quarters paralysis and death.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS *	GONADS **	GONADS ***	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	See Appendix A-2 * Rat testes, direct application ** Rat testes, water bath *** Rat testes, focussed beam, 37.5W
ULTRASONIC	SAFE					1W cm^{-2} 1 min	3 W cm^{-2} 1 min	not safe					
	DEGRADATION					1 W cm^{-2} 10 min	3 W cm^{-2} 5 min	37.5W 5 min					
	INCAPACITATION					2 W cm^{-2} 5 min	cm^{-2} 5 min	37.5 W 5 min					
	LETHALITY					2 W cm^{-2} 5 min	3 W cm^{-2} 10 min	37.5W 10 min					

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS See Appendix A-2, * Kidney of rat Pathology: (below)
		GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE	1-2W cm^{-2} 1 min	1-2W cm^{-2} 1 min		1 W cm^{-2} 1 min				**				** None
	DEGRA-DATION	1 W cm^{-2} 5 min	1 W cm^{-2} 5 min		1 W cm^{-2} 5 min				***				*** Intestine: congestion, hemorrhage, and necrosis; Kidney: congestion
	INCAPA-CITATION	1 W cm^{-2} 10 min	1 W cm^{-2} 10 min		1 W cm^{-2} 10 min				****	*****			**** Liver: congestion; Intestine: congestion, hemorrhage, and necrosis *****Kidney: hyaline droplet de-degeneration of distended bladder.
	LETHA-LITY	2 W cm^{-2} 5 min	1 W cm^{-2} 1 0 min		2 W cm^{-3} 5 min				*** ***				*** Liver: necrosis; *** Intestine: necrosis; Kidney: hyaline droplet degeneration.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS See Appendix A-2 * Underwater application, rats were used as experimental animals
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	* SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
ULTRASONIC	SAFE				?								
	DEGRA-DATION				3 W cm^{-2} 5 min					**			** Paralysis of lower extremities
	INCAPA-CITATION				3 W cm^{-2} 10 min								1/2 of the animals died; rest were paralyzed
	LETHA-LITY				3 W cm^{-2} 10 min								3/4 of the animals died.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		No psychological effects known except for pain.
ULTRASONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

APPENDIX A - Bibliographic Sources

1. Gilbert Baum: "The Effect of Ultrasonic Radiation Upon the Eye and Ocular Adnexa," Am. J. Ophthalmology, Vol. 2, Nov 1956.

2. J. W. Cowden and M. R. Abell: "Some Effects of Ultrasonic Radiation on Normal Tissues," Experimental and Molecular Pathology, Vol. 2, August 1963, pp 367-383

Add pages if necessary.

APPENDIX B - Amplification of Remarks

The experiments cited in the Matrix were performed with the transducer in direct contact with the eye. The effects observed appear to be due to a temperature rise rather than a mechanical effect. When a fluid coupling medium (water) was interposed between the transducer and the tissues, these effects disappeared. This may in part be explained by a dissipation of energy by the use of a coupling medium whose acoustic impedance lies between tissue and the transducer.

I have never observed any anatomical or physiological damage resulting from the use of pulsed ultrasound (0.1μs pulses, 2000 pulses/s repetition rate, 2000V applied to ½" diameter heavily damped quartz transducer--regardless of the duration of the exposure) at the levels used for diagnostic purposes, nor have I ever heard of any such damage spoken of by any investigators in this field. A number of unpublished studies indicate that dosage levels ten to a hundred fold greater than those normally employed for diagnostic studies do not produce any detrimental damage.

Data entered in the matrix are for continuous waves.

Add pages if necessary.

APPENDIX C - Other Possible Information Sources

Professor Ian Donald, University of Glasgow, Glasgow, Scotland; Dr. George Kossoff, at the Interscience Research Institute; and the Smith, Kline Instrument Co., Philadelphia, Penna.

Add pages if necessary.

APPENDIX D - Catch-all

Add pages if necessary.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				REMARKS
ENERGY FORM	LEVEL OF INTERACTION	DRUM	OSCICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	See Appendix 1 0 db = 0.0002μ bar
SONIC	SAFE											ear plugs	120 db: discomfort in ear 130 db: mild ear pain 140 db: sharp ear pain
	DEGRA-DATION	140 db	140 db	140 db	140 db							ear plugs	150 db: limit of subjective tolerance at 3 mi maximum exposure
	INCAPA-CITATION	160x db	160xx db	150 db	150 db							ear plugs	x rupture xx oscicular chain disruption.
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
SONIC	SAFE												
	DEGRA- DATION												
	INCAPA- CITATION												
	LETHA- LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
SONIC	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
SONIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

APPENDIX A - Bibliographic Sources

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Add pages if necessary.

APPENDIX B - Amplification of Remarks

Add pages if necessary.

APPENDIX C - Other Possible Information Sources

Add pages if necessary.

