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SECONDARY SUBJECT HEADINGS: AN HU AT IH M

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✓ Review

Animal Toxicology

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MEDICAL CONSIDERATIONS OF EXPOSURE TO MICROWAVES (RADAR)

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Considerable interest in the biological aspects of exposure to radar beams has been generated during the past year by widespread publicity of an alleged case of human death occurring after a brief exposure to an unknown quantum of microwaves. The incident served to direct attention to this relatively new agent, and questions naturally arose concerning the extent of the hazard, if any, to persons working with radar transmitters and to those who might be exposed in some manner to the energized beam. Many of these questions have subsequently been answered, and much needed research is being conducted by military and civilian agencies to more closely explore the multifaceted disciplines associated with this complex problem. Unfortunately, these less sensational but more scientifically conducted efforts have received little recognition or dissemination beyond the scientific world.

It is not generally known that apprehension over the biological potentials of microwaves dates back to the early days of World War II, when Daily¹ performed his original studies on U. S. Navy personnel engaged in the operation and testing of relatively low-powered radars. Although this study revealed no evidence of radar-induced pathology in human beings, numerous reports have since appeared indicating that tissue injury and animal death can occur under certain experimental conditions. These studies indicate that cataracts, corneal opacities, testicular degeneration, and hemorrhagic phenomena have been induced in anesthetized, small, furry, test animals by exposure to microwaves in the frequency range of 2,800 to 9,000 megacycles for various time exposures. Boysen,² using a transmitter with a frequency of 300 megacycles, exposed rabbits in a wave guide and produced damage to the central nervous system, degenerative changes in the kidneys, heart, liver, and gastrointestinal tract, and hemorrhagic changes in the respiratory tree. The power density measured in the wave guide was in excess of 0.1 watts per square centimeter. The animals were exposed for periods of 7 to 10 minutes, and all whose rectal temperatures exceeded 44.5 C (112.1 F) died. Boysen was of the opinion that the pathology and death were causally related to the hyperthermia.

Because of these rather startling findings and the apprehension engendered by their publication in scientific journals, the medical department of the

Apprehension over the possibility of injury to man by microwaves is based largely on the fact that sufficiently intense and prolonged radiation of this frequency has caused severe injuries to experimental animals. Several hundred workers who have been occupied about radar installations or have been exposed to radar beams have therefore been observed in a comprehensive medical surveillance program. This has been in progress for four years. The initial study was a comparison of 88 nonexposed persons with 226 radar-exposed employees, some of whom had worked with radar as long as 13 years. No acute, transient, or cumulative physiological or pathological changes attributable to microwaves have been revealed by this study in people working with high-power radar transmitters and frequently exposed to their output. These subjects are free to heed the warning sensation of heat and are advised to avoid exposure to any firing beam when in a zone defined by a minimum power density of 0.0131 watts per square centimeter. Since the development of increasingly high-powered transmitters is to be anticipated, the need for more precise and refined statements of human tolerance is evident.

airframe manufacturer, Lockheed Aircraft Corporation, coincidentally installing, testing, and servicing the most powerful airborne transmitters, early in 1954 instituted a comprehensive medical surveillance program for its several hundred employees working with radar or those who might be exposed to the energized beam. This program has now been in progress for four years and constitutes one of the longest continuous medical surveys of radar-exposed personnel in the United States. It is because of this that we believe the results of our efforts and observations should be presented.

It is not our intent to discuss either the physics of microwave propagation or its ignition hazards. This presentation will be limited to a brief discussion of the objectives, methodology, findings, and interpretation of our program.

From the Medical Department, Lockheed Aircraft Corporation.
Read before the Joint Meeting of the Section on Preventive Medicine and the Aero Medical Association at the 107th Annual Meeting of the American Medical Association, San Francisco, June 25, 1958.

Our objectives were threefold: (1) to detect any cumulative biological effects of long-time exposure to microwaves of varying frequency and power output in persons who had taken minimal precautions; (2) to observe possible effects on persons working for short periods of time with or near extremely high-powered airborne radar with pulsed wave emissions; and (3) to establish correlation between objective findings and units of exposure expressed in time-power density factors with the highly idealized objective of establishing safe maximum exposure standards.

