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REVIEW OF ELECTRONIC PRODUCTS RADIATION HAZARDS

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HEARING

BEFORE THE

SUBCOMMITTEE ON PUBLIC HEALTH AND WELFARE

OF THE

COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE

HOUSE OF REPRESENTATIVES

NINETY-FIRST CONGRESS

FIRST SESSION

ON

THE ADMINISTRATION OF THE RADIATION CONTROL FOR HEALTH AND SAFETY ACT OF 1968 (PUBLIC LAW 90-602)

MAY 23, 1969

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Electronics Industries Association:
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Day, J. Edward, special counsel.
Harris, H. H., member, EIA/Industry Ad Hoc Advisory Committee on X-radiation.
Thierfelder, C. W., member, EIA/Industry Ad Hoc Advisory Committee on X-radiation.
Health, Education, and Welfare Department, Public Health Service:
Elder, Dr. Robert, Bureau of Radiological Health, Environmental Control Administration.
Hansen, Hon. Chris A., Commissioner, Environmental Control Administration, Consumer Protection and Environmental Health Service.
Meyer, Dr. Alvin, Special Assistant to the Administrator, Consumer Protection and Environmental Health Service.
New York City Office of Radiation Control, Hanson Blatz, director.
Suffolk County (N.Y.) Department of Health, Seymour Becker, chief, Radiation Control Unit.
Underwriters' Laboratories, Inc., Arnold Smoot.

REVIEW OF ELECTRONIC PRODUCTS RADIATION HAZARDS

FRIDAY, MAY 23, 1969

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON PUBLIC HEALTH AND WELFARE,
COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m., in room 2322, Rayburn House Office Building, Hon. Paul G. Rogers presiding (Hon. John Jarman, chairman).

Mr. ROGERS. The subcommittee will come to order, please.

Today we are planning to receive testimony on the administration of Radiation Control for Health and Safety Act of 1968 (Public Law 90–602). We have a number of witnesses scheduled and I hope that we can proceed with all appropriate speed and still preserve a complete record on this very important subject. I have heard some reports that improvements in radiation control have been effected in the relatively short time since this law was enacted, and the committee will be most interested to learn the relationship between any improvements and the existence of the law.

Also we are interested in obtaining information about all existing or prospective problems in this field and in receiving information which would be helpful in further legislative consideration.

We have as our first witness today the Department of Health, Education, and Welfare, and representing the Department, the Honorable Chris Hansen, who is Commissioner of Environmental Control Administration, and Dr. Robert Elder, from the Bureau of Radiological Health.

Gentlemen, we will be glad to have you take the stand and receive your testimony.

STATEMENT OF HON. CHRIS A. HANSEN, COMMISSIONER, ENVIRONMENTAL CONTROL ADMINISTRATION, CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE, PUBLIC HEALTH SERVICE, DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE; ACCOMPANIED BY DR. ROBERT ELDER, BUREAU OF RADIOLOGICAL HEALTH, ENVIRONMENTAL CONTROL ADMINISTRATION; AND DR. ALVIN MEYER, SPECIAL ASSISTANT TO THE ADMINISTRATOR

Mr. HANSEN. Thank you, Mr. Chairman.

With your concurrence, Mr. Chairman, I would like to read my prepared statement.

Mr. ROGERS. That will be satisfactory.

You might identify yourself for the reporter.

Mr. HANSEN. I am Chris A. Hansen, Commissioner of the Environmental Control Administration.

Mr. Chairman and members of the committee, I am pleased to have this opportunity to bring to the members of the House Subcommittee on Public Health and Welfare up to date on our activities to implement the Radiation Control for Health and Safety Act of 1968, Public Law 90–602, which was enacted by the Congress on October 18, 1968. We are particularly cognizant of your interest, and the interest of the subcommittee in the act inasmuch as the first hearings on proposed electronic product radiation control were held by the subcommittee.

The act provides "for the establishment by the Secretary (of the Department of Health, Education, and Welfare) of an electronic product radiation control program which shall include the development and administration of performance standards to control the emission of electronic product radiation from electronic products * * *."

The Secretary delegated his responsibility under Public Law 90–602 to the Administrator of the Consumer Protection and Environmental Health Service. The Administrator, in turn, delegated the responsibility to the Commissioner of Environmental Control Administration. The Environmental Control Administration's Bureau of Radiological Health is responsible for day-to-day administration of the act.

I would like to summarize activities to implement the act section-by-section with a brief summary of activities being carried under each area. It may be helpful to point out that the various studies, investigations, and evaluations to which reference will be made in this presentation are in the development phase. We anticipate that the results of the studies which are called for under section 357 of the act will be available to the Congress by January 1, 1970. As results are obtained from our other activities, we will be pleased to make them available to the committee.

SECTION 355. DEFINITIONS

Definitions will be included in the initial interpretive regulations which we anticipate will be published in the Federal Register in the next 2 weeks. These implementing regulations develop the administrative procedures that are to be followed in the implementation of various sections of the act. The implementing regulations define the intent and scope of the enforcement program and specify certain legal procedural matters governing the manufacturer's responsibilities for electronic products which are offered for sale in the United States. The programmatic responsibility within the Department is also described

In addition to the interpretive regulations, we expect early publication of recordkeeping requirements which are related to a number of sections of the act including section 359, "Notification of Defects."

SECTION 356. ELECTRONIC PRODUCT RADIATION CONTROL PROGRAM

In addition to its ongoing program activities in the field of radiological health, the Environmental Control Administration has initi-

ated a number of new activities under section 356 of the act. For convenience, they are listed under three headings.

(A) Biological studies:

1. Facilities and equipment are now available for the study of the biological effects of low-energy X-ray photons similar to those emitted by television receivers.

2. The Environmental Control Administration is concerned about the possible genetic and cellular effects of microwave radiation. Specifically we are conducting chromosome studies and protein synthesis effects in the same frequency range as is emitted by microwave ovens. Initial findings have been published. A copy is available for the record.

Mr. ROGERS. We will make that a part of the record at this point.

(The following material was received for the record:)

EFFECTS OF 2450 MHz MICROWAVES ON PROTEIN SYNTHESIS AND ON CHROMOSOMES IN CHINESE HAMSTER[1]

D. E. JANES, W. M. LEACH, W. A. MILLS, R. T. MOORE, AND M. L. SHORE

U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Environmental Control Administration, Bureau of Radiological Health, Division of Biological Effects, Rockville, Md.

INTRODUCTION

Microwave radiation produces significant effects on a number of biological systems, including the nervous system, the eye, the circulatory system, and the reproductive system (1–3). These effects include lenticular opacities (4–7), testicular degeneration and reduced sperm production (9), arrested embryonic differentiation without an effect on cellular proliferation (8), and irregularities among chromosomes during mitosis (10). Subcellular effects observed after microwave radiation *in vitro* include changes in the electrophoretic pattern and antigenic reactivity of human gamma globulin (11) and reduced activity of alpha amylase (12).

The present study with male Chinese hamsters investigates the effects of whole body microwave irradiation on: (1) the *in vivo* incorporation of ^{14}C-labeled phenylalanine (Phe) into protein of liver and testis, and (2) the chromosomes of mitotic bone marrow cells. Incorporation of labeled amino acid into protein was decreased in both liver and testis. Chromosome stickiness phenomena were increased. Chromatid aberrations were not seen in the first division following microwave exposure.

Materials and Methods

Unanesthetized male Chinese hamsters (*Cricetulus griseus*), weighing 25–35 grams, 90–120 days of age, were used in this study. The exposure source was a microwave oven (2450 MHz, 12.25 cm. wavelength), operated with the door open. Operation of the radiation source was cyclical, 3 minutes on and 1 minute off. Hamsters were irradiated individually in a perforated screw-cap plastic cylinder (radius 2 cm., length 8 cm.) placed horizontally 50 cm. in front of the center of the oven cavity. The cylinder axis was parellel to the plane of the oven aperture so that the side of the animal faced the radiation source. Within narrow limits the animal could move freely.

Since the irradiation was not performed under far field conditions the average power density could not be determined with available instruments. Thus, two approaches were taken to provide relative characterization of the radiation fields. One employed hamster lethality; the other, calorimetry with spherical water loads.

---

[1] Presented at Radio and Microwave Radiation Applications and Potential Hazards Symposium at the University of Surrey, Stag Hill, Guilford, Great Britain, January 2–3, 1969. Submitted for publication in the proceedings of the Symposium.

Hamster Lethality

Hamsters were exposed according to the cycle described above for operation of the oven, and examined after each 3 minute-on exposure. At the end of the radiation cycle in which death occurred, the animal was rapidly removed and its rectal temperature measured with a thermistor probe encased in a flexible plastic sheath. The log probit plot of cumulative mortality of 30 hamsters is presented in Figure 1. Median time to death was 15.4 minutes. Ninety-five percent confidence limits on the median, according to the method of Litchfield (13) was 13.6 to 17.5 minutes. Rectal temperatures at the end of the irradiation period during which death occurred ranged from 37.9°–47° C, with a mean of 43.6° C.

Calorimetry

For calorimetry spherical pyrex glass containers having a volume of 200 and 500 ml (radius 3.63 and 4.92 cm, respectively) were filled with distilled water. The containers were insulated in styrofoam blocks. Pyrex beads (8 gm in 200 ml, 20 gm in 500 ml) were placed in the phantoms to facilitate mixing. The glass of the containers was assumed to be in thermal equilibrium with the water. The temperature of the water was measured with the thermistor probe before irradiation, and after 5 or 10 minute periods of mircowave exposure. The containers were placed in front of the oven so that their centers corresponded to the position of the center of the animal irradiation chamber. The average temperature rise per minute, ± one standard error, was 0.198± .001°C in the 200 ml water load and 0.178± .002°C in the 500 ml water load. Temperature rise was independent of the pre-irradiation water temperature in the range tested, i.e., 10–45°C. The average rate of energy absorption per unit of cross-sectional area of the spheres was 71.3×10^{-3} (200 ml) and 87.1×10^{-3} (500 ml) Joules sec^{-1} cm^{-2}. These values are useful reference points; however, they cannot be extrapolated to measures of the average power density of the microwave field because the absorption cross sections of these phantoms are not known. Current work with phantoms for which the absorption cross section is known may permit characterization of the power density of the microwave field (14).

Studies of ^{14}-C-phenylalanine (^{14}C-Phe) Incorporation into Protein

Chinese hamsters were exposed to microwave radiation. Either at one hour or at 20 hours after the midpoint of the irradiation or sham irradiation period, experimental and control animals were injected intraperitoneally with 12.5 μCi ^{14}C-Phe (12.5 μCi per 5.05 μg Phe). Twenty minutes after injection, the animals were sacrificed by decapitation and the liver and testes removed for analysis. Tissues from each animal were analyzed individually. Excised tissues were cooled to 0–4°C in an ice bath and weighed. The remaining procedures were carried out at this temperature with cold reagents unless otherwise noted. Tissues were homogenized in 1.5 times their wet weight in Hoagland's medium a (15) using a Dounce homogenizer (Medium A: 0.05 M Tris, 4.025 M KCI, 0.005 M $MgCl_2$, 0.25 M Sucrose, pH 7.5). Two hundred fifty μl of each homogenate were pipetted into individual test tubes and precipitated with 4 ml of 10 percent trichloracetic acid (TCA). Tubes were allowed to stand for 15 minutes and then centrifuged at 5°C. The supernatant was decanted and saved. The pellet was resuspended with 4 ml 10% TCA, the suspension centrifuged and the supernatant decanted. The pellet was then resuspended in 4 ml of 10% TCA, placed in a 90°C waterbath for 15 minutes, cooled to 0–4°C, centrifuged as before and the supernatant decanted. All of the supernatants were pooled for analyst of ^{14}C—acid soluble phenylalanine (^{14}C-Phe A.S.). The pellet was successfully suspended in 4 ml of a 3:1 alcohol: ether mixture, the suspension centrifuged and the supernatant discarded. Finally the pellets were suspended in 4 ml of anhydrous ethyl ether, suspensions centrifuged, and supernatants discarded. The pellets were air-dried and used for the analysis of ^{14}C-Phe incorporated into the acid insoluble fraction (^{14}C-Phe A.I.). The pellets were dissolved in 1 ml concentrated formic acid. Aliquots of the dissolved pellets, and ^{14}C-Phe A.S. were pipetted into 10 ml of Bray's scintillant (16). Samples were counted in a liquid scintillation spectrometer and were corrected for variable counting efficiency.

Cytogenetic Studies

Hamsters were irradiated either 15 minutes before or 15 minutes after, and 2 hours after, injection of 0.5 ml of a 0.1 percent solution of Colcemid (Ciba) used to arrest dividing cells at metaphase. Injected sham irradiated animals served as controls. Five hours after the injection of the Colcemid the animals were sacrificed with sodium pentobarbital. Bone marrow from the femurs was removed

and placed in hypotonic Hank's basal salt solution. Bone marrow cells were concentrated by centrifugation fiexd in 1 : 3 acetic acid-methanol, and spread on slides. These were evaluated for mitotic and chromosomal aberrations.

RESULTS AND DISCUSSION

Incorporation of ^{14}C-labelled phenylalanine into protein

In order to examine effects of microwave exposure on *in vivo* incorporation of ^{14}C-Phe into protein in liver and testes, it was necessary to determine both acid soluble and acid insoluble ^{14}C-Phe. The animals were injected intraperitoneally after irradiation, so variable amounts of ^{14}C-Phe may have been available for incorporation in the tissues of interest. The data on incorporation is expressed as relative activity =% injected dose in ^{14}C-Phe A.I./% injected dose in ^{14}C-Phe A.S.

Incorporation in irradiated hamsters was compared with the incorporation in sham-irradiated controls at 1.33 and 20 hours post-irradiation. The ^{14}C-Phe was available for incorporation for 20 minutes before sacrifice. Tables 1 and 2 present relative activity ± one standard error in liver and testis 80 minutes after midpoint of exposure. In liver the value for sham controls was 4.73 ± 0.33; for irradiated animals, 0.564 ± 0.334. The difference between sham and irradiated animals is significant ($P < 0.001$). The value for irradiated animals is not significantly different from zero. Thus, it would appear that at 80 minutes after microwave exposure labeled amino acid incorporation into liver protein was essentially abolished. A similar depression, though not as pronounced, was seen in testis 80 minutes after exposure. The value of relative activity in sham controls was 0.609 ± 0.093; in irradiated animals, 0.331 ± 0.065. Thus incorporation of labeled amino acid into protein was decreased by approximately 45 percent. The difference between sham controls and irradiated animals is significant ($P < .05$).

Table 3 presents data on amino acid incorporation in liver 20 hours after the midpoint of irradiation or sham exposure. The sham control value for relative activity in liver was 5.69 ± 0.46; for irradiated animals it was 5.37 ± 0.60. Incorporation of amino acid into protein, which was essentially abolished 80 minutes after exposure was restored to normal values 20 hours later. It should be noted that the average relative activities of livers of both groups of sham irradiated controls (Tables 1 and 3) are not significantly different from one another. However, the variance of the 20-hour group is greater than the 80 minute group, and the 80 minute average relative activity appears slightly lower than that of the 20 hour average. This is discussed in the next paragraph.

In contrast to the recovery of amino acid incorporation into liver, it can be seen that testis remained depressed relative to sham controls 20 hours after exposure to microwaves (Table 4). The value of relative activity for sham control animals was 1.09 ± 0.23; for irradiated animals it was 0.539 ± 0.082. This represents a depression of approximately 50 percent in amino acid incorporation into protein in irradiated animals. The difference between sham controls and irradiated animals was statistically significant ($P < .05$). The tendency towards lower incorporation observed 80 minutes after exposure (relative to 20 hour values) was more marked in testis than in liver. The relative activity for sham irradiated controls 80 minutes after sham exposure was 0.609 ± 0.093; 20 hours after sham exposure 1.09 ± 0.23. The mean values are significantly different ($P < .05$). The factors underlying this difference are not readily apparent. It is possible that hormonal stresses associated with the sham irradiation are involved. However, in each case exposure to microwave radiation did decrease the incorporation of labeled amino acid into testicular protein. This effect was observed as early as 80 minutes after irradiation and maintained at least through the 20th hour after exposure.

The finding of decreased amino acid incorporation into protein in liver and testis after microwave exposure cannot be equated to decreased protein synthesis without qualification. For instance, if microwave radiation results in an increase in the Phe pool in tissue (Phe A.S.), then the specific activity of the amino acid precursor (^{14}C-Phe A.S./Phe A.S.) will be lower in irradiated than in sham control animals. Under this condition the incorporation of equivalent amounts of Phe into protein in both groups of animals will lead to a decreased incorporation of ^{14}C-Phe in the irradiated animals. However, the degree to which incorporation of label was reduced in liver 80 minutes after irradiation, as well as the persistent effect in testis 20 hours after irradiation, suggest that increase in the size of the precursor amino acid pool may not be the mechanism underlying this effect.

Further experiments will have to be performed to establish the mechanisms underlying altered amino acid incorporation into proteins in tissues of microwave irradiated animals. The mechanism may be mediated through rise in body temperature, or may be an otherwise indirect or direct effect on protein synthesis.

It has been suggested that hyperthermia results in decreased protein synthesis and increased protein catabolism in tranquilized rabbits whose body temperatures were maintained at 41 ± 0.3°C for 24–46 hours (17, 18). However, possible alteration in amino acid pools was not investigated in these studies. Thus, a definitive statement on the mechanism for the altered protein metabolism after microwaves or hyperthermia is not possible at this time.

It is of interest to note that in the hyperthermia experiments in rabbits, rectal temperatures of 41.2° C. were maintained for 24–46 hours (17, 18). Hamster exposures to microwaves were accomplished in the present study within 0.25 hours, and resulted in a mean rectal temperature of 39.7° C. at the end of irradiation. The mean increase in rectal temperature of the irradiated hamsters was 4.2 ± 0.6° C. above that of the sham irradiated controls.

Cytogenetic Studies

In order to confirm the effects of microwave irradiation on chromosome previously observed with plant material (10), Colcemid-metaphase cells were examined in direct preparations of bone marrow from irradiated hamsters. Table 5 presents a summary of aberrations observed. Irradiation did not increase the incidence of aberrations in the animals. The interval between irradiation and fixation permits examination of cells that were irradiated either during or after DNA synethesis. Therefore only chromatid aberrations would be expected.

A substantial proportion of Colcemid-metaphase cells from some irradiated animals showed gross chromosomal anomalies which prevented cytogenetic analysis. The chromosomal appearance was similar to the "early physiological" or "stickiness" effects observed in dividing cells after X-irradiation (19). Because of the complexity in describing and understanding stickiness effects after X-rays (20), the stickiness in cells exposed to microwaves can be described only qualitatively at the present time. Stickiness may be observed either between parts of one chromosome (chromatid stickiness) or between two or more chromosomes (chromosome stickiness). The stickiness phenomena observed in metaphase cells are presented in Table 6. More chromatid stickiness was observed in cells from hamsters injected before microwave exposure than in cells from animals injected after irradiation. Substantial chromosome stickiness was observed only in the experiment in which cells were blocked in metaphase for two hours before irradiation.

Although chromosomal material is affected in stickiness phenomena, the effect may be considered as an irregularity in the mitotic process. Separation of adhering chromosomes is inhibited and cytokinesis may be incomplete, so that the cells may die (19). In preparations from animals irradiated two hours after injection, we found evidence that cells were escaping from the Colcemid block and attempting to complete cytokinesis. Chromatin bridges connected daughter nuclei in about 10–15 percent of the dividing cell population. Such effects have been previously described (10). If such cells survive to a second division after microwave irradiation, they may contain chromosome structural aberrations. Experiments to test this possibility are in progress.

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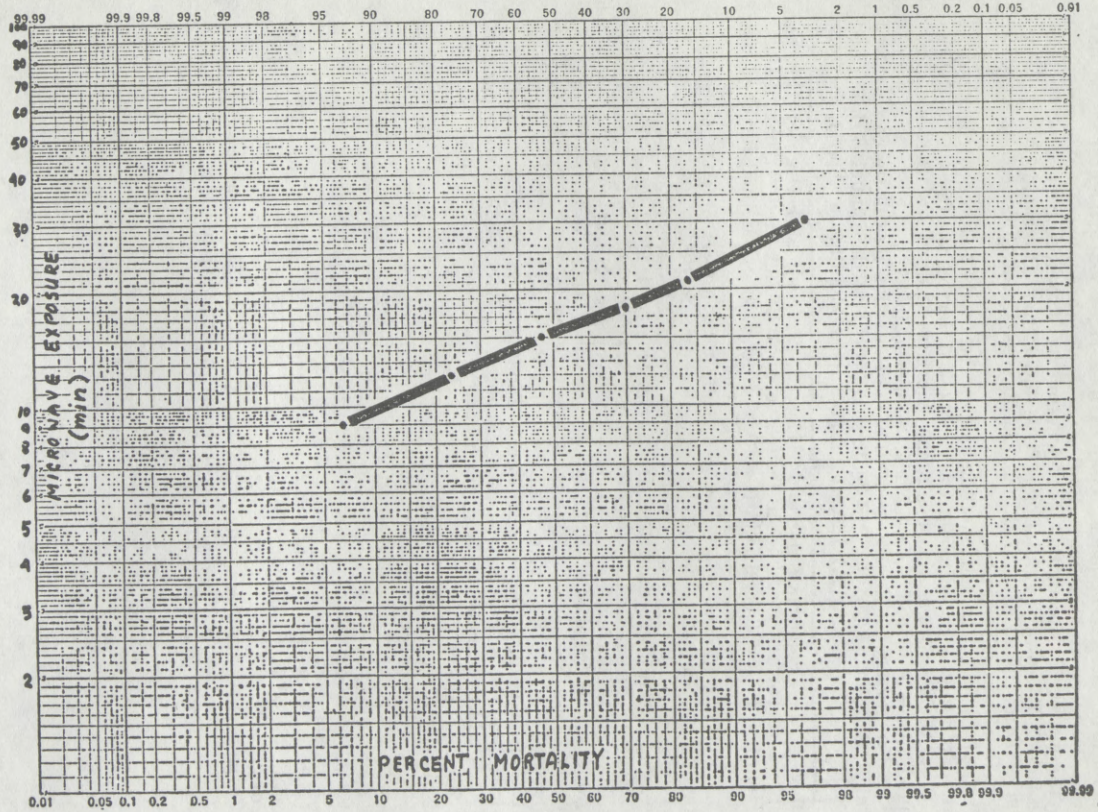


FIGURE 1. Cumulative percent mortality of Chinese hamsters during exposure to 2450 MHz microwaves. Animals were irradiated in a cyclical 3 minutes on, 1 minute off, pattern until they died in the microwave field.

