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Evaluation and Control of Exposures in Repairing Microwave Ovens

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Consumer exposures to microwave ovens have received considerable attention; however, there was only one report found in the literature concerning occupational exposure of oven repairmen. In repair and testing such ovens, the workmen must remove the casings and jump the safety interlocks. The workers are required to place their faces and bodies close to the energized magnetron. The medical evaluation of eight such repairmen is discussed in relation to the potential biologic side effects of such radiation, which include cataracts and thermal damage to the skin and deeper structures. Environmental evaluations revealed microwave levels in excess of 10 mw/cm², at the repairman's face and body. A simple, effective, and inexpensive control measure, using copper mesh screening, is described. This control reduces the worker's exposure to a level well below 10 mw/cm² and allows him to continue visually observing for malfunctions in and around the magnetron.

Introduction

THIS PAPER REPORTS data from a clinical study and environmental survey involving microwave oven repairmen. The investigation was conducted in cooperation with the Ohio Department of Health.

The term microwave is applied to an arbitrary range of the electromagnetic spectrum generally agreed to encompass wavelengths of from 3000 to 0.3 centimeters, or the equivalent frequencies from 10 to 100,000 megahertz (MHz). This range of frequencies includes radio and television commercial broadcast bands; the X, S, and L commercial and military radar bands; and certain frequencies designated for medical treatment and use in microwave ovens.[1]

Biological responses to microwaves are primarily thermal;[2] however, reports in the literature indicate that other responses may also occur. These nonthermal responses are thought to include electrical and magnetic field effects, which may affect the molecular structure of normal tissue, and specific biological effects, such as changes in electrophoretic patterns, increases in antigenic activity, and the production of cataracts in the lenticular tissue of the eyes.[3] Biological responses in laboratory animals were found to be the most severe and to last longest at wavelengths of around 10 centimeters.[4] Exposure control for those working with microwave sources in the past utilized the concepts of distance and shielding and, more recently, the concept of time of exposure. Maintenance of proper distance and shielding decrease incident energy levels; decreasing the exposure time reduces the total dose to the individual.

One of the first exposure criteria proposed

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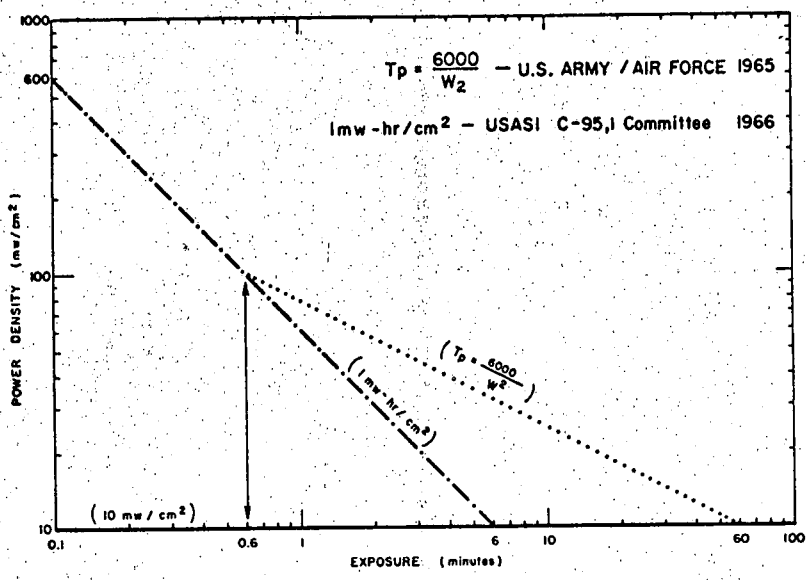

FIGURE 1. Exposure vs power density.

a maximum exposure level of 10 milliwatts per square centimeter (mw/cm²),[5] regardless of wavelength, site of exposure, duration of exposure, ambient environmental temperatures, or other environmental factors. The Russian maximum permissible intensities are reported to be 0.01 mw/cm² for a full workday of 8 hours, 0.1 mw/cm² for 2 hours or less per day, and 1.0 mw/cm² for periods not exceeding 20 minutes while the worker is wearing goggles.[6] Recent American recommended standards include the two-phase standard as proposed by the C-95 Committee of the United States of America Standards Institute (USASI).[7] This standard is based on energy density of 1 milliwatt-hour/cm² for exposure times up to 0.1 hour and on power density of 10 mw/cm² for time periods of 0.1 hour or more. Also there is the latest U.S. Army and Air Force criteria of

$$T_p = (6000/W^2)$$

where T_p is permissible exposure time in minutes during any 1-hour period and W is power density that the worker is exposed to in mw/cm². The army criteria[8] is applicable between exposure levels of 10 and 100 mw/cm². Figure 1 illustrates the difference between these last two criteria and shows that the only *apparent* point of agreement occurs at exposure levels of 100 mw/cm², under which both criteria set 0.6 minute as the recommended exposure time. It should be noted that under the USASI criteria the recommended exposure time is 0.6 minute *per one-tenth of an hour* (6 minutes), whereas the Army-Air Force criteria limits exposure to 0.6 minutes *per hour*. Most of the standards proposed and the research work conducted on biological effects have been associated with work in radar and range-finder operations.