Effects of Long Periods of Exposure

Our initial study included 226 radar-exposed employees and 88 nonexposed control subjects. The examination program was designed to detect in our subjects pathology similar to that observed in exposed animals and included procedures and laboratory studies previously performed by other investigators. Several additional procedures were used in an attempt to duplicate findings alleged to have been observed in a study of human subjects.

Examination in every case included an extensive system and organ inventory, with emphasis on the ocular structures, central nervous system, gastrointestinal and urinary tracts, hematopoietic system, and skin. Imbedded metallic foreign bodies were identified; a careful marital and fertility history was elicited; and duration and manner of exposure to radar was identified.

Physical examination was extensive with respect to the body systems as outlined above. In addition, each subject was inspected for manifest hemorrhagic phenomena. A modified test for Rumpel-Leede phenomenon was then performed by means of placing the blood pressure cuff on the arm and maintaining pressure midway between systolic and diastolic pressure for three minutes. The appearance of more than 10 fresh petechiae in a circle 4 cm. in diameter below the cuff was considered a positive result.

The second phase consisted of an ocular examination, including a slit-lamp study performed with the subject subjected to cycloplegia by a competent ophthalmologist; complete blood cell and platelet counts; chest x-rays; and urinalyses.

Among the radar groups were 83 with 2 to 5 years of exposure and 37 with 5 to 13 years. Many of them were exposed while in military service or with other companies prior to their employment at Lockheed. Few had observed any precautions whatsoever prior to 1953. Despite this, no pathology or adverse physiological effects unequivocally attributable to microwave exposure could be demonstrated. Minor variations in the red and white blood cell counts were comparable with those of the controls. An apparent decrease in polymorphonuclear cells and increase in eosinophils and monocytes was later

found to be due to a variation of interpretation by a laboratory technician. There were no significant variations in blood platelet counts. Abnormal urinalyses were found to be proportionate in both groups.

Physical abnormalities revealed a higher percentage of circulatory and gastrointestinal diseases in the controls, with a higher incidence of jaundice, severe headaches, and bleeding phenomena. Ocular pathology was considerably greater in the radar group. However, with the single exception of a small, solitary retinal hemorrhage, which absorbed completely within three months, all abnormalities were causally related to diseases or conditions not generally associated with microwave exposure. Chest x-rays were noncontributory. Modified tests for Rumpel-Leede phenomenon were interesting in that 8% of the control group showed positive results, compared to 2% of the radar group. There was no apparent correlation between positive findings and reduced platelet counts. Findings were negative in all but one subject with platelet counts below 200,000 per cubic millimeter. The positive results were, with this single exception, in persons with normal platelet counts.

Fertility studies revealed essentially the same percentage of offspring in both groups, when correcting for the larger number of unmarried men in the radar group. The percentage of childless marriages attributable to unknown causes was comparable, and in not a single instance in the radar group could an admission of male sterility be elicited.

On the basis of these findings we concluded that no person in this study had sustained any acute or chronic injury secondary to radar exposure. Reference is made to an earlier report describing our results in greater detail.¹

Effects of Short Periods of Exposure

The second objective of our program is currently being accomplished. Having established base-line or reference criteria, we proceeded to reexamine our personnel, first at 6-month, then at 12-month, and finally at 24-month intervals, approximately four years after the original study. This latter program is now in progress. As a result of our original study and findings it was decided to modify our procedures and eliminate several of the more costly, time-consuming, and noncontributory tests. An extensive medical questionnaire was prepared, and each subject was interviewed by a physician. Physical examinations were performed only when indicated on the basis of the medical history or laboratory studies. Ocular and slit-lamp studies were repeated, and complete blood cell counts and urinalyses were performed. Blood platelet studies were repeated on alternate years. A limited number of electrophoretic serum protein patterns were made

in an attempt to validate significant changes claimed to have been observed by another investigator.

Routine control studies were discontinued during the second and third examinations but were resumed in a limited degree during the present program.

TABLE 1.—Subjects in Medical Surveillance Program

Age, Yr.	Exposed Personnel by Study Group, No.					Controls, No.
	Single Test	1-Yr.	2-Yr.	4-Yr.	Total	
<20	1	0	0	0	1	0
20-29	62	15	30	5	112	12
30-39	46	24	55	21	146	52
40-49	14	8	22	16	60	20
50-59	5	1	3	4	13	6
Total	128	48	110	46	335	100

gram. Despite a small sampling of radar-exposed personnel to date (49) it is believed that this group, under surveillance for four years and with exposure to identifiable transmitters, will provide valuable information for comparative purposes. Additional information obtained includes number of days of sick leave, leaves of absence, and other health statistics for the year 1957. Also, a large number of tests for Rumpel-Leede phenomenon were performed on applicants for employment and employees seeking treatment for routine ailments. None of these subjects had had any known exposure to radar emanations.