TABLE 1

$$\text{Rel. Act.} = \frac{\%\ I\ D\ ^{14}C\text{ - Phe in Liver Protein}}{\%\ I\ D\ ^{14}C\text{ - Phe in Liver Acid Soluble}}$$

RELATIVE ACTIVITY*		
	SHAM CONTROL	IRRADIATED
1.	3.655	0.043
2.	4.868	0.831
3.	4.469	0.049
4.	4.409	3.735
5.	4.268	0.024
6.	—	1.010
7.	4.616	0.073
8.	5.095	0.063
9.	7.457	0.032
10.	4.080	0.331
11.	4.361	0.016
$\bar{X}$	4.73	0.564
S. E.	0.328	0.334
P <.001		

*Animals sacrificed 80 minutes post midpoint of exposure.

TABLE 2

$$\text{Rel. Act.} = \frac{\%\ I\ D\ ^{14}C\text{ - Phe in Testicular Protein}}{\%\ I\ D\ ^{14}C\text{ - Phe in Testicular Acid Soluble}}$$

RELATIVE ACTIVITY*		
	SHAM CONTROL	IRRADIATED
1.	0.481	0.146
2.	0.454	0.638
3.	0.424	0.455
4.	0.475	0.323
5.	0.645	0.018
6.	—	0.470
7.	0.615	0.107
8.	0.359	0.400
9.	1.368	0.376
10.	0.742	0.633
11.	0.510	0.080
$\bar{X}$	0.609	0.331
S. E.	0.093	0.065
P <.025		

*Animals sacrificed 80 minutes post midpoint of exposure.

TABLE 3

$$\text{Rel. Act.} = \frac{\%\ I\ D\ ^{14}C\text{ - Phe in Liver Protein}}{\%\ I\ D\ ^{14}C\text{ - Phe in Liver Acid Soluble}}$$

RELATIVE ACTIVITY*		
	SHAM CONTROL	IRRADIATED
1.	7.218	5.021
2.	2.364	5.004
3.	4.096	4.286
4.	5.252	5.615
5.	5.943	4.124
6.	7.681	4.720
7.	6.362	8.807
8.	6.160	–
9.	5.032	–
10.	4.101	–
11.	7.122	–
12.	6.934	–
$\overline{X}$	5.689	5.368
S. E.	0.455	0.603

*Animals sacrificed 20 hours post midpoint of exposure.

TABLE 4

$$\text{Rel. Act.} = \frac{\%\ I\ D\ ^{14}C\text{ - Phe in Testicular Protein}}{\%\ I\ D\ ^{14}C\text{ - Phe in Testicular Acid Soluble}}$$

RELATIVE ACTIVITY*		
	SHAM CONTROL	IRRADIATED
1.	0.892	0.332
2.	3.358	0.335
3.	0.752	0.478
4.	0.336	0.708
5.	1.175	0.425
6.	1.684	0.562
7.	1.064	0.932
8.	0.559	–
9.	0.570	–
10.	1.243	–
11.	0.677	–
12.	0.794	–
$\bar{X}$	1.092	0.539
S. E.	0.231	0.082
P <.05		

*Animals sacrificed 20 hours post midpoint of exposure.

TABLE 5.—*Chromatid aberrations and aneuploidy in bone marrow cells of microwave-irradiated Chinese hamsters*

Treatment Schedule[a]	Mitotic Index	Number of Cells Scored	Chromosome Aberrations	Chromatid Aberrations		Cells with Aneuploidy (2N=22)	
				Gaps	Breaks	<2N	>2N
MHz —0.25→ C —4.75→ Fix	11.0	50	0	0	0	0	2
C —0.25→ MHz —4.75→ Fix	6.1	50	0	2	0	2	0
C —2→ MHz —3→ Fix	5.0	49	0	0	0	0	0
C —5→ Fix	8.5	50	0	1	0	4	0

[a] C = Colcemid injection, MHz = microwave irradiation, numbers = intervals (in hours) between treatments.

TABLE 6.—*Stickiness in colcemid-metaphase bone marrow cells of Chinese hamsters*

Treatment Schedule[a]	Number of Cells Scored	% of cells with stickiness	Type of stickiness effects, % of cells	
			Chromatid	Chromosome
MHz —0.25→ C —4.75→ Fix	120	48.3	45.8	4.2
C —0.25→ MHz —4.75→ Fix	120	16.7	15.0	1.7
C —2→ MHz —3→ Fix	90	77.8	67.8	53.3
C —5→ Fix	120	23.3	19.2	5.0

[a] Symbols as in Table 5.

Mr. HANSEN. A study of the neurological effects of microwaves on monkeys is in progress. Dr. Maitland Baldwin, a recognized neurosurgeon, is collaborating with the research staff in this effort.

4. A study of the effects of microwave exposure to the lens of the eye will soon be underway. Dr. Russell Carpender, a recognized scientist, who has studies extensively in this area is now associated with our research staff.

5. A symposium entitled "Biological Effects and Health Implication of Microwaves" will be held at the Medical College of Virginia in September 1969. A review of the data presented at this symposium will be presented to Congress under section 360E, "Annual Report."

(B) Physical studies:

1. The characteristics and absorption phenomenon of low energy X-rays from television receivers and other electronic products are being investigated. This information is required for establishment and administration of performance standards.

2. Protocols are being developed for testing for compliance of television receivers with pending performance standards. The complexity

of design of this product has already required over 10 man-years of effort.

3. A minimal laser laboratory competence is being constructed and equipped in Rockville, Md. A literature review entitled "Biological Aspects of Laser Radiation" is available for the record.

Mr. ROGERS. Without objection that will be made a part of this record.

(The following publication was received for the record:)

BIOLOGICAL ASPECTS OF LASER RADIATION—A REVIEW OF HAZARDS

WELLINGTON MOORE, JR., D.V.M., PH. D.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

(Public Health Service, Consumer Protection and Environmental Health Service, Environmental Control Administration)

BUREAU OF RADIOLOGICAL HEALTH

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FOREWORD

The rapidly expanding technology in the laser field and the increased commercial and institutional applications of lasers makes it important that those responsible for protection of the public health and safety have the current information on the biological effects of radiation from lasers. This report reviews the scientific and technical literature available prior to 1968 on this subject and includes a discussion of both thermal and nonlinear effects. The report is intended as a reference for those concerned with the potential hazards of lasers and the establishment of programs for the prevention or control of exposure.

RAYMOND T. MOORE, M.D.,
Acting Bureau Director.

INTRODUCTION

Lasers emit highly directional, spatially confined, beams of intense monochromatic radiation. This radiation is potentially harmful to man. Considerable effort has been spent in studying the biological effects of this type of radiation. Of the possible biological effects of lasser radiation studied to date, the eye appears to be the most sensitive organ to injury. The lens of the eye focuses the incident visible laser radiation upon the retina resulting in an energy density at the retina of several orders of magnitude greater than the incident level at the cornea. For this reason, corneal intensities of visible laser radiation that could produce retinal damage are many orders of magnitude less than the incident intensities required to produce skin damage.

For radiation in the near-ultraviolet, near-infrared, and visible region of the spectrum, the retina is the critical part of the eye; for the ultraviolet and far-infrared regions, the portions of the eye enterior to the retina may be of greater concern. Already in the literature, there are substantiated case reports of severe ocular damage resulting from accidental exposure to laser radiation (1–3). Other aspects of personnel protection include protection against skin exposure, and protection from electrical shock.

The levels of laser radiation that constitute a hazard are difficult to establish because of variations in the type of laser and variations in biological factors. Since 1960 when T. H. Maiman (4) reported building the first ruby laser, a very large and diverse family of lasers has been developed. Laser radiation can be produced in a variety of generating modalities. Different wavelengths, intensity levels, pulse durations, and pulse repetition rates all influence directly the possibility of tissue damage. The array of devices utilizing the various properties makes it impractical to list each device. Biological factors applicable to all tissues, such as pigmentation, vascularity, and spectral absorption of the energy influence the degree of damage. In addition, there are organ-specific factors which influence the degree of damage to a particular organ. In the case of the eye, for example, pupil size, convergence power of the cornea and lens, and distance from the lens to retina, all influence the threshold level for damage. Because of the

multiplicity of these factors it is unwise to establish one threshold value for biological damage for all types of laser systems and conditions of operation.

MODE OF ACTION

The action of laser radiation on biological tissues may be divided into two broad areas: (1) those attributed to heat; (2) those not attributed to heat ((nonlinear effects). These nonlinear effects include mechanical effects such as target impulse, target recoil, pressure effects from thermal expansion with or without change of phase, and shock wave production; ionization effects and X-ray production; free radical formation and harmonic generation of other wavelengths in crystalline tissue components.

The production of nonlinear effects requires energy intensities that are catastrophic in biological tissues. If the impingement of a laser beam on matter is considered in a conventional manner, its effects have to be accounted for by the quanta released to the atoms and molecules through which it passes. Unlike X-ray quanta which are energetic enough to effect release of electronics from atoms to produce ions, the longer wavelength radiations are only sufficiently energetic to excite atoms by changing the orbital arrangement of electrons in the case ultraviolet light, excite resonant molecules in the case of visible light, and vibrate atoms in the case of infrared light. The majority of these processes result in a rise in temperature although some may produce photochemical changes where the chemical systems are capable of being unbalanced by energy changes. Most of the laser lesions in biological systems are attributable to heat or known photochemical processes; however, there are some observations which cannot be explained entirely by these mechanisms. At high intensities common with some lasers, optical processes of absorption and a re-radiation may not be linear (5).

Thermal Effects

Laser-induced thermal lesions have been produced in various tissues in several animal species and in man. A theory that has been advanced to explain thermal injury includes: (1) thermal alteration of protein, (2) other possible alterations in metabolic processes, and (3) nonprotein induced alterations in physical characteristics of cells (6). In studies on the effects of ruby laser radiation on the retina, Vos (7) indicated that most of the energy is absorbed by the melanin granules of the pigment epithelium. This absorbed energy is converted into heat which is transferred by conduction, convection, and radiation to the proteins around them. If these proteins are sufficiently heated, they may be denatured or coagulated. More vigorous heating produces vaporization of the tissue water with consequent disruption of tissue by bubbles of steam.

Attempts have been made to measure retinal temperature in the rabbit with sensitive thermocouples (8–10). Resolution of temperature changes has been limited by the properties of the thermocouples. Najac et al. (9) reported the temperature rise varied from 12.5 to 20.6°C above normal for a retinal threshold burn (small amount of coagulation in the center of the lesion) measured directly at the burn site. Mellerio (10, 11) found that just outside the area exposed to a laser beam of 5 millijoules (mJ) of energy, the retinal temperature rose from its normal 39°C to over 60°C. McGuff et al. (12) made temperature measurements with thermocouples implanted in tumors in the hamster. When the thermocouple was placed just beneath the mucosa covering the tumor, a temperature of 445°F was measured after a 140 J ruby laser pulse. At a depth of 2.5 mm below the tumor surface a temperature of 145°F was recorded. This pulse (140 J) was considerably above the threshold.

Irradiation through the intact skull in small animals led to death after relatively small doses, 100–200 J (13). This was ascribed to super-heating tissue to a gaseous state in a closed cavity with the production of an explosive force which drove the brain to the base of the skull forcing it through the tentorium and foramen magnum with fatal results.

Irradiation of the skin produced lesions resembling thermal burns. The amount of damage varied with the intensity of the irradiation and the degree of pigmentation. Irradiation of porcine skin with an energy of 10 J (image diameter of 2mm) produced subepidermal vesicles partially filled with fluid (14). Fine et al. (15, 16) irradiated the pigmented skin of the hamster and produced a lesion characterized by a small central area of penetrating injury resembling a second degree burn surrounded by an area of less intense damage that went

on to vesiculate. On microscopic examination, a punched out, well-defined, and sharply demarcated area of destruction was noted which later became infiltrated with inflammatory cells and was ultimately replaced by fibrous scar tissue. Unlike the gradual transition from maximum damage to normal tissue as seen in a thermal burn, the laser-irradiated area was separated from nonirradiated areas by a rather sharp line of demarcation (17). The sharp demarcation of necrosis suggests that the brief period of impact was not sufficient to allow heat to transfer to adjacent tissue. Laser radiation at a level of approximately 30–50 J produces relatively little damage to the skin of hamsters, but variations in the severity of the injury suggest a relation to the amount of pigment or to the number of hair follicles in the area (15).

In man, skin with high pigmentation showed significant changes in the epidermis after impact of a low-energy laser (5–10 J), including superfical scaling, superficial charring, crusting, and even ulceration (18). No evidence of changes was noted in skin of low pigmentation at this energy level. With high energy densities up to 100 J, singificant alterations may develop in low pigmented skin after a single impact, such as anesthetic areas with changes in the epidermis and significant modifications in the deeper blood vessels.

Morphologic and biochemical data indicate that the cytological effect of laser radiation depends upon the structural and absorption characteristics of the target tissue for the incident wavelength. Highly pigmented, very cellular tissues with sparse supporting collagenous stroma may be instantaneously vaporized. Tissues with dense collagenous stromata may be non-functional but no disintegrated. Ham et al. (19) have reported that the absorption of radiation by pigmented retinal epithelium was minimal at 4,000 Å, maximal at 5,00 to 5,500 Å, and diminished to negligible values at 13,000 Å. The pigmented retinal epithelium absorbs approximately 70% of the light at 6,943 Å and only 20% at 10,600 Å (20).

Thorell and Chance (21) have shown that nonpigmented cells show greatest optical density at approximately 4,150 Å and do not absorb appreciably in the red wavelengths. Bessis and Ter-Pogossian (22) destroyed red blood cells with laser radiation but found white blood cells unaffected. By suitably staining the white cells they were able to destroy those parts which took up the stain. A variety of cell types grown in tissue culture have been irradiated (6,943 Å) and, in general cells have been injured or destroyed in proportion to their degree of pigmentation (23, 24). Although nonpigmented cells did not appear to be damaged immediately after laser radiation, subtle changes were detected later. Rounds (23) observed cytoplasmic bleeding in unpigmeted cells within 10 minutes after exposure to 0.125 J/cm^2 of 3,471 Å lesser energy. Irradiation of transparent HeLa cells caused a decrease in oxygen consumption, and irradiation (2.5 J/cm^2) of intact chick hearts slowed the contraction rate (24). Cells can be sensitized to light by various organic compounds including many dyes such as erythrosine, acriflavine and acridine orange. Rounds et al. (24) demonstrated that nonpigmented cells could be sensitized to laser injury by prior vital staining with dyes such as Janus green. Moreover, laser irradiation of unstained cells appeared to make them more sensitive to Janus green. Experimental evidence suggests that laser radiation produces cytologic effects if a suitable substance is present to absorb the laser energy at the emitted wavelength and that the effects depend on the amount of energy absorbed by the cells.

Nonlinear Effects

A good deal of effort has been directed toward defining the non-linear effects of laser radiation and how they are mediated in biological systems. Considerable speculation and disagreement exist over the possible mechanisms involved. Some of the mechanisms which have been implicated in the nonlinear effects include: (1) mechanical effects including target impulse and target recoil, (2) pressure effects from thermal expansion with or without change of phase and shock wave production, (3) ionization effects and X-ray production (not likely in biological tissues), (4) free radical formation, (5) harmonic generation of other wavelengths.

The mechanical effects of laser radiation on materials has been discussed by Burkhalter (25) and he concludes that the total momentum of pulses from the most powerful lasers to date is of negligible magnitude (3,000 J of pulse energy per dyne-second of impulse). However, there is considerable recoil of the target from the mass blown away at the surface. No results were available for biological tissue.

Fine et al. (26) indicated that pressure waves could be produced as follows: (1) volatilization of material from the surface with generation of a mechanical impulse into the biologic system, (2) transient heating and associated thermal expansion of volume, without change of phase, (3) transient heating with change of phase, especially to a gaseous phase.

Litwin, et al. (27) have shown with mice that when the energy disposition occurs within a closed, filled cavity such as the skull, chest, or eye, and when the energy density is great enough to transform the tissue to a vapor or gaseous phase, high pressures will occur at the site of interaction. Because total volume of such a cavity is fixed, resultant transmitted pressures will be attenuated only slightly, and tissue destruction will be produced at sites distant from the original site of radiation. Mendelson and Ackerman (28) however, presented experimental evidence that pressure waves were sharply localized and rapidly attenuated in tissue, and that even Q-switched lasers with peak power of 10^7 watts are not likely to produce damage from shock waves beneath the skin of man.

Ionization effects and X-ray production from laser radiation have not been demonstrated in biological tissues. Igelman et al. (29, 30) failed to inhibit enzymes that are consistently inactivated by ionizing radiation, and Goldman (31) was unable to demonstrate ionization in tissues exposed to Q-switched lasers. Intense pulses capable of producing ionization have been produced by McClung and others (32). Data reported by Derr et al. (33) suggest strongly that free radicals are produced in black mouse skin and fibrinolysin preparations by irradiation with ruby laser output of approximately 100 J. Harmonic generation of other wavelengths in tissues has not been reported.

CRITICAL ORGANS

Eye

The absorption of high-intensity energy in the visible and near-visible portions of the electromagnetic spectrum by the eye has long been known to cause ocular damage (34). The potential ocular hazard of laser radiation was first discussed by Solon, Aronson, and Gould in 1961 (35). For radiation in the visible, near-ultraviolet, and near-infrared regions of the electromagnetic spectrum, the retina is considered the critical part of the eye, whereas in the ultraviolet and infrared regions, the portions of the eye anterior to the retina may be of greater concern. For wavelengths in the near-ultraviolet, visible, and near-infrared regions, the amount of energy required to produce retinal injury is many orders of magnitude less than that required to produce skin damage.

The effectiveness of laser radiation in producing retinal lesions is influenced by several factors: (1) pupil size, (2) spectral transmission through the ocular media, (3) spectral absorption in pigments of the retina and choroid, (4) retinal spot size. The size of the pupil determines how much light may enter the eye. The pupillary diameter varies from approximately 2 to 8 mm with the ambient light level, fixation distance, age, fatigue, and other factors (36, 37). Because the cornea, lens, and other parts of the ocular media have strong absorption bands for wavelengths below about 4,000Å and above 14,000 Å only energy in the near-ultraviolet, visible, and near-infrared reach the retina and choroid in amounts sufficient to produce damage, except in unusual cases (38, 39).

Geeraets et al. (40) determined the transmission of light through the human ocular media as a function of wavelength. It extends from approximately 4,000 Å to 14,000 Å exceeding 80% in the range of 5,000 to 9,500 Å. There were two peaks in the near-infrared, a large one at 11,000 Å and a much smaller one (10%) at 13,000 Å. For the ruby wavelength (6,943 Å) more than 94% of the light incident at the corneal surface of the eye coaxial to its principal optical axis will be transmitted to the retina (41). Lens opacities have occurred following irradiation at longer wavelengths in the infrared (42) and the microwave region (43). At frequencies in the ultraviolet, damage to the cornea can result especially at wavelengths shorter than 2,950 A, to which the cornea is relatively opaque (44).

The radiation which penetrates to the retina encounters three main tissue layers: retina, choroid, and sclera. In each of them, the radiation is subjected in varying degree to reflection, absorption, and transmission. A negligible portion of visible light striking the retina is absorbed by the inner layers of the retina (those first struck by radiation). Absorption of visible light takes place primarily in the melanin granules contained in the outer layer of the retina (pigment

epithelium, PE) and in the pigmented cells of the choroid. The degree of pigmentation varies widely among eyes and also among different topographical sites within the eye. Vascularization of the choroid provides an additional source of absorption. Peak absorption in the PE for light incident on the cornea occurs between 5,000 and 5,500 Å, (45).

The first harmonic of neodymium doped glass (5,300 Å) and the green lines in the argon continuous wave (CW) laser are in the spectral region where maximum absorption by the PE occurs. For the ruby wavelength (6,943 Å) about 10% is absorbed in the ocular media of man and, depending on the individual, 15 to 40% is absorbed in the PE and 10 to 80% in the choroid (40, 46). For the neodymium doped glass wavelength (10,600 Å) absorption in the PE varies from 5 to 15%. In this case much of the light is absorbed by the nerve fiber layer of the retina (inner layers), creating the potential hazard of loss of innervation to retinal areas (47). The PE is roughly 10μ thick while the choroid has a thickness of about 100μ. Consequently, the energy absorbed per unit volume (J/cm^3) in the PE may exceed that absorbed in the choroid by a factor of 10.

The size of the retinal image or spot determines the retinal area which receives th incident radiation. The minimal retinal spot size is limited by diffraction theory to approximately 100μ depending on pupil diameter, wavelength of light, and the degree of spherical aberrations in the eye. Theoretically, the spot size should increase with an increase in wavelength and decrease with increasing pupil diameter. The latter effect is offset by the effect of spherical aberrations which increase with greater pupil diameter. The image size is important in the dissipation of heat. The rate of temperature rise and the time taken to approach a steady state temperature are functions of image size. At very short exposure times, the radial heat flow will be negligible except for very small images. This is supported by histochemical evidence showing minimal radial spread beyond the image diameter for exposure times less than two milliseconds (48). A marked spread of biological damage beyond the confines of the original image was found for longer exposures (>20 ms). Ham et al. (45) plotted the irradiance in W/cm^2 versus image radius in microns for equilibrium temperatures in the retina. The level of irradiance decreased as the image size increased for a given temperature equilibrium.