APPENDIX D - Catch-all

Add pages if necessary.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO EYE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS Infrasound: 1-20 Hz Visual blurring at 140 db (= approx. 0.08Wcm^{-2})
		CORNEA	PUPIL	LENS	OPTICAL FLUID	CONES	RODS	EYE MUSCLES	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
INFRASONIC AND BAROMETRIC	SAFE												Perceptible visual field vibration: 130 db
	DEGRADATION												
	INCAPACITATION												
	LETHALITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO EAR							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	DRUM	OSCICLES	ROUND WINDOW	COCHLEA				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS 0 db = 0.0002μ Bar See Appendix A-1
INFRASONIC AND BAROMETRIC	SAFE												120 db: discomfort in ear 130 db: mild ear pain 140 db: sharp ear pain
	DEGRA-DATION	140 db	140 db	140 db	140 db								150 db limit of subjective tolerance at 3-min maximum exposure.
	INCAPA-CITATION	160* db	160** db	150 db	150 db								*rupture (A-1) **oscicular chain disruption
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO NOSE							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		OLFACTORY EPITHELIUM	OLFACTORY BULB	OLFACTORY TRACT					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		120 db: nasal cavity vibrations
INFRASONIC AND BAROMETRIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (SENSOR)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		PRESSURE SENSE	TEMPERATURE SENSE	CHEMICAL (PAIN)					ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
INFRASONIC AND BAROMETRIC	SAFE	110 db											senses sound wave
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO KINESTHETIC							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		POSTURAL SENSIBILITY (LABYRINTH)	GAMMA MOTOR SYSTEM						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
INFRASONIC AND BAROMETRIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO SKIN (COVERING)							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		EPIDERMIS	DERMIS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
INFRASONIC AND BAROMETRIC	SAFE												
	DEGRA-DATION												
	INCAPA-CITATION												
	LETHA-LITY												

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	BLOOD	LYMPH	MUSCULES	SKELETON	CARDIO-VASCULAR	MARROW	SPLEEN	ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS
INFRASONIC AND BAROMETRIC	SAFE					120* db 130** db							* Chest cavity vibrates ** Moderate chest cavity vibrations, pulse rate increases 10-40%
	DEGRA-DATION												
	INCAPA-CITATION												170 db: probable organ damage
	LETHA-LITY												180^+ db: Death?

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION				
ENERGY FORM	LEVEL OF INTERACTION	ADRENALS	PITUITARY	PANCREAS	THYROID	GONADS			ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC	COUNTERMEASURES	REMARKS See Appendix A-4 150 db: chronic stimulation causes failure of functional capacity of enzymes.
INFRASONIC AND BAROMETRIC	SAFE												
	DEGRA-DATION					150 db							testicular aching
	INCAPA-CITATION												170 db: Probable organ damage
	LETHA-LITY												180+ db: death?

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		GASTRO-INTESTINAL	URINARY	RESPIRATORY	LIVER AND GALL BLADDER				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		See Appendix A-2, 3. 150 db: death, 1 min for mice; 8 min for rats, guinea pigs.
INFRASONIC AND BAROMETRIC	SAFE	130 db											Abdominal discomfort
	DEGRA-DATION	140* db		140** db									*Nausea, vomiting; **Respiratory rhythm disrupted, gagging sensation.
	INCAPA-CITATION	150 db											Limit of tolerance 170 db: Probable organ damage.
	LETHA-LITY												180+ db: death?

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	DAMAGE TO CENTRAL NERVOUS SYSTEM						ALPHA RHYTHM	SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS See Appendix A-4 150 db: breakdown nervous cells, disrupts molecular structure
		CEREBRAL HEMISPHERE	CEREBELLUM	BRAIN STEM	SPINAL CORD				ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
INFRASONIC AND BAROMETRIC	SAFE												
	DEGRADATION	150 db											Transient headaches
	INCAPACITATION												170 db: probable organ damage
	LETHALITY												180+ db: Death? See Appendix A-5,6,7,8,9,10,11

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ENERGY FORM	LEVEL OF INTERACTION	PSYCHOLOGICAL EFFECTS							SPECIFIC ADVERSE EFFECTS DUE TO TRANSMISSION			COUNTERMEASURES	REMARKS
		ASSOCIATIVE SYMBOLS	ILLUSIONS						ANATOMIC	PHYSIOLOGIC	PSYCHOLOGIC		
INFRASONIC AND BAROMETRIC	SAFE												110 db: Apprehension 140 db: Anxiety, confusion
	DEGRA-DATION												150 db: limit of subjective tolerance.
	INCAPA-CITATION												
	LETHA-LITY												

APPENDIX A - Bibliographic Sources

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Add pages if necessary.

APPENDIX B - Amplification of Remarks

Data entered in this matrix relate to infrasound only (1 - 20 Hz), sinusoidal, pulsed, or modulated on a higher frequency carrier (100-3000 Hz)

No data were available on barometric-type pressure changes (from 1 Hz - 0.001 Hz).

Add pages if necessary.

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13. ABSTRACT

This report contains biological vulnerabilities to various energy forms such as electromagnetic radiations, ionizing particles, static electric and magnetic fields and acoustical energy forms. The vulnerabilities are given in Watt per cm^2 or Watt-Seconds per cm^2 for various body organs and body biological systems (blood circulation, lymphatic system, etc.).

This volume should be of interest to anyone who is concerned about health safety of individuals who would be potentially exposed to the abovementioned energy forms.

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