The results of our studies are graphically presented in the accompanying tables. Table 1 identifies radar-exposed personnel as to numbers, age group, and years under medical surveillance and compares them to the control group. The total ex-

posed personnel by study group (335) children is reflected in the larger number of unmarried men in this younger age group. Of those who are married and for unknown reasons have no offspring, the control group shows a somewhat higher percentage. The average number of children per family for each group is approximately two.

Table 3 lists comparative pathology or major subjective complaints for the various groups. These conditions were present at the time of the last examination or had been present the previous year. Among the radar-exposed group, sinus, gastrointestinal, genitourinary, and dermatological complaints were most prevalent. Headaches and nervousness were the commonest subjective com-

TABLE 3.—Comparative Pathology and Number of Subjects with Major Complaints in Medical Surveillance Program

Pathology	Exposed Personnel by Study Group (335)					Controls (100)
	Single Test	1-Yr.	2-Yr.	4-Yr.	Total	
Nervousness	4	1	2	3	10	4
Headache	5	...	5	3	13	6
Sinusitis	6	...	5	2	13	14
Hay fever	2	...	...	2	4	10
Respiratory disease or asthma	1	...	1	...	2	8
Circulatory and coronary disease	3	...	1	1	5	4
Peptic ulcer	...	1	4	2	7	...
Other gastrointestinal disorder	2	2	7	3	14	8
Urinary tract infection	2	...	5	1	8	8
Skin disorder	4	...	1	2	7	6
Arthritis, bursitis	3	...	2	2	7	10
Bleeding (nose, rectal, urinary)	3	3	2	...	8	4
Other	2*	1†	...	1‡	4	3§

* Mumps, deafness.

† Diabetes.

‡ Ruptured appendix with peritonitis (subject died).

§ Diabetes, hypothyroidism, hernia.

plaints. The control group exhibited sinus, allergic, gastrointestinal, joint, and genitourinary disease prevalence, with fewer headaches and skin and respiratory complaints. There were no marked deviations or trends from the common disorders and no unusual or unexplained hemorrhagic phenomena. Bleeding was primarily nasal, rectal, or urinary in origin, and generally of known causation.

Table 4 reveals ocular findings for the radar-exposed groups only. In our opinion not a single finding can be attributable to radar exposure. There were no cataracts characteristic of those experimentally induced in animals by hyperthermia, and the corneal scars were, in the main, associated with other known causative agents. There were no tendencies toward progressive ocular diseases, and the four-year group revealed no pathology significantly different from that of the other groups. Congenital sutural cataracts are commonly seen in the general populace and are of no significance.

Sick leave for the 49 subjects who were in the four-year group averaged 3.0 days for the year 1957, compared to 3.1 days for the entire factory. In addition, there were five absences of more than 30 days in the radar-exposed group for the following reasons: hemorrhoidectomy, herniorrhaphy, appen-

TABLE 2.—Fertility Data for Subjects in Medical Surveillance Program

	Exposed Personnel by Study Group					Controls		
	Single Test	1-Yr.	2-Yr.	4-Yr.	Total	Avg. No. of children	% With children	
Children, no.	112	36	158	76	382	1.94	...	152
Fathers, no.	72	18	77	30	197	...	...	72
No children	...	...	...	...	...	...	...	...
Cause known, no.	40	14	25	17	96	...	27	...
Cause unknown, no.	16	16	8	2	42	...	13	...
Total	128	48	110	49	335	...	...	...

* Major known causes: unmarried, wife sterile, birth control.

posture group has increased to 335 by the addition of newly hired or reclassified employees. Persons in the one-year study generally have had two examinations, in the two-year study two or three examinations, and in the four-year study three or four examinations. Only the results of the last examinations are included in subsequent tables.