Threshold Values for Retinal Damage

The threshold values for retinal damage (Table I) may be defined as the energy density required to produce, within a short interval of time (approximately 5 minutes) after exposure, a clinically visible retinal lesion. These values should not be taken as the absolute minimum for retinal damage since injury has been demonstrated at lower levels of irradiance by more refined techniques. Geeraets et al. (48) demonstrated impairment of enzyme activity at levels of irradiance 10 to 15% below those required to produce visible lesions. Also, retinal lesions may not become clinically visible immediately after exposure at low levels of irradiance.

For the rabbit, an energy value of 2.7×10^{-4} J (duration of exposure and size of exposed area was not reported) incident on the eye produced a visible lesion immediately after treatment whereas a lower energy value of 2.1×10^{-4} J produced a lesion detectable 24 to 48 hours after exposure (49). In the rabbit, the faint lesions which represented the threshold values for earlier observations disappeared within 14 days with no residual evidence of atrophy or pigmentation. The energy value necessary to produce a persistent, just detectable lesion 14 days after exposure was 3.4×10^{-4} J entering the eye (49). The anatomical area of the retina that is exposed is also important in establishing a threshold value. Data obtained from the rhesus monkey retina indicated that the macula (most sensitive area of the retina) was approximately two times more sensitive than the paramacular regions (50).

TABLE I.—THRESHOLDS FOR BIOLOGIC DAMAGE BY LASER RADIATION (λ=6,943 Å) AT THE RETINA OF THE EYE

Regulation or code	Threshold values		
	Q-switched (pulse duration)	Non-Q-switched (pulse duration)	Continuous wave
U.S. Air Force regulation No. 161–24, January 1967	0.125 J/cm² (10–100 ns)	----------	
British Ministry of Aviation Code of Practics for Laser Systems.	0.07 J/cm² (30 ns)	0.85 J/cm² (200 μs)	
University of California, LRL hazards control quarterly report 16 and 17, 1964.	0.08 J/cm² (30 ns)	0.7–0.8 J/cm² (200 μs)	
Uniform industrial hygiene codes or regulations for laser installations, ACGIH—1968.	0.07 J/cm² (30 ns)	0.85 J/cm² (200 μs)	6.0 W/cm² (white light)

Because of the understandable paucity of information on the human eye, threshold values are based upon data obtained from experimental animals, mostly rabbits. Extrapolation to the human eye must be made with caution. Research on retinal burns and clinical experience have shown that the rabbit retina provides a useful model for estimating a safe level of human exposure (51). The energy values necessary to produce threshold lesions are reported to be significantly lower in the rabbit than in the human (49, 50, 52). To produce a result in the rhesus monkey comparable to that in the rabbit, approximately 50% higher energy levels are required because of differences in pigmentation (50, 52, 53). Very limited results indicate that the human retina is less sensitive than the rhesus retina (50).

Seceral agencies have published safety standards for laser operations. Thresholds for biologic damage at the retina of the eye used in determining these standards are given in Table I. The threshold values for retinal damage are presented for three separate modes of operation, Q-switched, non-Q-switched, and continuous wave. The distinguishing feature of the Q-switched device is the rate of energy delivery. Power densities ranging from 1 to 100 MW/cm² (even GW/cm²) can be delivered in pulses ranging from about 5 to 100 nanoseconds (ns).

A radiation dose of 0.07 J/cm² will produce a visible lesion in the rabbit retina in 30 ns (54). The value is lower by a factor of 10 from that needed to produce a lesion at 200 μs with a non-Q-switched device. The levels are based upon retinal lesions of considerably greater size than the minimal spot size used in safety level calculations; however, it is reasonable to assume that the level is the same for minimal spot sizes for pulse lengths found in most pulsed lasers.

The output for the non-Q-switched devices ranges between the Q-switched and the continuous wave devices. The power output for continuous wave operation of gas lasers and semiconductor diodes rarely exceeds one watt. The hazard to the eye consists primarily of thermal damage to retinal proteins. If it is assumed that the retina of the human eye will tolerate a 1°C temperature rise above normal for considerable periods of time without sustaining irreversible damage, it has been calculated that 10^{-6} watt is a safe power level. Thus, 10^{-6} W incident on a retinal area 10μ in diameter produces a power density of 1.33 W/cm² (54). Possible thermal damage to lens proteins should not be overlooked as continued exposure could conceivably lead to opacification.

Maximum Permissible Levels at the Cornea

Some of the codes from the British, University of California, and the American Conference of Government Industrial Hygienists (ACGIH), have also given maximum permissible exposure levels for laser radiation (wavelength 6,943 Å) at the cornea. The establishment of such values would be a realistic approach since the beam intensity would be measured externally in ambient air. The safe irradiance levels at the cornea are determined by calculating the energy density at the cornea which is below that required to produce threshold damage at the retina. The safe corneal irradiance levels vary depending upon wavelength, pupil size, and duration of exposure. The maximum permissible exposure levels for laser radiation (wavelength 6,943 Å) at the cornea as proposed by the ACGIH code are given in Table II. The maximum permissible levels can be adjusted for other wavelengths by considering the amount of energy transmitted to, and absorbed by, the retina. The ACGIH code presents graphs for determining these values.

Skin

Exposure of the skin to laser radiation is an obvious hazard; however, the biological significance is much less than ocular exposure. There is a high probability that persons who work with laser generating equipment receive repeated exposures to their hands. Studies have been conducted on the skin of animals and to a very limited extent on man using a variety of energy levels and wavelengths. Summarizing the results, a certain energy density was required before there was any noticeable effect, either macroscopic or microscopic. The actual energy density required to produce a minimal skin lesion was dependent upon such factors as the degree of pigmentation, thickness of the keratinized surface, presence of hair, and its color.

TABLE II.—MAXIMUM PERMISSIBLE EXPOSURE LEVELS FOR LASER RADIATION AT THE CORNEA FOR DIRECT ILLUMINATION OR SPECULAR REFLECTION AT λ=6,943 Å (ACGIH-1968)

Pupil size	Q-switched pulse (J/cm²)	Non-Q-switched pulse (J/cm²)	CW laser (W/cm²)
Daylight 3-mm. pupil	5.0×10^{-8}	5.0×10^{-7}	5.0×10^{-5}
Laboratory 5-mm. pupil	2.0×10^{-8}	2.0×10^{-7}	2.0×10^{-5}
Night 7-mm. pupil	1.0×10^{-8}	1.0×10^{-7}	1.0×10^{-5}

In swine, epidermal injury could not be detected after exposure of an area 2 mm in diameter to an energy of 2 J (wavelength 6,943 Å) (14). Injury was apparent with 3 J after an interval of 30 minutes. In the superficial epidermis, the nuclei showed swelling and concentrations of chromatin along with vacuolization. At an energy of 9 J and an image area 2 mm in diameter, subepidermal vesicles formed. At 24 hours and 10 J of energy, the lesion appeared as a vesicle and pustule.

Fine and associates (16) studied the effects of neodymium-doped glass laser radiation (10,600 Å) on the skin of the Syrian hamster. Exposure to a single pulse (1 ms) of approximately 30 J produced an immediate injury resembling a second degree burn. The gross appearances of the lesions in the skin on the fifth day postirradiation suggested a more severe reaction in the lighter colored areas than in darker regions. This was also reflected in the microscopic appearance, which presented fewer hair follicles in the lighter areas than in the darker areas, coagulation necrosis, and leukocytic infiltration between necrotic areas and viable tissues. Fine et al. (15) studied the internal effects on hamsters following external irradiation of the abdomen with a focused 50 J ruby laser beam. Visceral injury of varying severity was produced and occasionally visceral perforations occurred at later stages.

Goldman (18) observed no changes in the skin of light pigmentation after exposure to low energy laser beams often as high as 5 to 10 J (duration of exposure not reported). The skin of high pigmentation showed significant changes in the epidermis after impact of a low-energy laser, including superficial charring and crusting, and even ulceration. At energy densities above 20 to 25 J a single impact produced epidermal changes in lightly pigmented skin. A single impact up to 100 J produced significant alterations such as anesthetic areas with changes in the epidermis and modifications in the deeper blood vessels.

In a normal Caucasian volunteer, irradiation of the skin with an unfocused 100 J ruby laser produced an area of instantaneous mild erythema which was insensitive to touch and persisted for four days. Little information is available on the effect of chronic exposure of the skin to laser radiation. In an individual with hypersensitive white skin, chronic exposure over a two-month period to a 0.5 J pulse produced a lesion with atypical cellular changes (55). Attempts to reproduce these changes in other individuals have not been successful.

Several codes give maximum permissible levels for laser radiation of the skin. The British Aviation Ministry code states that the total laser energy incident upon any part of the body other than the eye should not exceed 0.1 J/CM²s. The ACGIH Code (Table II) states that the maximum permissible exposure level for the skin should not exceed daylight levels for the eye by a factor of more 10^6.

DISCUSSION AND CONCLUSIONS

Concern over the hazards of exposure to laser radiation has resulted in the establishment of guidelines for human exposure by several agencies. Owing to

the incompleteness of knowledge concerning biological effects, particularly long-term ones, it is not possible to set firm protection standards at this time. Current guides are based upon the minimum dose required to produce a visible lesion. These threshold values may vary depending upon the criteria by which they are measured. For the eye, threshold damage has been determined by such varying means as ophthalmoscopy, light microscopic histology, histochemical study, and electroretinography. In histochemical studies (48), impairment of enzyme activity was apparent when the energy level of the light beam had been reduced by 10 to 15% below threshold for ophthalmoscopically visible or histologically detectable lesions. This raises the question of how damage in the human might be demonstrated below levels that are clinically apparent.

Very little is known about the potential cumulative effects produced by repeated subthreshold exposures either to the eye or skin. Current data in this area are not sufficient to provide information concerning the possibility of cumulative effects from repeated exposures. There appears to be some conflict over the significance of repeated subthreshold exposures in the production of damage.

Occupational hazards incidental to the use of lasers must be reduced to the very minimum. In addition to beam exposure, other potential hazards include contact with liquid nitrogen or other substances such as coolants, electrical shock, exposures to gases such as ozone, and explosions at capacitor banks, optical pump systems, and target area. A complete safety program is necessary to protect the operating personnel and other persons present at laser installations.

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Mr. HANSEN. Microwave ovens from all domestic manufacturers have been purchased and are being tested for adequacy of interlock design and door leakage. A report entitled "Preliminary Measurements of Electromagnetic Radiation Fields Near Microwave Ovens" is available for the record.

(The report referred to is a U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Environmental Control Administration, publication—Technical Services Branch staff report by D. L. Solem, D. G. Remark, R. L. Moore, R. E. Crawford, and H. J. L. Rechen—TSB No. 5 dated December 1968, and may be found in the committee files.)

Mr. HANSEN. We have also received results of microwave oven surveys from other Federal as well as State agencies. Excessive leakage above the manufacturer's design criteria has been noted in most surveys.

5. Over 200 color television receivers will be tested and evaluated by our own laboratories and under controlled conditions in the field. This work will be underway in June 1969. We have available a copy of the report "X-Radiation Control Programs in the Color Television Industry."

(The report referred to follows:)

X-RADIATION CONTROL PROGRAMS IN THE COLOR TELEVISION INDUSTRY—SUMMARY REPORT ON VISITS TO MANUFACTURERS, MAY 1968–DECEMBER 1968

D. R. SMITH, H. J. L. RECHEN, D. J. NELSON, JR., DIVISION OF ELECTRONIC PRODUCTS

U.S. Department of Health, Education, and Welfare, Public Health Service, Environmental Control Administration, Bureau of Radiological Health

DIVISION OF ELECTRONIC PRODUCTS

List of Publications

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TSB–1: Instrument for Measurement of X-Ray Emission from Television Sets (January 1968) (PB 178 808)

TSB–2: A Pilot Survey of X-Radiation Emissions from Color Television Receivers (In Pinellas County, Florida) (June 1968) (PB 178 809)

TSB–3: A Survey of X-Radiation from Color Television Sets in the Washington, D.C. Metropolitan Area (March 1968) (PB 178 810)

TSB–4: Biological Aspects of Microwave Radiation—A Review of Hazards (July 1968)

TSB–5: Report of Preliminary Measurements of Electromagnetic Radiation Fields Near Microwave Ovens (December 1968)

DEP–69–1: X-Radiation Control Programs in the Color Television Industry—Summary Report on Visits to Manufacturers—May 1968–December 1968 (March 1969)

FOREWORD

The staff of the Bureau of Radiological Health (formerly the National Center for Radiological Health) from May 1968 to December 1968, visited facilities of 19 color television manufacturers to obtain information on industry programs for the control of X-radiation emission from components and receivers.

The tour of the production, engineering and research facilities, and programs for X-radiation control were arranged by the individual manufacturers and were indicative of the full cooperation of the domestic television industry. Each visit provided an opportunity for a free interchange of information. Procedures used by the manufacturer in measuring X-radiation from color television receivers, and the design measures taken to reduce or eliminate X-radiation emissions, were emphasized. During the visits wherever appropriate, the Bureau staff made recommendations on improvement of X-radiation measurement and control techniques.

Discussion with senior management, production, engineering, quality control and marketing staff during the plant visits, as well as first-hand observations of industry practices and procedures, provided data and information which should be helpful both in planning for and in fulfilling industry and government responsibilities pertaining to such product certification, standards, and enforcement activities as may be required under Public Law 90–602, "Radiation Control for Health and Safety Act of 1968."

RAYMOND T. MOORE, M.D.,
Acting Director, Bureau of Radiological Health.

INTRODUCTION

In December 1967 and January 1968, The Bureau of Radiological Health,* with active cooperation of the Electronic Industries Association (EIA), conducted a survey of X-radiation emissions from color television receivers in the Washington, D.C., metropolitan area.[1] The purpose of the survey was to obtain information on X-ray emissions from home color television receivers of as many different manufacturers as possible. An earlier survey in Pinellas County, Florida, designed to measure the effectiveness of a shunt regulator tube correction program instituted by one manufacturer, had indicated that radiation emissions were occurring from components common to all mnufacturers, i.e., picture tubes, high voltage shunt regulator tubes, and high voltage rectifier vacuum tubes.[2]

In the Washington study, some X-radiation emission was detected from 268 of the 1,124 color television receivers surveyed. Sets of 20 domestic and five foreign manufacturers were included in the sample surveyed. Six percent of the receivers exhibited X-radiation exposure rates above the 0.5 mR/hr recommended

*At the time of the survey, the Bureau was designated as the National Center for Radiological Health. The Bureau was established on December 20, 1968, as a part of the Environmental Control Administration.

[1] A Survey of X-radiation From Color Television Sets in the Washington, D.C., Metropolitan Area, Technical Services Branch, NCRH, TSB Report No. 3, March 12, 1968.

[2] Hearings before the Subcommittee on Public Health and Welfare of the Committee on Interstate and Foreign Commerce, House of Representatives, on H.R. 10790, Serial No. 90–11, 1967, and Supplemental Hearings thereto Serial No. 90–27, 1968; and Hearings before the Committee on Commerce, United States Senate on S. 2067, S. 3211, and H.R. 10790, Serial No. 90–49, 1968.

by the National Council on Radiation Protection and Measurements (NCRP).[3] Other surveys by State and local health departments have indicated a higher percentage of receivers with X-radiation exposurelevels above 0.5 mR/hr.

Surveys, as well as laboratory studies,[4] have indicated that certain receiver design characteristics, namely shielding by structural materials or components, operating kilovoltage ranges, the choice of receiver components in the high voltage circuits, and circuitry permitting certain failure modes, were the important factors in controlling X-ray emissions from television sets.

X-ray survey methods used by representatives of receiver manufacturers during the Washington survey indicated that all factors in the measurement of X-rays were not being considered, and, therefore, the methods used were not adequate in all instances to insure that X-ray exposure levels in excess of the NCRP recommendations would be detected reliably during quality control procedures conducted on their receivers.[5] Moreover, a report of the Ad Hoc Advisory Committee on X-radiation from Color Television Receivers [6] to the Burau, stated that Bureau efforts would be better expended on a program to assure compliance with the NCRP recommendation in future TV receivers instead of a program to locate X-ray emitting receivers already in homes. The reduction, control, or elimination of X-ray from home color television receivers by improvement of the produc at point of manufacture is essential to certification of products under the Federal Radiation Control for Health and Safety Act of 1968, Public Law 90–602. At the invitation of the Color TV manufacturers, visits were made to design, production, and research facilities in order to obtain information for consideration in planning for a continuing and effective program of X-radiation emission control by the televtision industry and for the protection of the consumer.

OBJECTIVES

The visit to individual manufacturers gave Bureau staff members an opportunity to discuss with management and production personnel steps taken by manufacturers to measure X-radiation from television components and receivers currently in production. In addition, plant visits made it possible for members of the staff to (1) review efforts being made in the design of current and future models of receivers for the reduction of X-ray emissions, (2) review available industry and Bureau of Radiological Health data relative to the specific sources of X-radiation characteristics of the products, (3) observe procedures used for measuring X-radiation from color television receivers and components under plant conditions, (4) observe research and development efforts related to color television X-radiation emissions, (5) discuss design and production changes necessary to reduce or eliminate X-radiation emissions, (6) review servicing procedures recommended by the manufacturer for receivers currently on the market, and (7) discuss voluntary manufacturer standards related to the control of X-rays.

CONDUCT OF VISIT

A letter was written in reply to each company's invitation outlining visit and discussion guidelines. A Bureau of Radiological Health (BRH) team was constituted in terms of technical background to insure that typical aspects of production, quality control, and engineering facilities could be competently reviewed during discussions and tours. Discussions during plant visits depended somewhat on the planned presentations, if any, made by each of the manufacturers. Bureau personnel, however, at some point in each visit, raised questions or sought information on company organization, quality control programs, component testing, engineering design and research related to X-radiation control tests and standards, servicing organizations, and factors in marketing and distribution

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[3] National Council on Radiation Protection and Measurement, X-ray Protection Standards for Home Television Receivers, Interim Statement of the NCRP, Approved February 23, 1968.

[4] X-ray Patterns and Intensities From High Voltage Shunt Regulator Tubes From Color Television Receivers, H. F. Stewart, et al.; Measurement of X-ray Exposure From a Home Color Television Receiver, H. J. L. Rechen, et al., *Radiological Health Data and Reports*, December 1967.

[5] Calibration and Energy Dependence of the EPRL X-ray Survey Meter, H. J. L. Rechen, R. H. Schneider, R. K. Stoms, NCRH. Paper given at the Conference on Detection and Measurement of X-radiation From Color Television Receivers, March 28–29, 1968.

[6] Report of the Ad Hoc Advisory Committee on X-radiation From Color Television Receivers, sent to Mr. J. G. Terrill, Jr., Aug. 6, 1968.

required if correction programs should be necessary. Also discussed were import and export data, customer complaints, retrofits, and in-plant radiation control (Appendix 1).

At the time of the visit, names of individuals in the company responsible for administrative, engineering, and quality control functions associated with X-radiation emissions were obtained. Locations of principal production plants, quality control activities, and component manufacturing facilities of the company, and sources of components (picture, shunt regulator, and rectifier tubes) also were learned.

During the course of in-plant discussions, X-radiation data available for the models of receivers covered by the Washington area survey were reviewed. Current production data for these or subsequent models were obtained from some manufacturers. Research programs undertaken by the companies to identify suorces of possible X-radiation, to evaluate components, and to measure X-radiation also were important considerations.

Efforts were made to determine the steps the manufacturers were taking or planned to take to reduce X-ray emissions from receivers and to maintain receivers without detectable radiation. X-radiation emission quality control procedures used by the manufacturer were carefully evaluated through observation of procedures practiced at each plant. Questions typically asked during the visits were:

How many sets were measured to determine the X-ray exposure levels from a particular production or model run?

What were the procedures for X-radiation measurement?

What radiation measurement records were maintained by the company?

What actions were or would be taken, and at what X-radiation exposure levels?

At each of the manufacturers' plants, it was considered important to learn what was being done either to decrease X-radiation emission levels or to control the use of X-ray emitting components in receivers. The discussions centered on what facilities and equipment were used for component testing and what criteria were used for acceptance of components. The manufacturer was asked to provide copies of the component testing results, if available.

The availability of engineering designs or future improvements the manufacturer could make to reduce X-ray exposure levels was of particular interest. Design features included high voltage control circuits, solid state circuits, improved cathode ray tubes, increased inherent shielding of components, external shielding of components, substitution of improved tubes or other easily replaceable components, and chassis shielding.

A production defect might require that the manufacturer be able to locate the purchasers of the products. To examine this possibility, the following questions were asked:

What were the current production and distribution projections for the various model receivers?

What methods were available to the manufacturer for locating receivers after market distribution, and have these methods been improved?

Had the manufacturer made plans for a modification or correction of currently marketed recivers which might exhibit measurable X-radiation emissions?

The discussion of the educational and servicing aspects of a manufacturer's operation provided an opportunity to identify the extent of instruction and training given service personnel regarding X-radiation missions. Particularly important in this respect are (1) component replacement, (2) critical adjustments, i.e., operating high voltage, and (3) integrity of added shielding.

SUMMARY OF FACILITY VISITS

Since May 1968, Bureau representatives have visited color TV production facilities of 19 domestic manufacturers and seven related domestic component production facilities (Figure 1) (Appendix 2). A number of observatons from these visits are summarized to give an understanding of the extent of X-radiation measurement programs carried on by the manufacturers.