A review of the literature[9] indicates some concern with consumer exposure to energies from microwave ovens, mainly because of faulty door seals, but only one case involving an oven repairman has been recorded.[10] That case involved an oven repairman who turned on the unit with the door open. He subsequently filed a claim for injury specifying burns in the region of the lower abdomen and possible sterility. The latter claim was disallowed. The exposure of this occupational group as compared to the consumer must be assumed to be greater, and consequently, a greater likelihood of overexposure is possible.

Microwave Ovens

Microwave ovens operating at 2450 MHz (12.3 centimeters) utilize the biological response of energy absorption and conversion to

thermal energy to cook food or warm precooked frozen meals. Since 1945, when it was discovered that the output of a laboratory radar device would pop popcorn in a paper bag, the development of these ovens has increased to the point that models are being developed for use in the home.[11]

In modern ovens, the microwave source is a magnetron, the output of which is fed by a horn or waveguide into the cooking cavity. The electrical components of the oven, including the magnetron, are enclosed by a metal cabinet which, when removed from the oven, disengages electrical safety interlocks. In some models these interlocks are incorporated into the cooking cavity door-interlocks found in all ovens. The door and cabinet interlocks are designed to insure that before the magnetron can be energized to produce microwaves, the unit is sufficiently shielded to protect the user.

Discussion

Case History

A 40-year-old white man was first seen in November, 1967, with complaints referable to the skin, eyes, and genitalia. He has been the supervisor and chief repairman of automated vending machines and microwave ovens for over 5 years in a firm specializing in such devices. Periods of exposure to microwave ovens during repair work were frequent, varying from few to no hours per day to most of a working day.

Skin problems began in August, 1965, with an acute, transient scrotal and groin dermatitis that lasted a few weeks. Since the summer of 1966, he has had about twelve episodes of a rash on his lower abdomen and right thigh. The affected area would itch and burn, and it appeared to be blotchy and red, with "bumps" and "cords" under the skin. Lesions faded without scarring after 4 to 6 weeks. The areas involved were the closest portions of his body to the working level of the microwave ovens. He claimed that sometimes he sensed heat on the skin involved when he repaired these ranges.

For the past 1 to 2 years he has noted failing vision, and has had to wear glasses for the first time. Although he does not recall eye irritation directly related to the repair of microwave ovens, he has experienced "burning" of the eyes in the past 2 years.

Since March, 1966, he has noted the development of indurated nodules in his penis, leading to deviated and painful erections, and finally, to impotence.

Other than an allergy to penicillin and a peptic ulcer of the stomach, under medical treatment with antacids since 1965, his health has been good. He abstains from alcoholic beverages and smokes a pipe only.

Physical examination revealed a tall (6'8½") 187-lb, alert man with acneiform scars and papules on his face and back. There were solar degenerative changes with mild atrophy and telaniectasia on his cheeks and neck.

On the right upper anterior thigh, in an area 9 x 9 cm were serpiginous, mottled, reddish-blue and brownish-red, smooth, flat patches composed of discrete, nonblanching macules and papules. The abdominal skin was normal. There were no varicose veins or leg edema.

At the base of the penis and on the dorsum and sides of the penile shaft, proximal to the corona, were slightly tender, firm, ill-defined, smooth, deeply-embedded oval plaques, which were not movable and produced no alteration to the overlying skin.

Medical Evaluation

EYES. On November 9, 1967, the patient was seen by Dr. Taylor Asbury, Professor and Chairman, Department of Ophthalmology, University of Cincinnati, College of Medicine. There was no evidence of cataracts, retinal abnormalities, or increased intraocular pressure. There was a refractive error with acuity of 20/35 in the right eye and 20/50 in the left eye. The reduced accommodative power noted was possibly related to physiologic aging-induced presbyopia.