Table 2 reveals the fertility history of the radar-exposed and control groups. The slightly lower percentage in the first group who have fathered

dectomy, nervous breakdown, and skull fracture. These longer absences represent a rate of 10% for this small group, compared to a plant-wide rate of 8%. One death occurred among the radar-exposed group; it was attributable to complications after a ruptured appendix. The diagnosis was confirmed

TABLE 4.—Number of Ocular Findings in Radar-Exposed Groups

Pathology	Single Test (128)	1-Yr. (48)	2-Yr. (110)	4-Yr. (49)	Total (335)
Pterygium	1	1	2	1	5
Esotropia or exotropia	5	2	3	3	13
Cornea					
Old scars	4	1	4	1	10
Keratitis bullosa	1	...	...	...	1
Lens					
Cataract, sutural (congenital)	6	2	9	2	19
Cataract, traumatic	1	1	1	...	3
Vitreous "floaters"	1	1	1	1	4
Drusen	4	...	3	...	7
Other	6	4	3	4	17

Papilloma, acute iritis, telangiectasis, blepharitis; leukemia (2), episcleritis, pigment change in iris, allergic conjunctivitis; eclipse burn of macula, small retinal hemorrhage, medullated nerve fibers (3), macular scar (cause unknown), diabetic retinopathy, healed chorioretinitis, surgical ophthalmostomy.

on autopsy, and the pathological findings were typical of the disease process. Coincidentally, there were over 200 appendectomies, for acute appendicitis, performed on company personnel during the past year. In 1957 there were 113 deaths of company employees, including several cases of leukemia and plasma cell (multiple) myeloma. There was no known exposure to microwaves in any of these cases.

Table 5 reveals blood findings in the radar-exposed groups and in the 100 control subjects. Only the last blood cell counts for the radar group are shown. It is apparent that the blood picture of the radar-exposed and control groups is comparable in most respects. An unusually high incidence of increased monocytes and eosinophils is noted. However, it is somewhat higher in the control group, and the relative increase in these cells can be traced to the interpretation of one laboratory technician.

Blood platelet determinations revealed counts of less than 200,000 per cubic millimeter in only 2 of 243 subjects tested, despite a higher incidence of reduced counts in our original study. Of the 49 subjects studied over four years, only one had a reduced count. This was unusually revealing, in view of the attempts of at least one investigator to use this as an index of exposure. Also, since the same investigator associated exposure with positive findings on tests for Rumpel-Leede phenomenon, we decided to perform these tests on persons who routinely came to the attention of our medical department. Accordingly, 145 tests were performed on employees seeking minor first-aid care, management personnel undergoing annual health examinations, and a small number of applicants for employment. No subject was included in this study if he had knowingly been exposed to microwaves

during military service or employment. Of the 20 positive findings obtained, 14 were in men and 6 in women; these represented 14% of the group. Of these subjects, two presented histories of hemorrhagic tendencies, two had been exposed to considerable ionizing radiation (x-ray), three had undergone recent major abdominal or pelvic surgery, and one was taking sedative medication. Of the 88 subjects used in our original control group (in 1954), positive results were noted in 8%.

In 26 cases selected at random, electrophoresis of serum proteins was performed at a hospital laboratory. Many of these specimens were from subjects in the two-year and four-year groups. Results in 16 tests were reported within normal range for all component proteins; 10 revealed deviations as follows: elevation of gamma globulin level, 4; depression of beta globulin level, 3; elevation of beta globulin level, 1; depression of gamma globulin level, 1; and depression of alpha globulin level, 1. In only one subject was the deviation more than slight or considered significant, and this was partially reversed within two months after elimination of an active known infection. Deviations described are generally associated with dietary deficiencies, infections, or obesity. One subject had been exposed to ionizing radiation, two had known active infections, and two had undergone recent surgery.

In no case was there any significant decrease in serum albumin or total protein levels. The albumin-globulin ratio was within normal limits in all persons.