Production

The production of home color TV receivers reported by companies visited ranged from 100 to 6,000 per day. Production estimates obtained in this manner were substantially the same as the 5.5 to 5.8 million annual estimates quoted in

"Television Digest with Consumer Electronics."[7] Visits to the companies indicated that two basic chassis designs of color television receivers have been and are currently in production. One model containes a vacuum high voltage shunt regulator tube in addition to the high voltage rectifier and cathode ray tube. The other model is designed to operate without the shunt regulator tube. A third design, which substitutes a solid state device for the high voltage rectifier tube, is still considered experimental in the large screen models, but may soon be in extensive production.

Imports

Eight of the companies visited import small screen black and white and/or color television receivers, or picture tubes. One domestic company manufactures large screen receivers for domestic sale under a foreign manufacturer's label. A second company reportedly was considering obtaining foreign designs for production. The manufacturing facilities of foreign manufacturers exporting color TV receivers to the United States were not included in the visit, and therefore, all imported models were not observed. Several imported chassis were observed to have unshielded high voltage components. In addition, domestic manufacturers did not always subject imported models to the same quality control procedures as are used for domestic models. It will be necessary to obtain additional information on imports and to determine X-ray quality control procedures for the imported receivers as well as for domestic home color television receivers.

Quality Control of Receivers

Among companies visited, the percentage of TV receivers on which X-radiation measurements were made for quality control purposes ranged from 1% to approximately 10% of a day's production. X-radiation measurements were in most instances made on receivers selected for other observations or tests as a part of the normal production quality control sample. In no case did a manufacturer report that the X-radiation emission tests were a significant addition to the quality control costs. Seventeen of the companies visited used the Victoreen 440 RF portable ion chamber survey meter for their quality control (quality assurance) measurements with procedures adapted from the Joint Electron Device Engineering Council (JEDEC) publication[8 9] or Underwriters' Laboratories.[10] One company also uses the Public Health Service type X-radiation meter[11] for 100% screening of receivers. Three other companies were considering instruments of the Public Health Service design. In some cases, instrument readings were taken at specified locations on the receiver. In other plants, the instrument was moved slowely over the entire surface of the receiver.

X-radiation quality control measurements were made either during design or after production. Measurements of production models were made after adjustment of high voltage and user controls, as specified for normal operation, at a nominal line voltage, such as 120 VAC. Additional measurements on all six sides of the set with the line voltage elevated to 126, 130 or 132 volts AC were included by the majority of the test programs. In all cases, records of X-radiation measurements were kept. In general, the procedures followed were either established as written company policy or followed those stated to be used by the Underwriters' Laboratories. Levels of X-ray exposure rates at which companies reportedly would take action, varied throughout the industry. However, levels such as 0.1, 0.15, and 0.3mR/hr gross readings as measured by the Victoreen 440RF survey meter, were mentioned. An individual authorized to take action, such as increase production sampling, stopping production, or holding inventory, was identified in the organization of each manufacturer visited. In most cases, however, the individual responsible was not guided by specific written instruction or policy, but could exercise his judgment in determining the required action.

Quality Control of Components

Sixteen of the 19 companies visited have outside sources of supply for high voltage shunt regulator tubes and high voltage rectifier tubes. Three companies

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[7] Television Digest With Consumer Electronics, Vol. 9, No. 2, January 13, 1969, p. 7.

[8] Recommended Practices for Measurement of X-radiation From Display Cathode Ray Tube. JEDEC Electron Tube Council. Publication No. 64, September 1967.

[9] Recommended Practice for Measurement of X-radiation From Receiving Tubes. JEDEC Electron Tube Council. JEDEC Publication No. 67A. June 1968.

[10] Underwriters' Laboratories Proposed X-radiation Test Procedures, June 1968.

[11] Instrument for Measurement of X-ray Emission From Television Sets, Richard K. Stoms and Edward Kuerze. Technical Services Branch, NCRH, TSB Report No. 1, January 1968.

produce their own high voltage shunt regulator and high voltage rectifier tubes. Six of the companies are their own suppliers of cathode ray tubes, atlhough usually not exclusively. Another company obtains cathode ray tubes from a wholly owned subsidiary.

Each of the companies test components such as the shunt regulator and rectifier tubes in some manner, but not necessarily for X-ray production. The JEDEC procedures for these components were reportedly employed by five manufacturers of tubes, and by eight manufacturers of receivers.

Two other manufacturers of cathode ray tubes make X-radiation measurements on their tubes using procedures similar to, but not reported as, JEDEC procedures. Five other receiver manufacturers also make measurements on components for selection purposes, which although not stated as being JEDEC procedures, closely follow them. Records maintained by the companies show unshielded tubes measured in this manner with X-radiation output levels as high as 50 mR/hr.

New versions of high voltage shunt regulator tubes have been designed that incorporate features of lead enriched, heavier glass (as high as 49% lead oxide) and new anode and cathode designs within the tube to reduce transmitted X-radiation. Test data of component manufacturers have indicated that the X-radiation emission levels for new tubes have been drastically reduced by the thicker glass containing approximately 49% lead. High voltage rectifier tubes have been similarly improved, but not as predictably, by improved assembly procedures and by using thicker, lead enriched glass envelopes.

Two manufacturers of high voltage shunt regulator and rectifier tubes are developing production line testing machines which use Public Health Service developed circuitry with Geiger-Mueller tubes. This equipment is expected to measure and record X-rays from tubes while still in production at a rate approaching 750 per hour.

Daily lot tests and continuous samples of tubes are taken for X-radiation measurements from production at tube manufacturing plants. Measurements on the shunt regulator tube reportedly were generally made at 27.5 kV and 0.6 mA DC at 4.75 inches from the glass bulbs. A rejection level of 0.5 mR/hr on the full face of the 440 RF for the newer shunt regulator tubes was used by one manufacturer. The rejection level for the older versions of the shunt regulator tube was 10 mR/hr. The high voltage rectifiers were generally tested cold, with inverse voltage at maximum rating and reportedly were rejected at the 0.5 to 0.75 mR/hr level by one manufacturer. The component manufacturers reportedly have not established uniform criteria for rejection levels of the high voltage shunt regulator or rectifier tubes.

Within the last two years, the glass manufacturing companies have formulated new glasses to replace the funnel glass, tube face panels, and safety panels used during the earlier designs and production of cathode ray picture tubes. The cathode ray tube manufacturers have incorporated the newer glasses as they have become available, but are limited in their choices by their assembly machines and the glass tints available. The new glasses for the face panels contain about twice as much barium as the older glass. The companies also are testing higher barium content glass (22% BaO) face panels. An improved funnel glass also is being tested by the companies. Tube face safety panels may be laminated with an additional layer of glass; principally for anti-glare and to obtain correct light transmission characteristics, as well as for improved safety from implosion. It was reported that a recently introduced safety panel and resin assembly was withdrawn from production after problems developed with unfavorable glass yields.

It was observed that the cathode ray tube manufacturers consider the following minimum steps necessary in the design of tubes and control of X-radiation emissions:

Control of Product.—Make X-ray exposure rate measurements on new tube designs or modifications, including any new composition of glass, any new vendor's product, or changes in vendor's specifications, and routine sampling of the regular product.

Control of Glass Composition.—Consult with vendor on proposed funnel and panel glass changes and review information supplied by the vendor on the linear X-radiation absorption coefficients of the glass.

Engineering Specifications.—The cathode ray tube manufacturer has control of the bulb thickness specification. Deviations from specified bulb thickness by a glass manufacturer can cause the cathode ray tube manufacturer to reject the bulbs.

X-radiation from picture tubes was measured in accordance with JEDEC 64[8] using the Riverdale Precision TV–150 ion chamber and the 440 RF survey meter. Test procedures in the industry recently have been inter-compared by "round-robin" measurements of the minimum thickness picture tube.

At one cathode ray tube production facility X-radiation measurements were made on 19", 22", and 25" at 90° from cathode ray tubes at 27.5 kV and 0.75 uA, the recommended maximum ratings. A 15" tube of slightly thinner glass, was tested at 22.5 kV, 0175 uA, also the recommended maximum rating. In addition to these tests, most of the cathode ray tube plants also tested to a factory specification of 35 kV and 300 uA (100 uA/gun) for 19", 21", 22", and 25" tubes, and 27.5 kV and 300 uA for the smaller tubes.

It was stated by cathode ray tube companies that X-ray emission characteristics of their products are available upon request but that the information is not furnished routinely to customers.

Design Engineering

Design improvements of television receivers in many developmental stages were observed. These features include voltage control circuits, solid state rectifiers, and large size cathode ray tubes that are capable of operating at lower voltages. Other items under investigation are new designs of shunt regulator and rectifier tubes intended to reduce X-radiation emissions. In addition, improved chassis designs incorporating improved component shielding and features to prevent the adjustment of operating high voltage by unauthorized individuals were reported.

Labels

Some type of warning label pertaining to possible X-radiation emission from the high voltage assembly and the cathode ray tube is displayed by the majority of the companies. The statement on the high voltage usually took the form of: "For proper operation, high voltage should be adjusted to rated voltage for receivers, no higher. Voltage higher than this limit may cause receiver damage or produce X-radiation hazard."

A second label calling attention to the possible hazard from shock and X-radiation if the high voltage enclosure cover was not kept closed during the receiver operation and servicing, was used by most manufacturers. The warning labels on the picture tube usually suggested the wearing of safety goggles to prevent possible injury from glass in case of tube breakage, and an X-ray warning for servicemen that shielding of the cathode ray tube may be necessary to protect against prolonged exposure to X-rays at close range.

Generally such labels were not placed on the outside of the receiver where they would be visible to the purchaser. Some receiver manuals, however, do contain statements to the effect that precautions have been taken for adequate X-radiation protection, and advise that under proper use the set is safe. Some labels request the customer, if service is required, to contact a serviceman qualified by the company to check or repair the receiver.

In-Plant Radiation Safety

Thirteen of the manufacturers reported making in-plant surveys designed to measure X-radiation from possible sources such as test stands where high voltage tubes are activated. The surveys by ten companies include measurements made by film badges placed in engineering, production, and quality control areas. These companies reported film badge measurements have provided negligible readings. Two companies have, therefore, discontinued making film badge measurements. As part of the history of each employee, it seemed advantageous for the company to maintain a record of each employees exposure to ionizing radiation. Film badge readings would serve as a part of that record. In addition, a question on previous radiation history was asked during pre-employment physical examinations by a few companies.

Service Organizations

The degree of organization and corporate control of color television receivers repair and servicing varied widely throughout the industry. About one-fourth of the manufacturers have no organized service program. The remaining companies to a varying degree maintain service organizations, in some cases nationwide, including authorized service, franchised dealers, company controlled or owned service companies, qualified service centers, and authorized retail store service representatives. All manufacturers provide service manuals either through their

service organizations or for sale to servicemen. The service programs include training of servicemen, issuance of schematic drawings and other descriptive literature, and preparation and routine distribution of service bulletins and notes. Eighteen out of 19 of the manufacturers visited furnished servicemen literature, including some reference or advice on X-ray control. In most instances, this emphasized the need for proper high voltage adjustment for the receivers, preserving the integrity of shielding, and observing warnings regarding X-radiation. One possible deficiency in the servicing of color TV receivers is the accurate adjustment of the high voltage. Manufacturers could not assure that, either through training or by supply of equipment, that the high voltage measuring probes, if used, were properly calibrated.

Location of Products

Estimates of the percentage of receivers that could be located by warranty cards ranged from 30% to 99% for manufacturers that had a warranty card system. It was not possible to obtain an estimate from five manufacturers. The company which could locate approximately 99% of its original purchasers, but not transferees, was a kit company which either mailed the kits directly to customers, or retailed them from 14 stores. The warranties vary in type and duration, with the longer warranty, especially for cathode ray tubes, probably bringing the larger percentage return of cards. One of the largest manufacturers of TV receivers did not use warranty cards. The specific sales could be traced with some difficulty to dealers who then would be asked to locate receivers by general date code and chassis type.

OBSERVATIONS

Each of the companies visited had exhibited an awareness of the conditions that cause X-radiation emissions. Therefore, it is of interest to list some of the more important observations of the Bureau teams regarding industry programs for the control of X-radiation emissions from color TV receivers:

(1) The quality control techniques used did not seem to provide complete assurance that color television receivers being placed on the market were not exceeding the NCRP recommendation of 0.5 mR/hr in one hour on 10 cm^2 measured at 5 cm from any surface of the receiver. It was especially true when these procedures depended primarily on the use of the Victoreen 440 RF ion chamber survey meter, because of the limits on survey response time of the instrument and the possibility of missing small beams of X-radiation.

(2) It could be postulated that the companies which depend on added shielding to control X-radiation emissions could have a serious problem if designs were changed so that the shielding was inadvertantly removed from the X-ray generating tubes.

(3) Only one company had actually designed a shielding material for the anticipated X-ray exposure rate of the component which required shielding. Two other companies had designed a shielded socket for high voltage rectifier tubes. In a number of instances, the high voltage assembly was capable of emitting X-rays through perforations in the shield.

(4) The companies had limited control over the quality of the X-ray emitting components purchased from other manufacturers. The larger companies were beginning to exert some influence in this area through component testing programs and the X-ray emission specifications they are able to advertise for their components as a result of tests.

(5) It was observed that approximately 10 to 24 months were required to effectuate a production change in a receiver model. Rapid changes in external shielding were possible, but changes in tube types and circuitry required long periods of testing, including company acceptability tests, before they were put into effect.

(6) The ability of the manufacturer to conduct a program of modification in the field depended on the type of servicing and distribution system that he utilized. Most companies could locate approximately 60% of their receivers. However, the normal location capability ranged from 30% to 80%. A manufacturer of color TV assembly kits estimated it could locate approximately 99% of its receivers based on the return of warranty cards.

(7) The companies had not developed a reliable device to prevent adjustment of the high voltage to unusually high values. One receiver design had a diode voltage "hold-down" circuit which caused the picture to shrink, become unstable, and the high voltage to go down, if the shunt regulator tube failed. A number

of manufacturers had limited access to the high voltage adjustment by placing a riveted shield over it or by removing the control.

(8) Components could be sold without manufacturer identification, even by EIA codes. Tubes might be custom labelled. Some were labelled, "Replace only with a genuine _____ tube." Obviously the user was not made aware of the need to replace the tube with one of low X-ray emission equivalent because the named supplier was free to change his source of components without having the label reflect the true manufacturer.

(9) High voltage on a number of receiver models can exceed 30 kV with the picture remaining viewable for indefinite periods. Values of excessive high voltage could result from high line voltage, improper service adjustments, failure of the shunt regulator tube and associated circuitry, or a combination of causes. In some receivers, excessive X-ray emission is prevented in the current production because chassis or component are shielded in sheet metal. At normal high voltage, excessive X-ray exposure rates might or might not be measured, depending on the quality of the tubes selected for high voltage rectifiers and shunt regulators and completeness of the shielding.

(10) No manufacturer revealed definite plans to utilize operating voltages higher than the currently specified voltages in new designs, but most reserved the right to exercise this option if research projects improved performance or reduced costs. An industry conversion to higher operating voltages, i.e., above 30 kV, will require a thorough review of existing X-radiation control programs and the existing industry standards for X-radiation emissions.

(11) Because X-radiation measurements were performed at nominal line voltage (120 VAC) some manufacturers did not know what X-radiation characteristics of their receivers would be under less favorable operating conditions. Tests performed by the manufacturers in the presence of Public Health Service personnel on some receivers at line voltages of 130 VAC (in some cases with the shunt regulator tube disabled) generally resulted in emission levels above 0.5 mR/hr at the face of the picture tube.

(12) Advice on proper high voltage setting in service manuals and warning labels pertaining to possible X-radiation emission from the high voltage assembly and the cathode ray tube give some assurance that field servicemen are aware of precautions to take regarding X-radiation emission.

(13) In a number of instances, it was not possible to determine, even after some discussion, whether or not a written policy had been issued to the manufacturer's key personnel stating the criteria to which receivers were to be designed, and from which quality control tests could be developed pertaining to X-ray control. Many manufacturers apparently permitted the quality control staff to develop their own action criteria, independently of the designers.

(14) In general, production companies placed reliance on parts suppliers and on available radiation data for selection of components. A few companies had made some measurements on rectifier and shunt regulator components for X-radiation emissions. However, they principally selected components by engineering specifications. Generally, the testing of components for X-ray control was performed by the component manufacturers, if domestically manufactured components were used. A number of receiver manufacturers were beginning to exert their influence by performing quality control measurements on a number of components and by trying to obtain the best available components from an X-radiation standpoint.

(15) The companies, with the exception of the original shunt regulator tube modification program, have not developed programs to determine the status of receivers in the field or to correct those receivers that could be known X-radiation emitters. Even though new high voltage tube components and shielding have been developed, manufacturers are not incorporating them into receivers now in production or recommending their installation in receivers in the field. Delays may be attributed to (1) inadequate inventory of new components, (2) economic considerations due to large inventories of old materials and components, (3) requirements of engineering acceptability, (4) cost of production line changes, (5) lack of advertised specifications, (6) limited availability, (7) increased cost, and (8) lack of incentive to change. Therefore, sets will continue to be produced indefinitely according to the traditional program of production line X-radiation quality control. This will add to the number of receivers already in the field with the potential for excessive X-ray emissions.

(16) Visits to manufacturers have resulted in some additional points which should be considered more fully in future visits or inquiries, e.g., visits should

be scheduled to the manufacturers who produce only components and who were not visited in conjunction with visits to receiver manufacturers. An effort should be made to obtain detailed information from foreign manufacturers of color TV receivers or components in view of the popularity of imported receivers and high voltage parts.

(17) About one-fourth of the manufacturers were aware of State regulations concerning radiation from television receivers. The other manufacturers assumed, they said, that, if they complied with Underwriters' Laboratories requirements, they would automatically comply with the State requirements.

(18) No company reported to us that there were justifiable complaints from their purchasers although they had numerous inquiries, nor that any type of retrofit appeared necessary, with the exception of advice to servicemen about high voltage adjustment, shielding placement, and perhaps return of early shunt regulator tubes.

(19) Inquiries of manufacturers concerning in-plant surveys should be considered in more detail in any future visit. Of the ten companies using film badges for surveys, no company reported finding significant X-ray exposure to plant personnel during design, production, or test procedures.

SUMMARY COMMENTS

Visits to the production facilities of 19 domestic manufacturers of color television receivers indicate the industry has taken a number of steps to control X-radiation emissions. There are idenifiable and correctable deficiencies in the X-radiation emission control programs of the industry. Records of X-ray emission tests by the manufacturer at the factory indicate that receivers are being produced meeting the X-ray exposure control requirements established by the individual manufacturer. Additional evaluation and testing will be necessary before the purchaser of a color television receiver can be certain that there is no X-radiation exposure risk from the receiver under any condition of operation and service. It is recommended that efforts to achieve radiation-free consumer products be continued by both the television receiver industry and responsible government agencies.

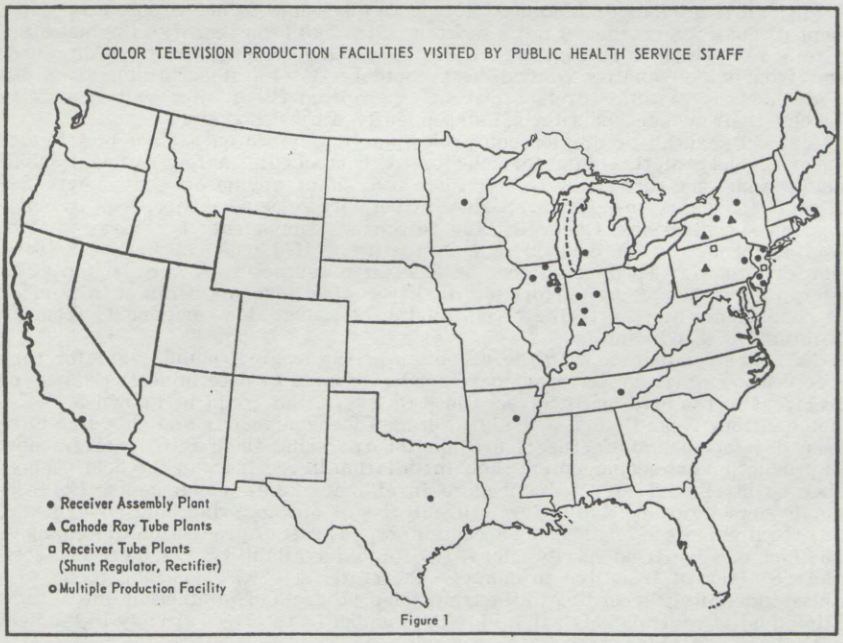


Figure 1

Appendix I

OUTLINE OF PROCEDURE FOR VISITS TO PLANTS

The following outline may be used by the Public Health Service representative to guide his discussions in meeting with the manufacturer, to take notes during the discussion, and to write the report of the visit:

I. Preparation for Discussion and Visit:
- A. Company notification
  - Send letter outlining procedures and guidelines for visits.
  - (Review files for previous correspondence.)
- B. Review results from Washington, D.C. TV survey.
- C. Review available technical information on sets manufactured by the company and on the components used in their fabrication.
- D. Review previous reports on visits.