SKIN. Biopsy of the active lesions on the right thigh on November 9, 1967, revealed an inflammatory reaction, related primarily to the blood vessels, at all levels of the skin down to subcutaneous fat. The blood vessels were encroached upon and distorted due to edema and the mixed infiltrate of lymphocytes, eosinophiles, and polymorpho-nuclear leukocytes. There was extravasation of red

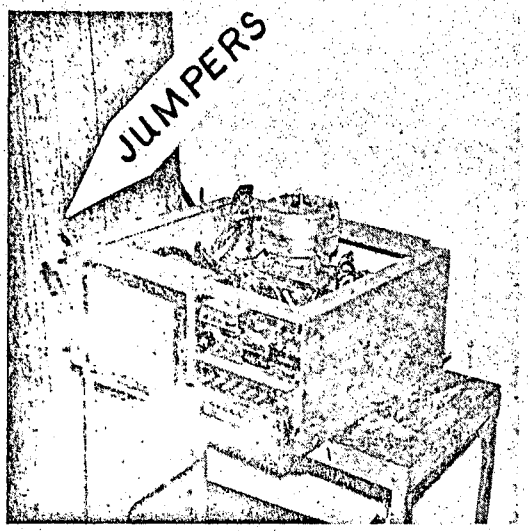

FIGURE 2. Oven with safety interlocks jumped.

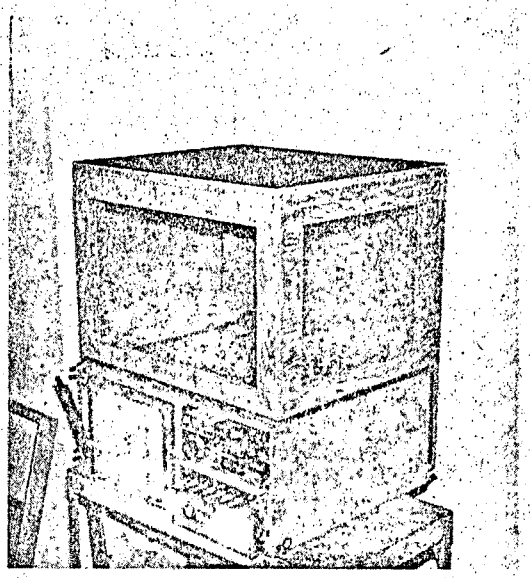

FIGURE 3. Protective cage in place.

blood cells and pyknotic nuclei. The impression of an angiitis (vasculitis) was concurred in by the Armed Forces Institute of Pathology, Washington, D. C. (communication of Drs. B. Highman and E. B. Helwig, January 9, 1968).

GENITALIA. A sperm count and bilateral testicular biopsy were performed in Dayton, Ohio, in December, 1967, by Dr. Frank A. Beltran, urologist.

SPERM COUNT. A volume of 1 cc indicated 40,000,000 spermatazoa, 60% with excellent motility and 10-15% with abnormal forms. (Normal is 3 to 7 cc with from 60 to 200 million spermatazoa per 1 cc; at least 75% with usual shape and motility. Sterility is usually associated with a volume of less than 3 cc and a sperm count below 60 million per 1 cc).[12]

TESTICULAR BIOPSY. The seminiferous tubules were normal with no significant atrophy. The total number of spermatazoa seemed decreased. A number of Sertoli cells had vacuolation (courtesy of Dr. Erlo Roth, pathologist, Kettering Memorial Hospital, Kettering, Ohio).

Environmental Evaluations

Environmental evaluation revealed that ovens were seldom repaired in the field, but were generally returned to the main repair shop for service. In the shop procedure, the repairman removes the outer metal casing or cabinet, and thereby disengages the electrical "safety" interlock system. To operate the oven under such conditions, the repairman then interposes a foreign metal object (usually a screwdriver) in the interlock gap. This completes the electrical circuit, and the oven can be operated through its various cooking cycles with an integral part of the system (the protective shield) removed.

This procedure is commonly known as "jumping the safety interlocks." Figure 2 illustrates an oven in this condition. In following this procedure, the repairman's face and body are approximately 24 inches from the magnetron. The repairman works this close to the oven so that he can observe its operation and note the occurrence and location of any malfunction or short circuiting. Neither environmental controls nor protective measures are in use during this operation. The minimum exposure time experienced by the repairman per job was approximately 4 minutes, or the summation of operating the oven through all of its cook cycles. If any trouble or malfunctions were encountered, the exposure time could be increased to a point limited only by the operating cycle of the magnetron, which is a function of the cooling capacity of that particular unit.

Potential health hazards of primary concern were exposures to microwave energies at

2450 MHz and the possibility of the emission of ionizing radiation as ultrasoft (grenz) rays, which could be produced by the magnetron when it operates at a plate voltage of 6300 volts.

Measurement of Microwave Energy

Microwave measurements were made with a Ramcor Densiometer, Model 1200A, which had been previously calibrated at 2450 MHz. Energy levels at a distance of 18 inches from the magnetron averaged 22 mw/cm² at the worker's face and 20 mw/cm² at his abdomen. At 24 inches, the levels dropped off to 20 mw/cm² (face) and 18 mw/cm² (abdomen), and at 36 inches they were 12 and 10 mw/cm², respectively. The repairman used an 8-watt fluorescent bulb to check for leaks around door assemblies. It was shown that a bulb of this type, hand-held, would glow steadily in energy fields of 18 to 20 mw/cm² and would flicker in fields of 6 to 8 mw/cm².