Maximum Exposure Standards

Our third objective was to delineate safe maximum exposure standards. Obviously, this was contingent on the detection of pathological changes

TABLE 5.—Comparative Blood Cellular Findings in Subjects in Medical Surveillance Program

	Exposed Personnel by Study Group, No.				Controls			
	Single Test	1-Yr.	2-Yr.	4-Yr.	Total	% of Total	Single Test	% of Total
Red blood cell count, per cu. mm.								
<4,500,000	...	9	1	1	11	2.3	0	0
4,500,000-5,000,000	...	20	9	11	40	12.5	10	10
White blood cell count, per cu. mm.								
Total
<5,000
5,000-10,000	...	18	7	21	46	17.0	16	16
Differential count								
Polymorphonuclear cells								
<50%	...	24	4	15	43	17.0	19	19
>50%	...	18	3	11	32	11.3	12	12
Monocytes (>2%)	...	13	10	10	33	15.4	21	21
Eosinophils (>4%)	...	16	1	12	29	11.3	16	16

in our subjects and determination of the exposure parameters with respect to frequency or wave length, field power density, exposure time, and total test environment.

It soon became apparent that this objective could not be achieved in our study. We uncovered no pathology caused by either single or repeated ex-

posure, and consequently we cannot speak authoritatively of so-called hazardous exposure conditions. The majority of our personnel had been exposed to radars of the following types: AN/APS-20A, B, C, and E; AN/APS-28, 30, 31, 33, and 45; AN/APG-10, SC, SX, and SR; AN/APS-6 and 7; and AN/APS-70. These transmitters operate in a frequency range of 400 to 9,000 mc and include powerful "S" band components. It was impossible to obtain precise data covering exposure time and average field power density, since these often were unknown. Exposure, however, varied from an occasional incidental contact with the beam to as much as four hours daily close exposure for periods up to four years. Exposures of several minutes a day at distances of less than 10 ft. from the radars were not uncommon.

Protective clothing was not worn by any of our subjects while in the radar beam. For some time precautions have been exercised in testing of our equipment and in exposure of personnel. In general, ground testing of high-powered, aircraft-mounted transmitters involves scanning of a very limited sector, with the antenna pointed toward an open, uninhabited field and rotating at 2 or 6 rpm, usually firing at reduced power.

Personnel were advised to avoid exposure to any firing beam when in a zone defined by a minimum power density of 0.0131 watts per square centimeter. A second zone, extending from the area previously defined to that with a minimum power density of 0.0039 watts per square centimeter, was deemed acceptable for occasional pass-through but no constant exposure, and, finally, there was a third limitless zone in which exposure was not deemed biologically significant.

Unfortunately, because most persons are exposed to radar emanations while on the ground and frequently within the so-called near radar field, it is extremely difficult to evaluate biological effects and hazards in relation to absolute power levels without accurate measurements. The need for such accuracy in quantitative determinations of exposure is obvious and can be achieved by the development of exposure meters reflecting absorption in quantum units of radar energy.

It has been suggested that the sensation of heat is almost universal on exposure to radar and that this in itself is indicative of an overexposure. In our study, only 17% of the 335 subjects experienced heat sensation and frequently only when in close proximity to "X" band radars. Almost 6% were aware of a buzzing or pulsating sensation when in an "S" band field. Less than 1% experienced other sensations or warning phenomena, such as sparking between dental fillings or a peculiar metallic taste. Eight subjects gave a history of metallic implants, such as bullets, buckshot, steel pins, and plates. None experienced any unusual

reaction attributable to the metal. There were no complaints of heat directed to rings, wrist watches, or bracelets.

Comment

During the past 18 years thousands of persons, in the course of their employment or while in military service, have been exposed to microwaves, many without protection. Concern over the effects of such exposure is natural and to be expected. The majority of radars in common use today are relatively low powered, with the exception of some military transmitters which exceed one megawatt in peak power output. Radars with many times this power will be operational in due course and may radically change our entire concept of the biological potentials of this form of energy.

Since microwaves of varying frequency and power output are also being used to provide television display, for diathermy, and in electronic ovens, the personal safety problem is one of general public interest.

Experiments to date have been conducted primarily on small fur-bearing animals and under unusual test conditions. It is generally accepted that the modus of injury by microwaves is a hyperthermia produced by absorption of this form of energy by the body. Extreme caution must be exercised in attempting to extrapolate the results of small animal responses to heat to those of the human body. Small fur-bearing animals have a high coefficient of heat absorption, a small body surface, and a relatively poor heat regulating system. The human body, by comparison, has one of the best and can readily adjust and maintain thermal homeostasis under severe stress conditions. Adequate physiological function can be maintained in environments of 240 F for 23 minutes if the humidity is low, and at least one subject has been exposed to a temperature of 400 F, for a period of approximately one minute, without tissue injury.