II. Conduct of Visit:
- A. Organization and administration
  1. Determine individuals in the company who are responsible for the various activities of interest.
     Example: Quality control and engineering
  2. Determine locations of final production plants and quality control facilities.
  3. Procurement procedures:
     (*a*) Determine sources of components.
     (*b*) Determine location of plants which supply components.
  4. Determine distribution system for final product.
- B. Program Survey Data Review:
  1. Review Washington, D.C. TV survey data with the manufacturer.
  2. Determine whether the models showing radiation are still in production and obtain an estimate of the number of models on the current market.
  3. Determine the company's current research activities in identifying sources of X-radiation in television receivers. Note the type of studies, i.e., radiographic film, spectral analysis, etc.
- C. Review of Quality Control Program:
  1. Determine where the facilities are located and what equipment is used for the program.
  2. Determine what features are included in the program for protection of plant personnel.
  3. Determine what facility or technique is used for calibration of radiation measuring equipment.
  4. Specific features of quality control program:
     (*a*) Determine the number of sets tested per number of receivers produced.
     (*b*) Determine the procedures of measurements.
     (*c*) Obtain production estimates (if possible).
  5. Determine whether quality control records are kept and obtain a copy of the record forms. Determine the procedure for keeping the quality control records.
- D. Review of Component Testing Program:
  1. Determine where the facilities are located and what equipment is used for testing components.
  2. Determine the criteria used for acceptance of components.
  3. Obtain component testing results and a copy of the testing procedure protocol.
  4. Determine whether the company has a contract for independent audits of the quality control and component testing programs. If X-radiation measurements have been made by contract, obtain an identification of the contractor(s).
- E. Engineering:
  1. Identify the design features used to reduce X-radiation in new models.
  2. Determine what modifications can be made to receivers currently on the market to reduce possible X-radiation emissions.

3. Determine the design features being incorporated or developed to reduce or prevent radiation emissions. Such features include high voltage hold down systems, inherent shielding components, shielding of components, shielding by the chassis and the use of solid state circuitry as replacement of high voltage tubes.
4. Determine the ratio of shunt regulated and non-shunt regulated receivers currently in production.

F. Servicing Information:
1. Determine the company's organizational set-up for providing servicing of their sets.
2. Determine the nature and scope of the company's training program for servicemen.
3. Obtain copies of educational materials and bulletins used to inform servicemen of radiation hazards and safety precautions.
4. Determine whether labels or warnings are placed on the receiver regarding X-radiation emissions. Obtain samples of each type of label or warning device being used.

III. Summation with Management:
A. Obtain estimates for production and distribution of receivers
B. Obtain information on the methods available to the manufacturer for locating receivers after market distribution.
C. Determine what in-plant safety program pertaining to X-radiation from TV receivers are conducted by the company and whether each employee's radiation exposure history is obtained and maintained.
D. Determine whether the manufacturer has developed plans for correction programs, should the need arise.
E. Review the visit findings with the manufacturer prior to completion of the visit.
F. Inform the manufacturer of the findings and recommendations by letter within a reasonable time period after completion of the visit.

Appendix II

VISITS TO MANUFACTURERS OF TELEVISION RECEIVERS

Manufacturer and location	Date of visit	Type of plant
Zenith Corp., Chicago, Ill	May 24	Research, engineering, and production (quality control).
Dumont Emerson, Jersey City, N.J	July 18	Do.
Setche'l-Carlson, St. Paul, Minn	Aug. 7–8	Do.
Philco-Ford, Philadelphia, Pa	Aug. 19	Do.
Magnavox, Fort Wayne, Ind	Aug. 21	Do.
Magnavox, Greenville, Tenn	Aug. 22	Production facility (quality control).
Warwick, Forrest City, Ark	Sept. 12	Engineering and production (quality control).
Warwick, Chicago, Ill	Sept. 13	Do.
Wells-Gardner, Chicago, Ill	do	Do.
Hoffman, Orleans, Ind	Sept. 19	Production (quality control).
Admiral, Chicago, Ill., Harvard, Ill	Sept. 20	Engineering, production, and cathode ray tube (quality control).
Packard Bell, Los Angeles, Calif	Sept. 26–27	Engineering and production (quality control).
Curtis Mathes, Athens, Tex	Oct. 15	Engineering and production.
Philco-Ford, Lansdale, Pa	Oct. 17	Component and cathode ray tube plant.
RCA, Harrison, Woodbridge, Somerville, N.J	Oct. 18	Component plants.
General Electric, Syracuse, N.Y.; Owensboro, Ky	Oct. 21–24	Production, engineering and components (cathode ray tube and receiver tubes).
Westinghouse, Edison, N.J.; Elmira, N.Y	Oct. 28–29	Do.
Sylvania, Batavia, N.Y.; Senaca, N.Y	Nov. 6–8	Production, engineering and components.
Motorola	Nov. 18–20	Engineering, production and component (cathode ray tube).
TMA (Muntz)	Nov. 20	Production and engineering.
Olympic	Dec. 5	Do.
Heath Co., Benton Harbor, Mich	Dec. 9–11	Engineering and assembly.

Mr. HANSEN. Our efforts relative to television receivers have been guided by an Ad Hoc Committee on Color Television. A copy of their recommendations are available for the record.

(The recommendations referred to follow:)

AUGUST 6, 1968.

Mr. JAMES G. TERRELL, Jr.,
Director, National Center for Radiological Health, Public Health Service, Department of Health, Education, and Welfare, Rockville, Md.

DEAR MR. TERRILL: This letter is the final report of the Ad Hoc Advisory Committee on X-Radiation from Color Television Receivers. It incorporates interpretation of data obtained from the Survey of X-Radiation from Color Television Sets in the Washington, D.C. Metropolitan Area recently performed by the staff of the National Center for Radiological Health (NCRH). An interim report was submitted on February 7, 1968.

After its organization early in December 1967, the Ad Hoc Advisory Committee on X-Radiation from Color Television Receivers met in Rockville, Maryland, on December 19, 1967, and January 15, 1968. At the request of the Secretary, DHEW, and the Surgeon General, PHS, the Committee addressed itself to the following questions:

1. Is the method utilized by the National Center for Radiological Health in the measurement of the x-rays emitted by color television receivers a reasonable system relative to the recommendations of the National Council on Radiation Protection and Measurements (NCRP) and the current state of the measurement art?

2. What can be recommended for individual manufacturer action with respect to varying radiation exposure levels relative to: number of sets resources of manufacturer, intensity of emissions, and identification of the cause of the emissions (excessive voltages, defective tubes and shielding)?

In regard to these questions, the Committee wishes to make the following comments:

1. METHOD OF MEASUREMENT

The Committee has received the operating characteristics of the instrument used by the NCRH to estimate radiation exposure levels in the vicinity of color television receivers and believes it to be sufficiently accurate for survey purposes when appropriate correction factors are applied for radiaton quality and for conditions where non-uniformity of the radiation field prevails.

If further development of x-ray instrumentation in this field seems necessary, it is recommended that the NCRH utilize the resources of the National Bureau of Standards as fully as possible. Technical assistance regarding the correction factors to be applied in present instrumentation for radiation quality and non-uniformity of the radiation field should continue to be sought from the NBS.

2. ANALYSIS OF THE NCRH WASHINGTON, D.C., SURVEY OF X-RADIATION FROM COLOR TELEVISION SETS

The National Center for Radiological Health sent a questionnaire to employees of the Public Health Service in the Washington, D.C., area requesting owners of color television sets to provide the Center information on the manufacturer and picture tube size of their sets and to volunteer their sets for radiation measurement. The request led to the availability of 1,124 color receivers of a variety of brand names and models from 21 domestic and five foreign manufacturers. All of these sets were monitored 5 cm from the surface on all six sides by NCRH representatives with survey instruments developed by the NCRH and by representatives from the manufacturer. The television sets were monitored under operating conditions considered normal by the owner. Radiographic film techniques were used in selected cases to supplement the instrumental results and to determine the beam size. Viewing habits for each family member were estimated by the owners.

Although the Washington survey examined the radiation levels prevailing about a relatively small number of television sets, the Committee believes that this number is sufficiently large and represents an adequate cross-section of manufacturers to permit the derivation of estimates of the size of the U.S. population viewing sets not in compliance with NCRP recommendations (i.e. the population at risk) and the average annual exposure received by that population.

Population at Risk

To estimate the population at risk the Committee has taken into account the following parameters:

(*a*) Number of viewers of color television receivers.

(*b*) Number of color television sets found to emit radiation at exposure rates in excess of 0.5 mR/h at 5 cm.

(*c*) Direction of the radiation emanating from the television receiver.

(*d*) Age of viewing population.

(*e*) Viewing habits of each age group.

Number of Viewers

The Electronic Industries Association has estimated that there were 15 million color TV sets in the United States at the end of 1967. Based on the Washington survey, an average of three persons view each yet. Hence the expected number of viewers of color television receivers in the total population is of the order of 45 million.

Receivers Exceeding NCRP Recommendations

In the NCRH survey conducted in the Washington Metropolitan Area, 6% of the color television sets (66/1124) were found to emit radiation in excess of the current NCRP recommendation of 0.5 mR/h at 5 cm. These levels were measured with the NCRH survey instruments referred to under Methods of Measurement above.

Direction of Radiation

Of the 66 receivers found to emit radiation in excess of NCRP recommendations, 44 emitted radiation from the front, bottom, left or right side, and hence could expose individuals in the vicinity of the receivers. This number represents 3.9% of all sets surveyed. Only 12 of the receivers (1%) emitted radiation 5 cm from the front greater than the 0.5 mR/h level.

Age of Viewing Population

The Washington survey divided the viewing population into three age groups: 0–14 years, 15–44 years and 45 years old and over. From the United States Census of Population (1960) these age groups represent 31.2%, 39.8% and 29.0%, respectively, of the total population in the United States. For each of the three age groups the population at risk can be determined by multiplying the number of viewers by the fraction of sets emitting radiation in excess of NCRP recommendations by the fraction of population in the age group.

The population at risk (P) from watching color TV in the United States for the several groups follows:

0–14 Years

$P=45{,}000{,}000\times0.01\times0.312=140{,}000$

15–44 Years

$P=45{,}000{,}000\times0.01\times0.398=180{,}000$

45 Years and Older

$P=45{,}000{,}000\times0.01\times0.290=130{,}000$

These populations are subjected to a range of exposure levels depending on the color television sets viewed.

TABLE I.—*Distribution of measured exposure rates for color TV sets emitting X-radiation greater than 0.5 mR/h at 5 cm from the front face*

Measured exposure rates (mR/h) 5 cm from receiver surface:	*Number of sets measured*
0.75	3
1.5	5
2.9	1
5.6	2
10.0	1
Total	12

Exposure Estimates to Population at Risk

The following estimates of exposure have been derived only for persons exposed by radiation emitted from the front surface of their television receivers. It has not been possible to estimate exposures received from other surfaces by persons not

watching television because data on their occupancy patterns were not obtained in the Washington survey. Nevertheless, in the judgment of the Committee, the availability of such information would not have materially altered the recommendations made by the Committee later in this report.

The estimated annual exposure, not including backscatter, received at the skin surface by each of the age groups may be calculated from the expression,

$$E = \Sigma E_o Q L$$

where

E=Average annual estimated exposure (mR/y)
E_o=Average Exposure rate of 12 measured sets exceeding 0.5 mR/h at 5 cm from front surface (mR/h)
Q=Factor adjusting values of E_o for distance at which viewers are seated
L=Length of exposure (hours per year watching TV)

The average exposure rate (E_o) for the 12 sets described in Table I which had x-radiation emissions from the front face exceeding 0.5 mR/h is 2.8 mR/h. From the NCRH Washington survey, it appears that the average viewing distances and the number of hours viewed per year are as follows: For the 0–14 age group, the average viewing distance is 165 cm and the average viewing time is 1300 hours/y; for each of the two older groups, the viewing distance is 285 cm and the viewing time 800 hours/y. Experimental data published by Braestrup[1] indicate that values of Q for these viewing distances, when the source of the radiation is the picture tube are of the order of 0.030 in the case of the 0–14 year olds and 0.011 in the case of the two older groups. Table II lists average annual exposure estimates calculated on the basis of the values given above.

TABLE II.—*Estimated average annual exposure*[1] *received by the skin of the population at risk*

Age group (years) :	*Estimated annual exposure (mR)*
0 to 14	110
15 and older	25

[1] Excluding backscatter.

It was pointed out in section I of this report that measurements made with the radiation instruments used in the NCRH Washington survey require correction for narrow beam conditions. This is due to the fact that these instruments have a minimum sensitive area of approximately 13 cm^2 and hence any radiation beams smaller in cross-sectional area than this will yield measured exposure values less than actual values in proportion to the ratio of the beam's area to 13. The extent of this problem was evaluated from film taped to the outside of 45 receivers examined in the survey. From these studies it appears that exposure levels may be as much as 5 times higher than measured values under some circumstances. It is noteworthy, however, that since this radiation is small in cross-section, it is quite unlikely that any one part of an exposed individual will be subjected to these levels for a protracted period of time (see National Committee on Radiation Protection and Measurements (NCRP) "X-Ray Protection Standards for Home Television Receivers", February 23, 1968).

3. RECOMMENDATION FOR CONTROL

Based on the anlysis of the NCRH survey results as described above, the following recommendations are made by the Committee:

(*a*) With respect to color television receivers manufactured in the future, all components should be virtually free of external radiation and in no instance should they emit more than the NCRP recommended level, presently 0.5 mR/h of x-radiation at a distance of 5 cm from any surface under any expected conditions of operation.

(*b*) With respect to color television receivers currently in distribution channels, all components not meeting recommendation (a) should be replaced or corrected as soon as practicable.

(*c*) With respect to color television replacement components currently in distribution channels, all components not meeting recommendation (a) should be removed from distribution as soon as practicable.

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[1] X-ray Emission From Television Sets. Carl B. Braestrup and Richard T. Mooney, Science, Vol. 130 (October 1959).

(*d*) With respect to color television reeceivers now in use by consumers, all components not meeting recommendation (a) should be replaced or corrected at the earliest time a receiver requires servicing.

The foregoing recommendations have been made with the understanding that compliance may be achieved by the industry either by the inherent design of a components or by the addition of suitable shielding material around it. It is noteworthy that under conditions, service repairmen may not be expected to receive radiation exposures in excess of the maximum permissible limits applicable to persons occupationally exposed.

The Committee also wishes to call attention to the fact that the Washington survey suggests that there are a small number of color TV sets in the United States that emit substantially higher levels of x-radiation than the average exposures given in Table II. To locate these receivers will require an enormous amount of effort. The Committee believes this effort would be better expended on a program to insure that all receivers in the future comply with NCRP recommendations.

Finally, because the population at risk currently is relatively small, no additional surveys of color televisions are thought to be necessary. Again, it is thought desirable that more effort should be directed toward the prevention of components and receivers not in compliance with NCRP recommendations from reaching the public. The NCRH should work with industry, State health departments, the Underwriters' Laboratories, the United States of America Standards Institute and other suitable organizations to achieve this goal.

Sincerely yours,

RUSSELL H. MORGAN, M.D.
Chairman, Ad Hoc Advisory Committee on X-Radiation from Color Television Receivers.

(Committee members: LeConte Cathey, Merril Eisenbud, Karl Z. Morgan, Arthur F. Naylor, Harold O. Wyckoff, and Russell H. Morgan, Chairman. Executive Secretary, Robert H. Neill.)

Mr. HANSEN. (C) Liaison activities: We have consulted and maintained liaison with a number of Federal and State agencies, as well as with private organizations with an interest in a radiation control program. These include Federal agencies such as the Department of Defense; Department of Commerce (including the National Bureau of Standards); Department of Labor; Atomic Energy Commission; the Office of Telecommunications Management; numerous State radiological health agencies—to whom reference will be made later; private organizations such as Electronic Industries Association; the Association of Home Appliance Manufacturers; the National Electrical Manufacturers Association; and the National Council on Radiation Protection and Measurement.

The Bureau of Radiological Health has provided technical support and guidance, as well as the loan of radiation detecting instruments to a number of State and local radiological health units for surveys of color television receivers and microwave ovens. The survey data collected by the States and local agencies has been reviewed by the Bureau of Radiological Health and will be helpful in establishing performance standards for both products.

SECTION 357. SPECIAL STUDIES

Currently 28 people are detailed to the following nine specific studies:

A. Individual State survey of State radiological health programs was started by the BRH regional representatives on May 1, 1969. This study and analysis interprets the individual State capabilities and needs prior to their acceptance of a role in any cooperative effort under Public Law 90–602.

B. Radiological Health State Program Directors' meeting: A meeting was held in Montgomery, Ala., March 23–28, 1969, to discuss the State's role in the cooperative implementation of Public Law 90–602. A summary of the overall recommendations will be forwarded to the individual State health officers for their review and opinions in accordance with the requirement established under Public Law 90–602.

C. Sales, distribution, and uses of radium and accelerator produced isotopes in the United States: This study will clarify the dimension of the problems represented by health hazards from these radioisotopes which are not controlled under the Atomic Energy Act of 1954.

D. Analysis of X-ray survey data: This study is an in-depth analysis of the X-ray equipment being used in medical arts in 30 States. The data will indicate the types of equipment, user, workload, and other significant operating criteria on 36,000 separate installations.

E. Used X-ray equipment: Kentucky, Illinois, North Carolina, California, and New Jersey have agreed to cooperate in a survey to determine the extent that X-ray equipment is purchased as used equipment.

F. Compatibility and uniformity of State regulations: This study is an in-depth comparison of existing State laws and codes in radiological health as compared to the model code recommendations by the Council of State Governments.

G. High school electronic product survey: Two hundred schools in nine States are being visited by teams made up of State personnel and Federal representatives to review with the science teachers the types of electronic products being used.

H. Standards for nonmedical electronic products: A study of the location, number, and use of certain specific high voltage electronic products such as accelerators is being prepared. The report will review pending performance standard criteria.

I. Electronic products inventory study: This study is the start of a continual inventory of electronic products in use and will include an estimate of future sales. Future reports will indicate relative public health significance and priorities for the establishment of needed performance standards.

SECTION 358. PERFORMANCE STANDARDS FOR ELECTRONIC PRODUCTS

A. Standards development: The first standard will be promulgated prior to January 1, 1970. We are preparing performance standards for television receivers, microwave ovens, and X-ray diffraction equipment. Due to the time required to establish standardized measurement techniques, laboratory product testing criteria and recordkeeping protocols, it is most probable that only the television standard will be established prior to January 1, 1970. Technically, it will be possible to prepare a series of needed standards in subsequent years. We hope to be able to publish these standards at an increased rate.

B. Technical Electronic Product Radiation Safety Standards Committee: The Environmental Control Administration contacted various industry, State and Federal organizations to obtain their recommendations for membership on this committee. Letters of invitation have been sent to prospective members and the Department is awaiting their replies. Some replies are already in.

SECTION 359. NOTIFICATION OF DEFECTS IN, AND REPAIR OR REPLACEMENT OF, ELECTRONIC PRODUCTS

As noted under section 356, we are currently evaluating several types of electronic products for possible defects. The implementing regulations, as well as the recordkeeping regulations, further amplify the law by indicating by manufacturer's responsibility under this section. There have been no notifications by manufacturers to the Secretary of HEW, on an existing defect on a product after the enactment date of the law.

SECTION 360. IMPORTS

Steps are underway for informing foreign manufacturers of electronic products exported to the United States, of all regulations and standards, as well as their particular responsibilities under Public Law 90–602.

SECTION 360E. FEDERAL-STATE COOPERATION

Under section 357, of this review it was noted that several special studies have been initiated to define the relationship between the Federal and State agencies. These studies essentially will review the State's interest, recommendations, resources, and authority to cooperate in the implementation of the law. We believe that this authority will be most useful in the implementation of the act.

This concludes my summarization of activities that have been carried out in implementing Public Law 90–602, Radiation Control for Health and Safety Act of 1968. I will be pleased to endeavor to answer any questions which the committee may have with respect to implementation of the act.

Mr. ROGERS. Thank you very much, Mr. Hansen.

I wonder if Dr. Elder has any comments at this time.

Mr. ELDER. No, sir, not at this time. Thank you.

Mr. ROGERS. Mr. Kyros, any questions.

Mr. KYROS. Yes, I have some questions, Mr. Chairman.

Mr. Hansen, I recall last year when we were working on Radiation Control for the Health and Safety Act that one of the things that seemed urgent was the development of performance standards for TV sets, among other things—I think that TV sets was the item that was the more important. As I understand it from your testimony, as yet you haven't formulated specific performance standards as to what you want for television receivers, is that right?

Mr. HANSEN. We do not have all the details in, that is correct.

Mr. KYROS. What about that 0.5 milliroentgens at the distance of two——

Mr. HANSEN. Two inches, I believe.

Mr. KYROS. Does the same standard still apply that you are using?

Mr. HANSEN. Of course, it was an interim standard that was recommended by our ad hoc committee, and we feel we are still in need of additional information before making specific recommendations on the standard.

Mr. KYROS. Before you set standards you were going to set up a technical electronic product radiation safety standards committee, is that right?

Mr. HANSEN. Yes.

Mr. KYROS. Have you set up that committee yet?

Mr. HANSEN. This is the committee I referred to earlier. The Secretary has issued invitations, and we hope it will be set up in the near future.

Mr. KYROS. But we passed this bill in October of last year, and I understood there was considerable urgency, or so we were told anyway, by the then administration. And now it is May and you still haven't got a committee together over the standards.

Mr. HANSEN. As indicated in the testimony, we have solicited recommendations, and have made the recommendations to the Department for the Secretary to make the selections.

Mr. KYROS. Who have you asked for as the five members from governmental agencies?

Mr. HANSEN. We, of course, are not selecting the committee. It is up to the Secretary. We submitted to the Secretary a list of names for his selection.

Mr. KYROS. Has the Secretary actually named or asked for five people from the governmental agencies?

Mr. HANSEN. We understand that invitations have been issued, but all the acceptances have not yet been received.

Mr. KYROS. How about the five members from affected industries?

Mr. HANSEN. These also, we understand, have been requested.

Mr. KYROS. How about the five members from the general public?

Mr. HANSEN. They also.

Mr. KYROS. As I understand it, then, you can't set the standards until you have the committee set up?

Mr. HANSEN. That is correct.

Mr. KYROS. I think you have taken a long time, because if I understood the testimony that came out on the standards for the TV sets, we ourselves—that is, you, as Government officials—weren't even certain that those were the standards that should apply?

Mr. HANSEN. That is correct.

Mr. KYROS. But you don't know why it has taken so long, that is, several months to get a committee?

Mr. HANSEN. The recommendations were submitted. And, of course, apparently it takes some time to review the list. And I presume that the process of selection is one that requires a good bit of research, and I presume that that is the primary cause.