Determinations of ionizing radiation were made with a Victoreen 440 survey meter. The instrument was not radio-frequency (RF) shielded and, accordingly, gave erratic readings around the magnetron. Film badge dosimeter packets were mounted around the work area for a period of one week, during which time several ovens were repaired. Subsequent processing and evaluation of the badges did not reveal any measurable levels of ionizing radiation.

Environmental Control of Microwave Energy

A control device developed for this operation consisted of a wooden frame, approximately 12 inches deep, 12 inches high, and 24 inches wide covered with ordinary copper mesh screening on all sides except one. This cage is placed on top of the oven as a protective device that allows the repairman to observe the functioning of the oven. Figure 3 illustrates the cage in use with an oven. Energy levels were reduced to a maximum of 5 mw/cm², except at certain points where the cage did not make firm contact with the oven frame, or where the screening material had been overlapped at a seam. In these cases, excessively high readings (greater than 25 mw/cm²) were observed. A subsequent model, which used a screening overlap along all edges and which has seams only at a framing member, proved to be more than adequate as a control. It is important that a device of this type be connected to a satisfactory electrical ground to reduce the hazard of electrical shock.

Conclusions

GENERAL. The supervisor and chief repairman of microwave ovens had several abnormal conditions; the relationship of those conditions to microwave radiation is speculative.

EYES. The changes in visual acuity are commonly seen in the normal population. Cataract formation and retinal abnormalities usually reported as a consequence of exposure to microwave radiation were not seen in this case.[13]

GENITALIA. This man had Peyronie's disease, or plastic induration of the penis. This condition has been reported frequently since its description by Peyronie in 1743,[14] and has not heretofore been ascribed to microwave energy exposure. Therefore, its relationship to such energy might be only fortuitous. The impotence associated with reduced spermatogenesis and altered Sertoli cells might also be coincidental. However, we cannot discount a true causal relationship to the microwaves. Degenerative testicular changes, which have been induced in experimental animals, were not seen.[15]

SKIN. The clinical appearance was that of a thermally-induced erythema *ab igne* versus vasculitis. The latter was seen histologically. The absence of skin lesions on the body, other than on the lower abdomen and anterior thigh, with a negative history of drug ingestion, tended to rule out drug allergy. The mixed infiltrate and hemorrhage into the skin, with small medium-sized blood vessel inflammation down to the level of the subcutaneous fat, suggest a relationship with incident microwave energy. Similar experimentally-induced microwave damage has been seen in animals, and in the viscera (intestinal organs) in the fatal human case reported by McLaughlin.[16]

EXPOSURE OF WORKERS. Seven coworkers of the subject were examined on November 13, 1967. Their exposure to microwave energy

ranged from insignificant (since they worked 10 to 20 feet from these ovens) to several hours a day of direct exposure while they repaired the radar ranges for varying periods up to 5 years. Four had visual complaints ranging from tiredness, watering, and burning to decreasing acuity, but these were not always related to the work environment. No gross ocular abnormalities were seen, but slit-lamp examinations for cataracts were not available. There were no skin or genital complaints, nor were abnormalities of these areas seen.

Summary

One of eight workers in a repair shop for microwave ovens was noted to have a recurrent, blotchy, hemorrhagic eruption on abdomen and thigh, which was histologically an anglitis (vasculitis). There was no known cause; but its anatomic localization, pathologic picture, and temporal relation to the subject's work suggested the possible causal role of microwave energy.

Adequate protection can be afforded the worker by use of a simple, inexpensive device to intercept and absorb the microwave energy. The device is a wooden frame covered with copper mesh screening which is placed on the oven to shield the worker from the microwave energy. Such a device can reduce microwave energy to levels less than 5 mw/cm².

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Ceric and Ferrous Dosimeters

AEC-NASA Tech Brief 68-10426 reports on a method of providing ceric and ferrous dosimeters with increased precision and sensitivity for the 50-5,000 rad range of biological interest. The addition of ammonium thiocyanate to a ferrous sulfate dosimeter solution which had been irradiated and handled in the usual manner produced a two-fold increase in sensitivity and a diminished temperature effect. The determination of the ferric thiocyanate complex can be made by one of colorimetric procedures.

The ceric dosimeter system was based on the observation that the fluorescence of fluorescein is quantitatively destroyed by the ceric ion. Inquiries concerning either of these dosimeters may be directed to the Office of Industrial Cooperation, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439 (please specify reference B68-10426).