Conditions of radar operation and testing vary from experimental conditions. Humans are generally exposed while in free air and rarely to a stationary energized beam. Some radar beams are extremely narrow, and only a small portion of the human body is instantaneously exposed. The body can dissipate heat readily to the environment between such exposures. One is reminded of a similar problem associated with exposure of personnel to the thermal effects of ultrasonic energy. In an analogous situation, small fur-bearing animals were destroyed by hyperthermia when placed in a jet engine noise field, yet there is no evidence of any adverse heating effects on man when exposed to the same environment. It has been estimated that it would require many million times the ultrasonic energy of that generated by any current jet engine to produce these effects in human beings.

There is reason to believe that the dramatic effects observed in small animals exposed to whole-body radiation will not be reproduced in larger, live animals under identical test conditions and that the human body will be the most resistant of all. This is not to imply that localized application of heat cannot injure human tissue. We have witnessed one case of accidental 15-second exposure, at a 6-to-10-in. distance, to an "X" band radar of over 100,000 watts in peak power output, with resultant erythema and a sensation of warmth for an hour but with full and uneventful recovery. Unless carefully controlled and operated, microwave diathermy with use of "S" band frequencies can cause local tissue damage.

In our study we have failed to detect any acute, transient, or cumulative physiological or pathological changes in subjects working with and frequently exposed to high-power radar transmitters. It would therefore appear extremely unlikely that there exists a biological hazard to the radar technician observing reasonable precautions or that the general public, exposed to greatly attenuated and intermittent doses of microwaves in the environment, is in any danger of body injury. We can see no causal relationship between microwave exposure and any increase in such conditions as coronary heart disease, leukemia, bone and lung cancer, and degenerative diseases of the nervous system.

There is need for additional research to explore the effects on living tissue of extended wave lengths and frequencies of microwaves and transmitters of higher energy, and military research is being directed in this area.⁵ Col. G. M. Knauf has reported on the progress of this research at the American Medical Association's Annual Meeting in San Francisco. It is hoped this study will provide the basis for establishment of a realistic safety program acceptable to all scientists.

Finally, a plea is made for deductive rather than inductive research in this difficult field. With the increasing exposure to microwaves in and around the home, as well as in industry, careless and scientifically uncorroborated reports of human injury and death cannot avoid receiving dramatic and widespread dissemination. Such reports should not appear unless sufficient scientific data are included to support the conclusions and unequivocally establish the modus of injury. If radar is incriminated, the report must contain a definite history of exposure, including proper identification of the transmitter, wave length, power density, exposure time, symptomatology, laboratory data, pathological findings, and other factors.

Summary

In 1954, a medical surveillance program was instituted, covering 335 employees working with or exposed to microwaves in an airframe manufac-

turing company. Examinations have been performed at intervals of 6, 12, and 24 months in an effort to detect acute or cumulative biological effects of exposure at various intervals to energized radar beams in the 400-to-9,000-mc range and with peak power output exceeding one megawatt. Whenever possible, identical examinations were also accomplished on a nonexposed control group.

The examinations have failed to detect any significant changes in the physical inventories of the subjects. The incidence of death and chronic disease, sick leave, and subjective complaints was comparable in both groups. A high percentage of eye pathology was identified, but none with causal relation to the hyperthermia produced by microwave absorption. Fertility studies revealed essentially the same findings for both groups.

Laboratory studies for total red and white blood cell counts and differential counts revealed no significant changes above those noted in the control group. Urinalyses and chest x-rays were noncontributory with respect to radar exposures. Electrophoretic serum protein level determinations were performed on 26 subjects, with insignificant or accountable deviations in 10. Platelet counts and controlled capillary fragility studies for Rumpel-Leede phenomenon revealed the fallacy of using either to identify radar exposure. In addition, only a small percentage of the exposed subjects had been aware of heat or other subjective warning phenomena. Neither these tests nor subjective complaints were considered reliable indexes of exposure.

Absolute or safe maximum exposure standards were impossible to define, inasmuch as no radar-induced pathology could be identified. Subjects had been exposed for various periods, at indefinite distances, to a multitude of radars under flexible test conditions. The need for more precise and refined exposure data is indicated.

On the basis of these studies there appears to be no justification for public concern about the effects of greatly attenuated microwave energy in the environment. It would seem, therefore, that one may continue to enjoy his television without undue apprehension.

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