(The following letter and attachment were received by the committee:)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
PUBLIC HEALTH SERVICE,
Washington, D.C., June 4, 1969.

Hon. JOHN JARMAN,
Chairman, Subcommittee on Public Health and Welfare, Committee on Interstate and Foreign Commerce, House of Representatives, Washington, D.C.

DEAR MR. JARMAN: During the hearing before the Public Health and Welfare Subcommittee of the House Committee on Interstate and Foreign Commerce on May 23, 1969, a representative of the Department of Health, Education, and Welfare testified that we would provide a list of committee members of the Technical Electronic Product Radiation Safety Standards Committee required under the Radiation Control for Health and Safety Act of 1968, as soon as such committee was appointed and the members accepted.

We have completed the administrative actions on appointment of the committee. A public announcement of the establishment of the committee is being made.

Enclosed is a list of the names of committee members. As you know, the committee will advise the Secretary on the performance standards to be established under the Radiation Control for Health and Safety Act of 1968 for products that may expose consumers to radiation hazards.

We assure you that the electronic products radiation control program is going to receive major emphasis and we will keep you informed of its progress. We appreciate your continuing interest in this program and the other health programs of this Department.

Sincerely yours,

WILLIAM H. STEWART, M.D.,
Surgeon General.

MEMBERS OF THE TECHNICAL ELECTRONIC PRODUCT RADIATION SAFETY STANDARDS COMMITTEE

Public members: Dr. Russell H. Morgan, Baltimore, Md.; Edward J. Legan, Washington, D.C.; Dr. Edward B. Lewis, Pasadena, Calif.; Herbert M. Parker, Richland, Wash.; Dr. Robert D. Moreton, Houston, Tex.

Government members: Comdr. Charles F. Tedford, Washington, D.C.; Dr. John M. Heslep, Berkeley, Calif.; Lester R. Rogers, Washington, D.C.; Dr. Roy A. Parker, Baton Rouge, La.; Myron Domsitz, Washington, D.C.

Industry members: George M. Wilkening, Murray Hill, N.J.; Dr. Walter P. Dyke, McMinnville, Oreg.; Dr. Mason C. Cox, Southbridge, Mass.; Harris O. Wood, Philadelphia, Pa.; Thomas H. Rogers, Stamford, Conn.

Mr. KYROS. When we were reviewing the bill last year one of the questions that came up was whether the electronics industry in the United States would cooperate fully in providing information, data, material, and the possibilities of inspection of site in their plants, in keeping with the bill that we passed. Are you satisfied that as of today they have cooperated?

Mr. HANSEN. We have no basis of complaint at this time. Of course, we are not very far into implementing the law, as I have indicated, but up to this point the manufacturers have certainly cooperated with us.

Mr. KYROS. So certainly at this time you would have no interest in presenting to us—and I didn't see it in your testimony—any request for any additional—well, not sanctions, but power for your agency to be able to inspect electronics products.

Mr. HANSEN. That is right. we are barely starting with the implementation of the law, and we do not see the need at this point in time. Maybe at a later date it will be necessary.

Mr. KYROS. Mr. Hansen, there is something I don't think I understood. Since your department appeared here last there has been a reorganization, in what used to be the National Center for Radiological Health.

Mr. HANSEN. Correct.

Mr. KYROS. Will you explain to us, please, what has happened in the interim?

Mr. HANSEN. I believe it was last July 1 the Food and Drug administration and the Public Health Service were combined, and three primary organizational units were created at that time, the National Institutes of Health, the Health Service and Mental Health Administration, and the Consumer Protection and Environmental Health Service. And the Consumer Protection and Environmental Health Service in turn was broken down into the Food and Drug Administration, the Air Pollution Control Administration, and the Environmental Control Administration. And within the Environmental Control Administration the Bureau of Radiological Health is one of the pri-

mary units, and for all intents and purposes it is the same organization that existed before, except the name has been changed to conform with the reorganization.

Obviously in the process of implementing the new law, 90–602, we are making some minor organizational change to permit us to operate more effectively within the structure.

Mr. KYROS. In other words, the predecessor, the National Center for Radiological Health, had certain functions, but you don't really feel that it has been downgraded because of this change, is that right?

Mr. HANSEN. No, indeed not.

Mr. KYROS. You still haven't been able to get a simple standards committee of one man?

Mr. HANSEN. Of course, the responsibility for that goes beyond the Bureau of Radiological Health.

Mr. KYROS. But you are the administrator, you are the one that needs the committee in order to give you the standards, so that you can go out and enforce the act, isn't that right?

Mr. HANSEN. That is correct.

Mr. KYROS. So have you complained?

Mr. HANSEN. We have made numerous inquiries and requested early attention to this.

Mr. KYROS. Should it be so hard to get a committee? Don't we have in government and industry and the general public trained people who understand this kind of problem, so that we could get a committee together? What should be the problem holding that up.

Mr. HANSEN. There is available a long list of eligible candidates. The problem in implementing the selection—I don't have the detailed information on the cause for delay, but I believe we are expecting it in the very near future.

Mr. KYROS. But in the 7 months interim isn't there a possibility that the consumer has been adversely affected by the nondevelopment of standards on some products that have come out?

Mr. HANSEN. We have been working very diligently with our scientists and engineers in this gearing up to implement the law. And to this point in time we have not been seriously handicapped for want of a committee. However, we are now rapidly reaching the point where the use of the committee is urgent.

Mr. KYROS. But while you are getting geared up to implement the law, in your own words, people are still using color TV sets—not that I am saying they are harmful, I have them in my own house—and other products. And what I am asking you specifically is, can you name any instances of excessive radiation on any products which have been developed in the past several months by your bureau?

Mr. HANSEN. Excuse me, I missed part of that.

Mr. KYROS. Can you name any instances in the past several months in which you have found excessive radiation from any product?

Mr. HANSEN. Dr. Elder, do you have any specific item?

Dr. ELDER. We are looking at a number of products that may be emitting radiation, as mentioned in Mr. Hansen's testimony, the microwave oven and TV receivers as well. But we cannot answer to the committee that we know of a specific product having excessive radiation emission which was manufactured after the enactment date of the law.

Mr. KYROS. You couldn't anyway, really, without having the standards that are set forth here, is that right? You haven't just adopted as interim standards the ones that existed before by the private radiation control agencies?

Dr. ELDER. It is the National Council on Radiation Protection.

Mr. KYROS. You don't have any power by using that standard, do you have to have the standard set forth in this act, isn't that right?

Dr. ELDER. I think that it is necessary, in terms of a performance standard for the types of products that are coming off the line, to meet a given standard. That is an authority in the act. However, there is also the defects section which provides that if a product manufactured after October 18 possess a serious defect, the Secretary could require the manufacture to correct it. We have had no cause to utilize that authority to date.

Mr. KYROS. You have found nothing with any defects so far, is that right, within the last 7 months?

Mr. HANSEN. The microwave oven—I don't know whether production occurred before or after October 18, but we have found defective interlock systems on the microwave ovens which we have been actively pursuing.

Dr. ELDER. This might be a good example. We purchased some microwave ovens for testing and on one of them the interlock was found to have a very poor design, that could be easily defeated. We contacted the manufacturer, and on a voluntary basis he came to Washington. In an informal meeting we told him that we were concerned about his product. He informed us that that particular design was made before the 18th of October, 1968. However, he is fully cooperating, and has developed a kit to modify those ovens to improve the interlock; and has showed us the new types of designs that he is producing. This is an example of a voluntary activity, and not specifically enforcement.

Mr. KYROS. It seems to me that with all the press that we had before on this committee to get this legislation out last year—my own impression was that it was necessary to get geared up, as you said, to set up standards and then to be able to advise the industry so that cooperatively we wouldn't have any problems come about, as we did on the color television sets, with the hazard that frightened a lot of people—probably some unduly, I would urge you to get your standards as fast as you can.

Thank you for appearing here this morning.

Thank you, Mr. Chairman.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. Thank you, Mr. Chairman.

Mr. Hansen, you have been Commissioner of the Environmental Control Administration for how long?

Mr. HANSEN. Since the first of July 1968.

Mr. CARTER. Had you previously been associated with a similar bureau——

Mr. HANSEN. I was with the National Institutes of Health as director of the Division of Research Services for the previous 13 years.

Mr. CARTER. What is your background, please, sir.

Mr. HANSEN. I have an undergraduate degree in civil engineering, and a graduate degree in sanitary engineering.

Mr. CARTER. Sanitary engineering. Have you ever studied X-rays, how they are developed and so on?

Mr. HANSEN. Not in great detail.

Mr. CARTER. What is the principle behind our computer design? Are there any X-ray emissions from our computers?

Mr. HANSEN. Not that I am aware of.

But I would defer to Dr. Elder here on that question.

Dr. ELDER. The computer, if it were a solid state design, and did not have a vacuum tube which is necessary for production of X-rays, of course would not emit radiation. However, some computers have cathode display tubes, which are, of course, vacuum tubes. We know of no problems associated with this product. But this is one that theoretically could produce X-rays. We have been given the understanding that the voltages, as reviewed last year, are being held down on these particular display devices.

Mr. CARTER. That is true, they do have cathode tubes, computers do, and they do emit X-rays also. That is also true.

What is your name, please, sir.

Dr. ELDER. Robert Elder.

Mr. CARTER. What is your background, please.

Dr. ELDER. I have a bachelor's degree in public health, a master's degree in public health, and I have a bachelor's degree in civil engineering, and I have a doctor of science in biophysics, stressing particularly physics and molecular biology.

Mr. CARTER. Biophysics and molecular biology?

Dr. ELDER. Yes, sir.

Mr. CARTER. Have you had any training in X-rays?

Dr. ELDER. Yes, sir. My previous assignment to this was at Oregon State University, where I taught as an associate professor of radiological physics.

Mr. CARTER. Have you had any experience in the use of X-rays and so forth?

Dr. ELDER. Yes, sir. I have used them in my own research as well as in laboratories, and have taught the basic elements.

Mr. CARTER. However, your doctorate was in what subject?

Dr. ELDER. In biophysics.

Mr. CARTER. What about your staff? Do you have people—how many people do you have who have been trained in radiology and X-rays? Do you have expertise in this field?

Dr. ELDER. Medical radiology?

Mr. CARTER. No, sir, any kind.

Dr. ELDER. We have had for a good many years an extensive in-house training program.

Mr. CARTER. I want to know——

Dr. ELDER. Their qualifications, sir?

Mr. CARTER. Yes, sir; their background in school, not in-house training.

Dr. ELDER. I could certainly provide that in detail for the record, and would be most pleased to do so.

Mr. CARTER. Do you have any who has had extensive experience in X-rays there? If you have, name them. I would like to know who they are.

Dr. ELDER. For example, at our southwestern laboratory we have Dr. Harold Stewart, who was specifically trained in X-rays. He directed the development of the automatic collimator. We have other highly competent engineers that are specifically trained in this area.

Mr. CARTER. But not necessarily radiologically trained?

Dr. ELDER. Yes, sir; radiologically trained.

Mr. CARTER. It was brought out that it would take a great deal of expertise in this field a year ago when this program was developed, and it was suggested by some that the Bureau of Standards be called in on this where they have expertise in such fields. I have a great deal of respect for you gentlemen, but certainly you must have people who know about X-rays that are able to measure them.

Mr. HANSEN. We do have many scientists and engineers.

Mr. CARTER. I have been asking you who they were.

Dr. ELDER. That was just an example. I would be more than pleased to submit a long list in this area.

(The following material was received by the committee:)

CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE, ENVIRONMENTAL CONTROL ADMINISTRATION, BUREAU OF RADIOLOGICAL HEALTH—STAFF CURRICULUM VITAE

OFFICE OF THE DIRECTOR

Name	Title	Education	Certification
Moore, Raymond T., M.D	Acting Director, Bureau of Radiological Health	B.S., Arkansas Teachers College, 1939; M.D., University of Arkansas School of Medicine, 1944; master of industrial medicine, University of Rochester, 1959.	Diplomate, American Board of Preventive Medicine, 1964.
Elder, Robert L., Sc.D	Associate Director, Bureau of Radiological Health	B.S., public health, Indiana University, 1953; M.S., public health, University of North Carolina, 1955; B.S., civil engineering, Oregon State University, 1958; D.S., biophysics, Johns Hopkins University, 1964.	Professional Engineer.
Wheeler, Andrew C	Assistant Director, DOD Liaison	D.V.M., Kansas State University, 1950; M.S., Radiology, Michigan State University, 1955.	
Neill, Robert H	Director, Compliance Office	B.S., Mechanical Engineering, Stevens Institute of Technology, 1951; M.S., Radiological Health, Harvard University School of Public Health, 1962.	

STAFF CURRICULUM VITAE—Continued

DIVISION OF ELECTRONIC PRODUCTS

Name	Title	Education	Certification
Nelson, Donald J., Jr	Director, Division of Electronic Products	B.S., chemical engineering, Texas A & M, 1948; M.P.H., University of Michigan, 1955; M.S., nuclear engineering, University of Michigan, 1956.	
Rechen, Henry J. L	Associate Director, Division of Electronic Products	B.C.E. (sanitary), Cornell University, 1941; M.C.E. (sanitary), Cornell University, 1947; U.S.N. postgraduate school, 1949; certificate in nuclear defense engineering; M.S. in nuclear physics, Ohio State University, 1951.	
Leupold, Rodger L	Chief, Testing and Evaluation Branch	B.S., nuclear engineering, Kansas State University, 1959; M.S., radiological physics, Columbia University, 1962.	
Wromble, Richard F	Sanitary Engineer	B.S. in civil engineering, University of Notre Dame, 1961; M.S. in sanitary engineering, University of Michigan, 1964.	
Kline, Alfred B., Jr	Seminar Program Officer	B.S. in chemistry, Duquesne University, 1955; M.P.H., University of Michigan, 1961.	
Schneider, Roger H	Chief, Radiation Measurements Laboratory	B.S. in physics, Stanford University, 1959; M.S. in radiological health, New York University, 1963.	
Smith, Donald R	Chief, Surveillance Branch	B.S. in public health, environmental health, University of Michigan, 1954; M.P.H., radiological health, University of Michigan, 1961.	
Warr, Charles P., Jr	Physicist	B.A., Vanderbilt University, 1964; M.S., Emory University, 1967	
Solem, Duane L	do	B.E.E., University of Minnesota, 1963; M.S., radiological health, University of Tennessee, 1967.	
Herman, Bruce A	Physicist	B.S., physics, City College of New York, 1968	
Brown, David G	Deputy Chief, Radiation Measurements Laboratory	B.S., physics, Stanford University 1964; Ph. D., physics, University of California at Berkeley, 1968.	
Ruggera, Paul S	Electrical Engineer	B.S.E.E., University of Wyoming, 1966; M.S. in bioengineering, University of Wyoming, 1968.	
O'Keefe, Dr. Edward J	Medical Staff Officer	B.A., biophysics, Yale University, 1962; M.D., Yale University School of Medicine, 1966.	National Board of Medical Examiners.
Smith, Thomas M	Assistant Chief, Testing and Evaluation Branch	B.S.E.E., Clemson University, 1967; M.S. industrial management, Clemson University, 1968.	
Cloke, R. L	Sanitary Engineer	B.S., electronics engineering—California State Polytechnic College, B.S., physics, California State Polytechic College, 1967; M.S.E.E., University of California at Berkeley, 1968.	

DIVISION OF MEDICAL RADIATION EXPOSURE

Name	Title	Education	Certification
Villforth, John C	Director, Division of Medical Radiation Exposure	BS., sanitary engineering, Pennsylvania State University, 1952; MS., sanitary engineering, Pennsylvania State University, 1954; MS., physics/biology, Vanderbilt University, 1958.	American Board of Health Physics, 1962.
Cole, William S., M.D	Deputy Director, Division of Medical Radiation Exposure.	M.D., University of Virginia, 1937	Diplomate, American Board of Radiology, 1949.
Boggs, Richard F	Chief, Radioactive Materials Branch, DMRE	B.S.C., Rensselaer Polytechnic Institute, 1959; M.S., nuclear engineering, Georgia Institute of Technology, 1965.	Environmental Engineering Intersociety Board Diplomate, American Academy of Environmental Engineers Professional Engineer, State of New York.

DIVISION OF MEDICAL RADIATION EXPOSURE—Continued

Name	Title	Education	Certification
Gitlin, Joseph N	Chief, Radiological Systems Section, Radiation Machines and Applications Branch, DMRE.	B.A., University of Pennsylvania, 1950. M.P.H., Johns Hopkins University, 1967. Candidate, D.P.H., Johns Hopkins University, 1969.	
Murphy, George B., M.D	Radiologist, Radiological Systems Section, Radiation Machines and Applications Branch, DMRE.	M.D., University of Illinois, 1957	American Board of Radiology, 1964.
Cassady, James R., M.D	Radiologist, Development and Evaluation Section, X-ray Exposure Control Laboratory, DMRE.	B.A., University of California, 1959, M.D., Harvard Medical School, 1963.	
Williams, Kenneth D	Chief, Biological Uses Section, Radioactive Materials Branch, DMRE.	M.S., physics, University of Virginia; M.S., radiological science, Johns Hopkins University.	American Board of Radiology in Radiological Physics, 1960.
Sutton, Joseph D., M.D	Nuclear Medicine Specialist, Biological Uses Section, Radioactive Materials, Branch, DMRE	B.A., Yeshiva College, 1962, M.D., Albert Einstein College of Medicine, 1966.	
McDowell, Richard B., D.D.S	Chief, Radiation Machines and Applications Branch, DMRE.	B.A., Indiana University, 1952, D.D.S., Indiana University of Dental School, 1956; Public health advisory training, University of Michigan School of Public Health, 1966.	
Heidersdorf, Sidney D	Chief, X-ray Exposure Control Laboratory, DMRE	B.S., Loras College, 1958; health physics, University of Washington, 1958–59; training, radiological health, University of Washington, 1965.	
Properzio, William S	Chief, Development and Evaluation Section, X-ray Exposure Control Laboratory, DMRE.	B.S., electrical engineering, Worcester Polytechnic Institute, 1962; training branch, internship training, Oregon State University, 1965–66; graduate student for training in nuclear engineering, Oregon State University, 1966.	
Wold, Gary J	Pharmacist, Dosimetry and Calibration Section, X-ray Exposure Control Laboratory, DMRE.	Radiological health curriculum, University of Miami, 1965–66; training branch, University of Miami, 1965–66; internship training program, 1966.	
Gundaker, Walter E	Chief, Industrial Radiation Section, Radioactive Materials Branch, DMRE.	B.S., civil engineering, Newark College of Engineering, 1959; Masters, bioradiology, University of California, 1964.	Professional Engineer, State of New Jersey.
Pettigrew, George Layton	Radioactive Materials Specialist, Technical Evaluation Section, Radioactive Materials Branch, DMRE.	B.S., civil engineering, Southern Methodist University, 1962	
Schmidt, Gail D	Chief, Technical Evaluation Section, Radioactive Materials Branch, DMRE.	B.A., Wisconsin State College, 1956; M.S., physics, Vanderbilt University Graduate School, 1957; radiological hygiene, University of North Carolina, 1963–65; working toward Ph.D., school of public health.	American Board of Health Physics.
Wellman, Henry N., M.D	Chief, Nuclear Medicine Laboratory, DMRE	B.S., Rockhurst College, 1956; M.D., St. Louis School of Medicine, 1960; radiological health curriculum, University of Cincinnati, 1963–66 (Borden award for outstanding research done in medical school).	Diplomate, American Board of Internal Medicine, 1969.
Sodd, Vincent J	Acting Chief, Radiopharmaceutical Section, Nuclear Medicine Laboratory, DMRE.	B.S., chemistry, Xavier University, 1956; M.S., chemistry, Xavier University, 1958; Ph. D., University of Pittsburgh, 1963.	
Mack, James F., M.D	Radiologist, Clinical and Dosimetry Section, Nuclear Medicine Lavoratory, DMRE.	M.D., St. Louis University Medical School, 1962; radiology residency, University of Los Angeles Medical Center, 1963–67.	
Bailey, John G	Operations Officier, Division of Medical Radiation Exposure.	B.S., civil engineering, University of Washington, 1957; M.S., radiological hygiene, Harvard University, 1950.	

STAFF CURRICULUM VITAE—Continued

OFFICE OF FIELD OPERATIONS

Name	Title	Education	Certification
Miller, James W., D.D.S	Assistant Director for Regional Operations	A.A., Chaffey College, 1948; D.D.S., Marquette University, 1955; M.S., University of California, 1960; M.P.H., Johns Hopkins University, 1967.	
Flora, David H	State Regulatory Affairs Officer, Office of Field Operations.	B.S., bacteriology, Colorado A.M. College, 1950; radiological health curriculum, University of Pittsburgh, 1963–64.	

OFFICE OF TRAINING AND GRANTS

Name	Title	Education	Certification
Dahl, Arve H	Director, Office of Training and Grants	B.S., civil engineering, University of Washington, 1940; M.S., sanitary engineering, Harvard Graduate School of Engineering, 1941; certificate of completion, Industrial College of Armed Forces, 1961.	
Galpin, Floyd L	Staff Officer, Office of Training and Grants	B.S., chemical engineering, University of Oklahoma, 1958; health physics, University of Michigan, 1960; M.S., civil engineering, University of Oklahoma, 1963.	

OFFICE OF CRITERIA AND STANDARDS

Name	Title	Education	Certification
Snow, Donald	Director, Office of Criteria and Standards	B.S., civil engineering, Case Institute of Technology, 1937; M.S., civil engineering, University of Wisconsin, 1941.	
Setter, Lloyd R	Chief, Standards Services Branch, Office of Criteria and Standards.	M.S., water and sewage research, Rutgers University, 1929; Ph.D., water and sewage research, Rutgers University, 1932.	

DIVISION OF BIOLOGICAL EFFECTS

Name	Title	Education	Certification
Mills, William A	Director, Division of Biological Effects	B.S., physics, chemistry, and mathematics, Lynchburg College, 1951; M.S., physics and mathematics, Vanderbilt University, 1954; Ph. D., biophysics and biometry, Medical College of Virginia, 1964.	Recipient of Elda E. Anderson award (Health Physics Society), 1969.
Telles, Norman C., M.D	Acting Deputy Director, Division of Biological Effects.	B.S., biology, Massachusetts Institute of Technology, 1951; M.D., Boston University, 1956; M.S., radiobiology, University of Rochester, 1958.	
Wagner, M. Thomas, Jr	Senior Pharmacist	B.S., pharmacy, University of North Carolina, 1953; Hospital pharmacy, Duke University, 1954; M.S., radiation biology, University of Rochester, 1962: Ph. D., radiation biology, Colorado State University, 1967.	Licensure, pharmacy, North Carolina.
Jessup, Gordon L., Jr	Mathematical statistician	B.S., animal science, University of Maryland; M.S., genetics, physiology, University of Maryland; Ph. D., genetics, statistics, physiology, Oregon State University.	
Harris, Jesse Young	Staff Officer, Biometric Support Unit	B.S., animal science, Rutgers University, 1958; M.S., nutrition, statistics, Rutgers, 1960; M.S., radiological health, radiological biology, Rutgers, 1964; Ph. D., nutrition, radiological biology, 1968.	
Chiacchierini, Richard Philip	Statistician	B.S., mathematics, St. Bonaventure University, 1965; master of experimental statistics, North Carolina State University, 1967.	
Cisar, Clayton F	Chief, Animal Care Unit	B.S., animal husbandry, South Dakota State College, 1958	
Davis, Audrey K	Research Radiobiologist	B.S., chemistry, Memphis State College, 1947; Ph. D., physiology, University of Tennessee College of Medicine, 1951.	
Thomassen, Robert W	Veterinarian	B.S. veterinary medicine, Colorado State University, 1955; D.V.M., veterinary medicine, Colorado State University, 1956.	Certified by American College of Veterinary Pathologists.
Cloud, Dennis F	----do----	D.V.M, veterinary medicine, University of Missouri School of Veterinary Medicine, 1968.	
Lambert, Paul D	Bachelor of Science, Chemistry, Geneva College—1950.	D.V.M, veterinary medicine, University of Pennsylvania, 1954; M.P.H., Johns Hopkins School of Hygiene and Public Health, 1960.	
Leach, William M	Chief, Genetics Studies Section, Experimental Studies Branch.	B.S., biology, Berea College, 1956; M.S., radiation biology, University of Tennessee, 1962; Ph. D., zoology, University of Tennessee, 1965.	
Yao, Kenneth T. S	Geneticist	M.S., plant genetics, National Central University (China), 1942; Ph. D., animal genetics, University of Edinburg, Scotland, 1947; postdoctor study, animal genetics, Cambridge University, England, 1948.	
Beyer, Emanuel C., M.D	Surgeon, Project Officer	B. and M.S., University of Detroit, 1959 and 1962; M.D., Wayne State University, 1967.	
Ward, Billy C		B.S., veterinary science, Texas A. & M., 1963; D.V.M., veterinary medicine, Texas A. & M., 1964. Ph. D., comparative pathology, University of California, 1967.	
Shively, James	Veterinary Pathologist	D.V.M., Kansas State University, 1946; M.P.H., Johns Hopkins School of Hygiene and Public Health, 1953; M.S., University of Rochester, 1956.	American College of Veterinary Toxicology.

STAFF CURRICULUM VITAE—Continued
DIVISION OF BIOLOGICAL EFFECTS—Continued

Name	Title	Education	Certification(s)
Pollock, Edward J., M.D		B.A., chemistry, Northwestern University, 1961; M.D., Harvard Medical School, 1966; Fellow in biochemistry, Harvard Medical School, 1963–64.	
Lytle, David	Physicist (general)	B.S., physics, Kent State University, 1963; M.S., physics, Cornell University, 1965; Ph. D., biophysics, Penn State University, 1968.	
Muroff, Lawrence, M.D	Researcher	A.B., Dartmouth College, 1964; B.M.S., Dartmouth Medical School, 1965; M.D., Harvard Medical School, 1967.	Diplomate, National Board of Medical Examiners.
Childress, Joseph		B.S., biology, chemistry, East Texas State University, 1965; M.S., biology, chemistry, East Texas State University, 1967.	
Hellman, Kiki	Microbiologist	B.S., biology and chemistry, University of Akron; Akron, Ohio, 1954; M.S., microbiology (cellular physiology), University of Michigan; Ann Arbor, Mich., 1956.	
Geiger, Franklin		B.S., University of South Carolina, 1960; M.D., Medical College of South Carolina.	Certified to practice medicine and surgery.
Stara, J. F	Veterinarian Director, Radionuclide Toxicology Laboratory DRH.	D.V.M., veterinary medicine, University of Georgia, 1954; M.P.H., public health epidemiology, Harvard School of Public Health, 1955; M.S., radiobiology, University of Rochester, 1960.	Michigan Veterinary Board, 1956; Ohio Veterinary Board, 1963.
Nelson, Neal S		B.S., University of Illinois, 1955; D.V.M., veterinary medicine, University of Illinois, 1957; Ph. D., pharmacology, University of Chicago, 1964.	
Berman, Ezra	Full, Veterinarian O	B.S., physiology, Michigan State University, 1958; B.S., veterinarian science, Michigan State University, 1960; D.V.M., Veterinarian Medicine, Michigan State University, 1962.	
Rosenstein, L	Mechanical Engineer	B.S., Drexel Institute, 1954; MS, env. engineering, Drexel Institute, 1965; Ph.D. (expected June 1969), University of Cincinnati.	
Wolfangel, Robert G	Radiobiologist	B.S., pharmacy, St. Louis College of Pharmacy, 1962; MS, industrial pharmacy, St. Louis College of Pharmacy, 1964; Ph. D., bionucleonics, Purdue University, 1967.	Licensed Pharmacist, Missouri.
Wright, James F	Director Veterinary, Research Pathologist	Preveterinarian training, 1947, LaSalle College; V.M.D., veterinary medicine, University of Pennsylvania, 1951.	
Youmans, Harry D		B.A., physics, Emory University, 1958.	
Tell, Richard A		B.S., physics, Midwestern University, Texas, 1966; M.S., radiological health, Rutgers, 1967.	
Rolofson, James W	SA HSO	B.A., physics, Nebraska Wesleyan University, 1964, M.S., health physics, North Dakota State University, 1966.	
Anderson, George E	SA San E	B.S., electrical engineering, University of Washington 1963	
Behling, Ulrich Hans	SA HSO	B.S., natural science, Rutgers, 1965; M.S. radiological health, physics, Temple, 1966; M.S., radiological health, physics, University of Pittsburgh, 1967.	
Shore, Moris L	Chief, Physiology and Biophysics Laboratory, Acting Chief, Experimental Studies Branch.	B.A., biology-chemistry, Southwestern, Memphis, 1950; Ph. D., physiology-biochemistry, University of Tennessee School of Medicine, 1954.	
Hazzard, DeWitt G	Acting Chief, Metabolic Studies Section	B.S., dairy science, Penn State University, 1954; M.S., dairy science, Penn State University, 1957; Ph. D., nutrition-biochemistry, University of Connecticut, 1963.	

Fred, Richard Kassler	D.D.S., Ph. D	Predental, Emory University, 1953–55; D.D.S., dental, Emory University, 1955–59; dental internship, U.S. Public Health Service, Staten Island, N.Y., 1959–60; Ph. D., medical physics, University of California, 1967.	
Lamanna, Anthony	Research Chemist	B.A., chemistry, Columbia Union College, 1951, George Washington University, chemistry-inorganic, 1955–59.	Licensed Electrical Contractor.
Janes, David E., Jr	Senior Sanitarian, Investigator (biophysics)	B.A., physics, William Jewell College, 1956; A.E.C. fellowship in radiological physics, University of Washington, 1957; course work completed on Ph. D. program in biophysics, Medical College of Virginia, 1964.	
Zaremba, Terrye G	Chemist	B.A., chemistry, Temple University, 1964; M.S., biochemistry, George Washington University, 1968.	
Budd, Roger A	Research Biologist	B.A., biology, Hartwick College, 1964; M.S., zoology, George Washington University, 1969.	
Silverman, Charlotte	Chief, Epidemiologic Studies Branch	M.D., medicine; M.P.H., public health; D.P.H., epidemiology.	Certified American Board of Preventive Medicine and Public Health.
Roney, Paul L	Supervisory Survey Statistician	B.A., mathematics, University of Minnesota, 1948; graduate study, 1 year, biostatistics.	
Brennan, Paul J	A HSO	BA, mathematics, Harvard College, 1967	
Brown, Morton L	Supervisory Survey Statistician, Senior Grade	BA, University of Chicago, 1953; graduate study in demography 1954–56.	
Palmer, Allen H	Full San. E	B.S., civil engineering, University of Rhode Island, 1961	Registered Professional Engineer, District of Columbia, 1967.
Pressman, Barry David	Senior Assistant Surgeon	B.A., Dartmouth College, 1964; B.M.S., Dartmouth Medical School, 1965; M.D., Harvard Medical School, 1967.	Diplomate of National Board of Medical Examiners.
Hemphill, F. M	Scientist director	B.S., medicine, University of Texas, 1931; M.S., public health, University of Michigan, 1941; Ph. D., epidemiologic science, 1950.	
Bender, Charles A	SA HSO	M.S., statistics, Kansas State University, 1967	
Erickson, David S	SA HSO—Health Physics	B.S., biology, Albion College, 1966; M.S., health physics, University of Pittsburgh, 1967.	
Tompkins, Edythalena	Supervisory Statistician	B.A., major, biochemistry, minor, General Medical Sciences, Stanford University, 1939; graduate school, organic chemistry, Stanford University, 1940; graduate school, statistics, Stanford University, 1952–54.	
Schreiber, William M	Surgeon Pathologist	A.B., Englisn, Harvard College, 1957; M.D., medicine, Ohio State University, 1963; Vanderbilt University, medicine, 1963–65; Yale University, 1965–67.	
Robertson, Thomas L		Th. B., Holmes Theological Seminary, 1954; Furman University, September 1954 to June 1955; Roanoke College, B.S., 1957; M.D., University of Virginia School of Medicine, 1962.	
Robertson, James D	Surgeon Internist	B.A., chemistry, Duke University, 1962; M.D., medicine, Duke University, 1966; intern in pathology, UCLA, January 1966 to December 1966.	
McGregor, Douglas H	Surgeon Pathologist	B.A., Duke University, Trinity College, 1961; University of Edinburg, 1961–62; M.D., Duke University School of Medicine, 1966; internship and residency, UCLA School of Medicine, 1966–68.	
Key, Charles R	SR Surgeon Research Associate in Medicine	B.S., Oklahoma State University, 1955; M.D., University of Oklahoma, 1959; M.S., University of Oklahoma, 1964.	
Hall, William J	Surgeon Internist	B.A., Premed, Holy Cross College, 1961; M.D., Medicine, University of Michigan, 1965.	
Greidinger	Surgeon Pathologist	B.A., biology, Johns Hopkins University, 1959; M.D., medicine, Johns Hopkins University Medical School, 1963.	

STAFF CURRICULUM VITAE—Continued

DIVISION OF ENVIRONMENTAL RADIATION

Name	Title	Education	Certification
Weaver, Charles L	Director, Division of Environmental Radiation	B.S., civil engineering, University of Maine, 1940; M.S., University of California, 1954.	American Board of Health Physics, professional engineer.
Bales, Ronald E	Deputy Director, Division of Environmental Radiation.	B.S., chemical engineering, University of Minnesota, 1943; M.S., Harvard University, 1947.	Professional engineer, American Academy of Industrial Hygine.
Silhanek, Jay J	Deputy Chief, Radiological Surveillance Branch, DER.	B.A., Monmouth College, 1955; B.S., Case Institute of Technology, 1955; M.S., University of Wisconsin, 1957; M.P.H., University of Michigan, 1961.	
Augustine, Robertson J	Chief, Radiological Surveillance Branch, DER	B.S., physics, University of Michigan, 1955; M.S., nuclear engineering, University of Michigan, 1957; M.P.H., radiological health, University of Michigan, 1959; Ph.D., environmental health, University of Michigan, 1962.	American Board of Health Physics.
Oakley, Donald T	Chief, Environmental Studies Section, Nuclear Facilities Branch, DER.	B.S., electrical engineering, University of Maryland, 1960; M.S., environmental health, University of Michigan, 1967.	American Board of Health Physics.
Harward, Ernest D	Chief, Nuclear Facilities Branch, DER	B.S., civil engineering, Duke University, 1951; M.S., sanitary engineering, University of North Carolina, 1952.	
Martin, James E	Deputy Chief, Nuclear Facilities Branch, DER	B.A., physics, Vanderbilt University, 1956; M.P.H., radiological health, University of Michigan, 1961; Ph.D., environmental health, University of Michigan, 1965.	

RADIOLOGICAL HEALTH REPRESENTATIVES

Name	Title	Education	Certification
Harris, Saul J	Radiological Health Representative, Region II, ECA.	B.S., Queens College of Flushing, N.Y., 1943; M.S., Columbia University, New York, management engineering.	Certified Health Physicist, 1960.
McTaggart, James A., D.D.S	Radiological Health Representative, Region VII, ECA.	D.D.S., Baylor Dental University, 1957; University of California, radiological health curriculum, 1965.	
Nelson, Clifford E	Radiological Health Representative, Region IX, ECA.	B.S., M.B., M.D., 1945–48, University of Minnesota	

SOUTHWESTERN RADIOLOGICAL HEALTH LABORATORY

Name	Title	Education	Certification
Stewart, Harold F	Chief, Electronic Products Studies	B.S., chemistry, Sterling College, 1958; M.S., University of Kansas, 1960; Ph. D., Colorado State University, 1965.	
Melvin Carter, Ph. D	Director, Southwestern Radiological Health Laboratory.	B.S., civil engineering, 1949, Georgia Institute of Technology; M.S., public health engineering, 1951, Georgia Institute of Technology; Ph. D., sanitary nuclear engineering, 1960, University of Florida.	
Eugene T. Vandersmissen	Medical Advisor to the Director, SWRHL	M.S., bacteriology M.D	Board certified in radiology.
Sell, Thomas C	Chief, Technical Training and Reports	B.S., Dickinson College, 1953; M.P.H., environmental health, University of Michigan, 1960.	
Shearer, S. David	Chief, Techincal Services	B.C.E., Clemson University, 1955; M.S., University of North Carolina, 1957; Ph. D., University of Wisconsin, 1962.	
Coleman, Richard D	Chief, Environmental Surveillance	B.S., civil engineering, 1948, Purdue University; M.S., sanitary engineering, 1949, University of California; M.S., industrial hygiene, 1954; Harvard School of Public Health.	

SOUTHEASTERN RADIOLOGICAL HEALTH LABORATORY

Name	Title	Education	Certification
Regnier, John E	Director, Southeastern Radiological Health Laboratory.	B.S., chemistry, 1956, South Dakota School of Mines; M.S., Engineering, 1963, University of Florida; Ph. D., Engineering, 1965, University of Florida.	
Bedrosian, Paul H	Chief, Radium Technology Unit	B.S., civil engineering, Northeastern University; M.S., sanitary engineering, 1959; University of Florida; Ph. D. in sanitary engineering, 1961, University of Florida.	
Moghissi, A. A	Research Chemist	B.S., 1953, Tech. University, Karlsruhe, Germany; M.S., 1956, Tech. University, Karlsruhe, Germany; Ph. D., 1960, Tech. University, Karlsruhe, Germany.	Certified Physical Chemist.

NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY

Name	Title	Education	Certification
Morgan, Seal	Director, Northeastern Radiological Health Laboratory.	B.S., chemistry, 1949, George Washington University; M.S., chemistry, 1959, George Washington University.	

Mr. CARTER. I would like to see this included in the record, because it is very necessary that we have people who are well trained.

Have you developed standards for the X-ray emission of color television, for instance?

Mr. HANSEN. The development of the standards is still in process. We have not completed it. We hope to have it soon.

Mr. CARTER. I understand. I know that that is difficult to do.

Mr. HANSEN. Yes, it is.

Mr. CARTER. To determine whether there is a biological effect. Of course, no one knows whether there is or not. But there may well be. It may be even that minimal amounts of X-ray exposure can cause mutations, is that not true?

Dr. ELDER. Yes, sir; that is true.

Mr. CARTER. You are at the present time studying the biological effects of emissions of X-rays, are you not?

Mr. HANSEN. Yes.

Mr. CARTER. Where and how are these studies being conducted?

Mr. HANSEN. We have studies underway through grants as well as in-house.

Mr. CARTER. Are they biological studies? What forms of life are you using, what experimental animals?

Dr. ELDER. We have a variety of animals: the Chinese hamster, the rat, the mouse—and we have used rabbits. At Colorado State we are supporting a very large program in the low-level exposure of the beagle. In this study we are looking specifically at low-level long-term effects.

Mr. CARTER. What have been your effects up to this time that you have observed from exposure to these X-rays?

Dr. ELDER. The scientific papers we presented are highly specialized, but we might take the combination of radiation exposures with other agents, such as the induction of viral agents into cells following radiation incidence. Our cat leukemia study that we are supporting is also very important.

Mr. CARTER. We are more interested in the effects of radiation rather than cat leukemia or the injection of viral substances into cells. Of course, we realize that this is important, but as I understand it, your position is to find the biological effects of X-ray emissions, not viral studies.

Dr. ELDER. Maybe I didn't make myself clear.

Mr. CARTER. I don't believe you did.

Dr. ELDER. What I mean is, you might have a viral agent, or you might have an effect which in itself is insufficient to harm someone. Yet if they were exposed to a small amount of radiation, then the effects might occur. It is this type of synergistic effect that we are particularly interested in, as well as the direct effects on chromosomes, and studies of this type.

Mr. CARTER. Of course, we realize that in many cases that is true, there are many factors that perhaps predispose toward cancer development, and something triggers them off. But more than anything else, we are interested in the effects of these X-rays, what do they do, and what results have you obtained.

Dr. ELDER. Sir, I would be most pleased to submit the listing of them.

Mr. CARTER. Can you tell us one development?

Dr. ELDER. I believe that the Colorado study has a series of papers in this area by specific title.

Mr. CARTER. We would like a little summarization of some of these things to see just where we are.

Dr. ELDER. We would be most pleased to submit those.

(The following publication was received for the record:)

RADIATION BIO-EFFECTS

Summary Report January-December 1968

William A. Mills, Ph.D., Chief
Radiation Bio-Effects Program
Rockville, Maryland 20852

Compiled and Edited by
Donald M. Hodge

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration
Bureau of Radiological Health

(59)

NOTICES

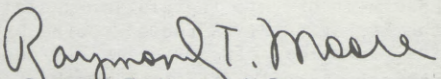
This report contains preliminary data and was prepared primarily to record the year's work, and is not intended as a substitute for publication in the open literature. It is subject to revision and does not represent a final report. Please do not quote from or refer to this work in open literature without permission from individual authors to reference the material as a personal communication.

The use of commercial preparations or products specified in this report in no way constitutes endorsement by the U.S. Public Health Service.

FOREWORD

During a recent reorganization of the Bureau of Radiological Health (formerly National Center for Radiological Health), the research associated with the Radiation Bio-Effects Program was integrated into an expanded biological research group named the Division of Biological Effects. The studies summarized in this report are representative of the biological investigations conducted by the Program during 1968.

Following the enactment of the Radiation Control for Health and Safety Act of 1968 in October, the Bureau of Radiological Health was authorized to administer, with some exceptions, the day-to-day functions implementing the Act. The responsibility for conducting biological research in areas covered by the Act has been delegated to the Division of Biological Effects. Future investigations by the Division may therefore consider not only those areas included in this summary, but also the biological effects of radiations from virtually the entire frequency spectrum. As in the past, results of this research will appear in Government reports and in appropriate scientific journals.



Raymond T. Moore, M.D.
Acting Bureau Director
Bureau of Radiological Health

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PREFACE

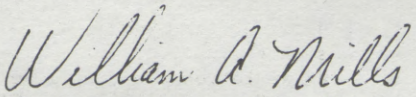
This report summarizes the research activities of the Radiation Bio-Effects Program during 1968. The first part of the report outlines the administrative organization of the Program and the Laboratories that comprise it. In day-to-day laboratory operations, however, the administrative divisions are rather indistinct, and communications and information exchanges are unrestricted throughout the laboratory.

Until this year, the prime emphasis in this Program has involved research identifying the effects of low levels of ionizing radiation on animals or animal systems. In October 1968, the Public Health Service Act was amended "to provide for the protection of the public health from radiation emissions from electronic products." This Radiation Control for Health and Safety Act of 1968, gave the Secretary of Health, Education, and Welfare the responsibility for developing and administering performance standards to control the emission of radiation from electronic products and to undertake research and investigation into the effects and control of such radiation emissions.

Enactment of this legislation has altered the scope of responsibility of the Radiation Bio-Effects Program. We are now interested in examining the biological effects of much broader spectra of mechanical and electromagnetic emissions. Although the source of energy impinging on the biological specimen is no longer restricted to that of ionizing radiation, our interest in the result--biological alterations induced by the energy received--remains unchanged.

Dr. Arthur H. Wolff, former Chief of the Radiation Bio-Effects Program, is now associated with the Office of Research and Development in the newly established Consumer Protection and Environmental Health Service. Through the foresight and efforts of Dr. Wolff and men like him, the Radiation Bio-Effects Program was conceived and has evolved into its present form. The guidance and leadership practiced by Dr. Wolff established the competence of the Program in the field of ionizing radiation. It is in the spirit of his foresight that the Program shall develop its widened scope of responsibility.

As has been the policy in the past, the results of our findings will, for the most part, be published in the open literature. Publications and presentations by Program investigators during 1968 are listed in the appendix of this report.



William A. Mills, Ph.D., Chief
Radiation Bio-Effects Program
Bureau of Radiological Health

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RADIATION BIO-EFFECTS PROGRAM

The Radiation Bio-Effects Program, Bureau of Radiological Health, conducts an multidisciplinary research program aimed at defining the long-term effects of low-level radiation exposures in man. These studies, of public health significance, include an examination of the biological effects of non-ionizing radiations such as microwaves and radiowaves as well as the effects of X and γ rays and other emanations that are of high enough energy to produce ionization.

Greater knowledge of the relationships between radiation exposure and biological effects has become imperative as our population is confronted with potentially increasing exposure levels. The projected increases in population exposure will accrue through increasing use of radiation in medicine, industry and in consumer products, and the projected commercial use for nuclear energy.

Animal studies, conducted in our laboratories and elsewhere, provide evidence to support the hypothesis that the unborn and the young may be uniquely sensitive to the deleterious effects of radiation. Using a variety of mammalian species, these experimental findings have shown that radiation exposure of adult animals inhibits the production of certain proteins and enzymes. The experimental results suggest that these effects may be the result of radiation-induced alteration of DNA, the molecule which carries genetic information that exercises control over all phases of cellular activity.

Studies of cellular genetic material--chromosomes--have shown that radiation doses as low as 10 rads can produce visible damage in chromosomes. Cultured cells from different organs appear to be equally sensitive to radiation. The age of a person at the time of irradiation does not appear to affect the extent of chromosome damage; such radiation damage may persist for a number of years.

The interactions between environmental factors and ionizing radiation are being examined extensively. Studies of cultured cells treated with radiation and viruses have shown that radiation markedly predisposes the cells to malignant transformation by the viruses. It has been shown that a chemical agent, ethionine, which is not specifically carcinogenic to mammary tissue, will increase mammary tumors when combined with radiation.

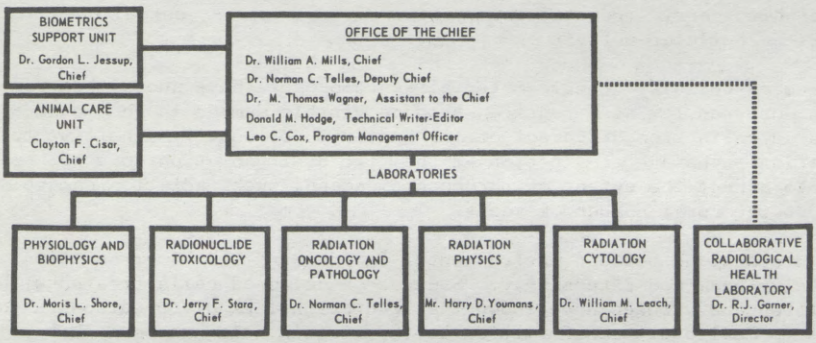
In the field of radiation dosimetry, the type of radiation emitted by some faulty color television receivers has been evaluated, making

possible calculations of the radiation exposure to humans. Through various experimental techniques, X-ray doses to the brain, eye, and thyroid gland have been calculated to provide a laboratory basis for evaluating the results of an epidemiological study of 20,000 children in Israel whose hair was removed by soft X rays as part of a treatment for ringworm of the scalp.

To examine the lifelong effects of single, low doses of radiation, a large dog colony has been established in collaboration with Colorado State University. Other studies have focused on the uptake metabolism, internal distribution, and secretion of certain radionuclides of such elements as iodine, strontium, and lead. These investigations examine the dose distribution and biological effects of such internal emitters on the organs and blood forming systems of several species, principally the cat.

To conduct these investigations, the Radiation Bio-Effects Program is organized as outlined below. Biological research conducted by each of the six laboratories and discussed in the later sections of this publication is ably supported by the Biometrics and Animal Care Units.

RADIATION BIO-EFFECTS PROGRAM



BIOMETRICS SUPPORT UNIT
Dr. Gordon L. Jessup, Chief

The Biometrics Support Unit provides statistical design and data analysis services to the Radiation Bio-Effects Program laboratories for a variety of radiobiological investigations. The results of these services are lucidly and concisely summarized in a newly adopted "Biometrics Analysis" report that is proving to be an invaluable source of information. The standard format for these reports includes statements of the objective, experimental procedure, analysis, and conclusions.

The Unit also develops mathematical models to characterize physical or biological systems, coordinates the design of experiments, and conducts research in mathematical and statistical methodology. The Unit cooperates with the investigators to define experimental objectives and variables, formulate mathematical functions, define and estimate the components of variance, and synthesize number systems to characterize, compare, and evaluate individual factors and their interactions.

ANIMAL CARE UNIT
Mr. Clayton F. Cisar, Chief

The Animal Care Unit provides animals and animal care for the studies conducted by the Radiation Bio-Effects Program at the Rockville, Maryland, laboratory. The Unit plans with the investigators the space, the most suitable species or strain, and the special breeding or handling required for a particular study.

One part of the Animal Care Unit provides animals for relatively short-term studies; the other part, operated by contract, provides care for animals in long-term experiments. During the year the two facilities handled approximately 7,200 rats, 280 mice, 37 dogs, 8 monkeys, and odd lots of guinea pigs, rabbits, Syrian hamsters, swine, and cats. Approximately 2,000 Chinese hamsters were produced during the year. This number is expected to increase as the species becomes more popular.

The general health of the animal colony has been excellent and must be rigidly maintained. The subtle effects displayed by animals exposed to radiation might otherwise be overshadowed by symptoms of ill health. The strict hygienic discipline maintained by the caretakers is mainly responsible for the absence of disease outbreaks.

Methods of handling animals exposed to radiation and radioisotopes have been studied in the Animal Care Unit. Also, animal production methods and genetic traits of selected species have been examined.

The four pairs of rat kangaroos (Potorous tridactylis) have been particularly useful to the Radiation Cytology Laboratory because their

chromosomes are relatively large, few in number (13 in the male, 12 in the female), and are easy to identify (Figure 1). Leukocytes separated from blood are easily grown in culture, and cell strains derived from the kidney, cornea, thyroid, and testicle have been maintained for more than a year. However, the four pairs of rat kangaroos maintained in this laboratory have produced only two offspring in the four years since they were obtained from Tasmania. One of these died soon after birth but the other has been raised to maturity. Breeding difficulties might be overcome if these animals were maintained in large outside enclosures during the summer months. The slow reproduction rate is probably one factor that limits the popularity of this species for scientific research.

Congenital cataracts associated with skull malformations were noted in a strain of Sprague-Dawley rats obtained from the National Institutes of Health. Through a cooperative study with NIH the cataracts were found to be inherited through a fully-expressed simple autosomal recessive gene. Histopathologic study revealed a distinctive overproduction of the lens capsule and proliferation of lens epithelium. This is a unique finding in animals and resembles changes seen in some human syndromes associated with congenital cataract.



Figure 1. Tasmanian Rat Kangaroos and Chromosomes (inset) of Male.

RADIATION CYTOLOGY LABORATORY
Dr. William M. Leach, Chief

The Radiation Cytology Laboratory examines cellular responses to radiation. Primarily, morphological studies relate the extent of an effect to the radiation exposure. Cells are irradiated while growing in vitro or are cultured from irradiated animals. Humans, rat kangaroos, and Chinese hamsters are used for the major part of the studies.

A. HUMAN STUDIES

1. Radiation Effects on Human Peripheral Leukocytes

Little information is available in the area of chromosomal response of human peripheral leukocytes irradiated in situ. As discrete and relatively available human populations are identified with known radiation exposure histories, the Radiation Cytology Laboratory has attempted to ascertain changes in their chromosomes. Two groups have been examined: One, a small group undergoing experimental X-ray and drug therapy for chronic lymphocytic leukemia; and the other, a group occupationally exposed to beta- and gamma-emitting mixed isotopes.

a. Chromosomal Analysis of Patients During Treatment for Chronic Lymphocytic Leukemia
E. C. Beyer, W. M. Leach

A study of chromosomal changes in persons treated with whole-body X radiation for chronic lymphocytic leukemia (CLL) was initiated collaboratively with the Radiation Branch, National Cancer Institute, National Institutes of Health. Thirteen patients were followed serially for various periods of time to observe chromosomal damage in cultures derived from peripherally circulating leukocytes. For clinical reasons, the treatment of CLL patients was expanded to include chemotherapy. Patients are now receiving the chemotherapy as an adjunct to X-ray therapy. Inasmuch as the drugs being used are radiomimetic, the use of chromosomal changes as an index of in situ damage has become impossible.

It is possible that the leukocytes which grew in cultures were normal, not leukemic. The possibility has been examined initially

by the staining of Periodic Acid-Schiff (PAS) bodies in lymphocytes. The staining of cultured cells derived from normal volunteers has been successful, but is not quantitatively reliable enough to invite direct comparisons of the stainabilities of cultured cells derived from normal and CLL patients.

b. Chromosomal Analysis of Persons with Body Burdens of Mixed Radioisotopes
E. C. Beyer

In 1967 spectrometric analysis of body burdens of persons occupationally in contact with a variety of radioisotopes was initiated at the Northeastern Radiological Health Laboratory, National Center for Radiological Health. Although the body burden was well below established limits for each isotope, the persistence of the body burden made chromosomal analysis of the workers an attractive possibility.

A total of ten exposed persons were entered on the study. Peripheral blood was obtained and leukocyte cultures were established with standard culture techniques. Cells were harvested after 48 hours of growth at 38°C and 72 hours of growth at 37°C.

The results of the chromosome analysis from the first contact with the group are shown in Table 1. On the basis of the results, additional contacts with the group are planned.

TABLE 1. ABERRATIONS IN BLOOD CULTURES FROM RADIONUCLIDE WORKERS

Body Burden, μCi[a]	Cumulative Rem During Employment[b]	No. of Cells Scored	Calculated Yields per 100 Cells		
			Chromatid Aberrations	Chromosome Aberrations	Aneuploidy
0.73	19.7	61	4.9	1.6	4.9
0.63	8.4	47	4.2	0	14.9
0.62	4.9	47	0	2.1	6.4
0.46	7.3	41	2.4	2.4	9.8
0.23	4.7	58	8.6	0	15.5
0.14	1.3	100	12.0	2.0	5.0
0.13	3.5	25	4.0	0	16.0
0.12	0.7	77	10.4	0	11.7
0.08	1.8	100	16.0	0	11.0
0.02	5.5	75	6.8	4.0	6.8
-c	-	25	4.0	0	4.0

a. Determined from whole-body counting techniques by Northeastern Radiological Health Laboratory, Winchester, Mass., within 3 months of the cell culturing.
b. From employer's records of film badge readings.
c. Not a radionuclide worker.

2. Studies on Possible Etiologies of Congenitally Defective Aneuploid Humans
H. R. Nankin, S. Brecher

Aneuploidy in congenitally defective humans is thought to result from unequal distribution of chromosomes by nondisjunction during gametogenesis. In mitotic cells acrocentric chromosomes may be grouped together nonrandomly in colchicine-blocked cells. The clustering of acrocentric chromosomes has been termed satellite association, and is shown in Figure 2A. The possibility that causes of satellite association in mitotic cells may also operate in cases of nondisjunction in meiotic cells has led to a study of satellite association in leukocyte cultures from normal human female volunteers.

Satellite association was found to decrease with increasing time of culture, e.g., from an average of 89.9 percent of metaphase cells in 48-hour cultures to 66.1 percent in 96-hour cultures. Because from 2 to 10 acrocentric chromosomes may participate in satellite association, an association index, the percent of acrocentric chromosomes in satellite association, was determined. The association index paralleled the satellite association curve for time in culture.

The appearance of nucleoli in cells in prophase and prometaphase was examined. In azure B bromide stained cells, nucleoli were observed in 26.8 percent of prophase/prometaphase cells cultured for 48 hours, in 31.6 percent of cells cultured for 72 hours, and 13.1 percent of cells cultured for 96 hours. At each culture time over half of nucleolar-containing cells showed one nucleolus. As many as 20-30 chromosomes were apposed to the stained nucleolar mass (Figure 2B). However, the identification of the chromosomes was not possible.

3. X-Ray Effects on the Nucleolus and on its Role in Chromosome Distribution
S. Brecher

The possible connection between nucleolar material and satellite association, implied in the above study, led to the development of a technique to examine nucleoli in colchicine-arrested metaphase cells in cultures of human peripheral blood. Nucleoli can be caused to persist into metaphase by addition of cobalt ions to the culture for an interval before fixation. Nucleoli in over 50 percent of metaphase cells in cobalt-treated cultures have been observed. The persistent nucleoli are surrounded by chromosomes. The relationship between the nucleolar size and the number of adhering chromosomes is shown in Figure 3. Fixation procedures to allow visualization of the nucleoli preclude positive identification of adhering chromosomes.

Persistent nucleoli, after exposure of 50 to 300 rads of X rays, break apart. The range of the number of nucleolar fragments has not been determined.

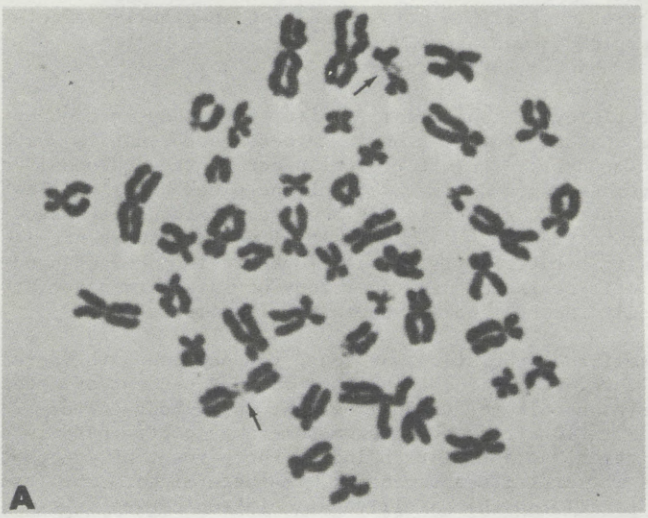


Figure 2A. Satellite Association between Acrocentric Chromosomes of a Cultured Human Lymphocyte. Short satellited arms of acrocentric chromosomes are closely apposed to similar arms of other acrocentric chromosomes (arrows).

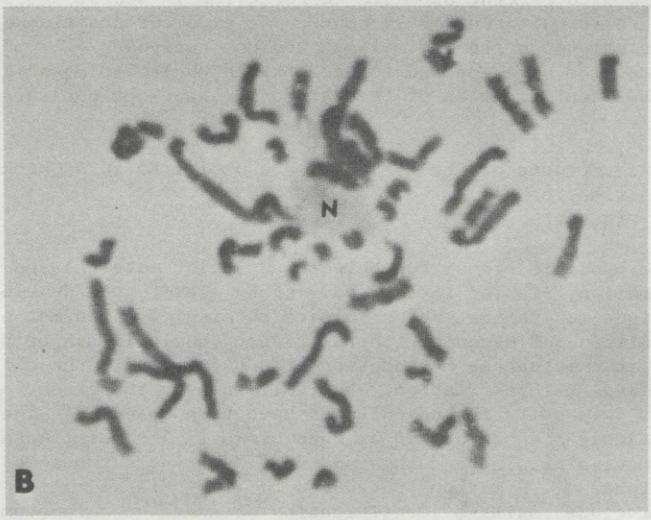


Figure 2B. Nucleolar-Chromosomal Association. Some chromosomes of cultured human lymphocytes are oriented around nucleolar material (N). Similar orientation is observed during a part of prophase and in Colcemid-blocked metaphase cells with visible nucleolar material.

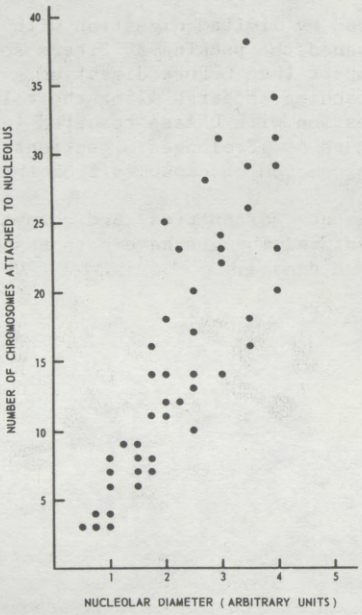


Figure 3. Relation between Nucleolar Diameter and the Number of Chromosomes Adhering to the Nucleolus. Measurements of the longest diameter of the nucleolar mass (N) were made on photographs of metaphase cells of cobalt-treated lymphocyte cultures.

4. Ultrastructure of X-Irradiated Chromosomes
J. G. Abuelo, D. E. Moore, S. Brecher

Resolution of the problem of strandedness of chromosomes is critically required for the accurate interpretation of X-ray-induced chromosome aberrations. Ultrastructural studies of chromosomes were therefore initiated. For electron microscopic examination, chromosomes were spread on the surface of a Langmuir trough and dried on grids in CO_2 at the critical point.

Colchicine-blocked metaphase chromosomes showed a bipartite, or chromatid, organization. Specific sub-chromatid organization was not observed. In extended areas 8-16 parallel fibers were oriented with the longitude of the chromosome. Fiber loops were observed along the periphery of chromosomes. Other fibers extended beyond the main chromatin mass, as well as between the arms of sister chromatids. In the kinetochore region fibers crossed from one chromatid to the other. The diameter of the fibers ranged between 190 and 290 Å. The diameter

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of the fibers was reduced by limited digestion with trypsin and Pronase. The digestion also loosened the packing of fibers so that the chromosomes appeared less compact than before digestion. In the loosened chromosomes a sort of banding appeared along their length, shown in Figure 4A. Limited digestion with DNAase resulted in breakage of the fibers, as shown in Figure 4B. Prolonged digestions with either the proteases or the DNAase removed chromosomes from the grid.

Chromosome fragments, dicentrics, and chromatid gaps have been observed. No ultrastructural changes have been associated to date with the regions of chromosome damage.

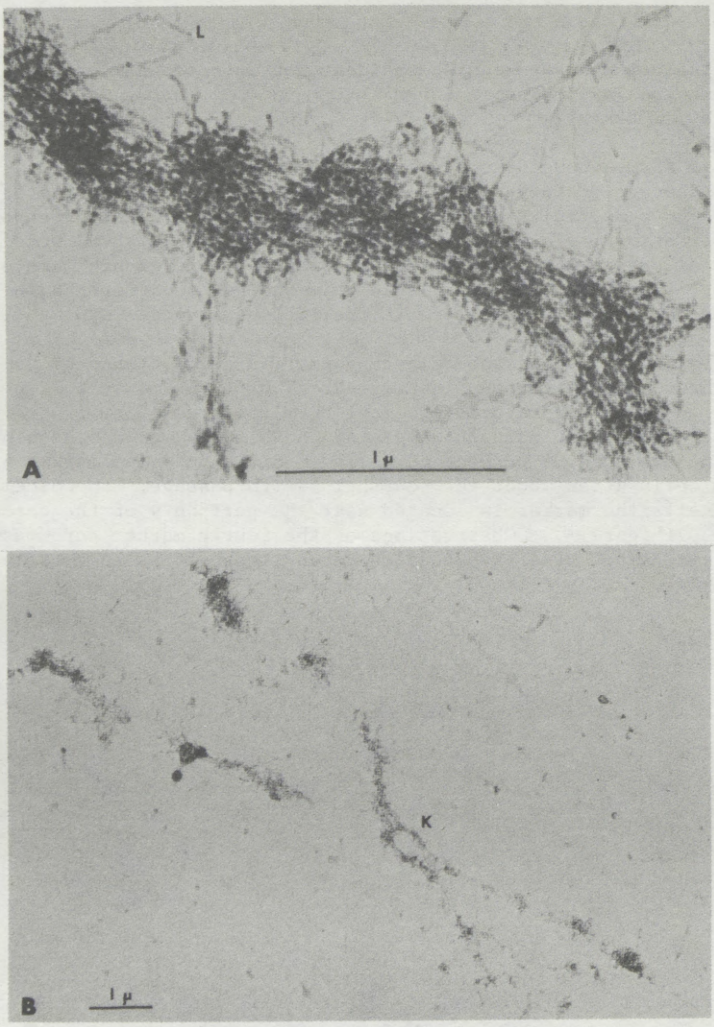


Figure 4. Electron Micrograph of a Whole-Mounted Chromosome. Chromosomes were obtained by lysis and spreading Colcemid-blocked metaphase cells on a water surface. Preparations were transferred from amyl acetate to CO_2, and dried above the critical point of CO_2. A. Alternating dense and less dense pattern of banding in a chromatid. In the less dense regions fibers may be observed with an orientation parallel to the longitude of the chromosome arm. L = chromosome fiber "loop". B. Chromosome after partial digestion with DNAase (5μg/ml). K = kinetochore (centromere) region of the chromosome.

B. ANIMAL STUDIES

1. Influence of Age on the Incidence of Chromosomal Aberrations in the Thyroid
W. M. Leach

If X-ray-induced tumorigenesis in thyroid glands depends, in part, on the age of the animals at the time of irradiation, the age variation in sensitivity may be reflected in the incidence of chromosomal aberrations. To examine this effect, Chinese hamsters were irradiated at one week or one year of age, and thyroid glands were prepared for tissue culture. Available data showed no difference in the yields of chromosome aberrations in the two age groups.

In the course of sub-culturing thyroid cells, three or four marker chromosomes have been identified. Two of the markers have been observed in other laboratories in long-term cultures of cells derived from other tissues of Chinese hamsters. A third marker has been observed in more than 95 percent of cells in division. The marker appears in cells after about the fourth in vitro passage. In Colcemid-blocked cells the marker is located near the periphery of the chromosome group (Figure 5). Observations of the fourth marker chromosome are not extensive. Its frequency in cells is about the same as the third marker.

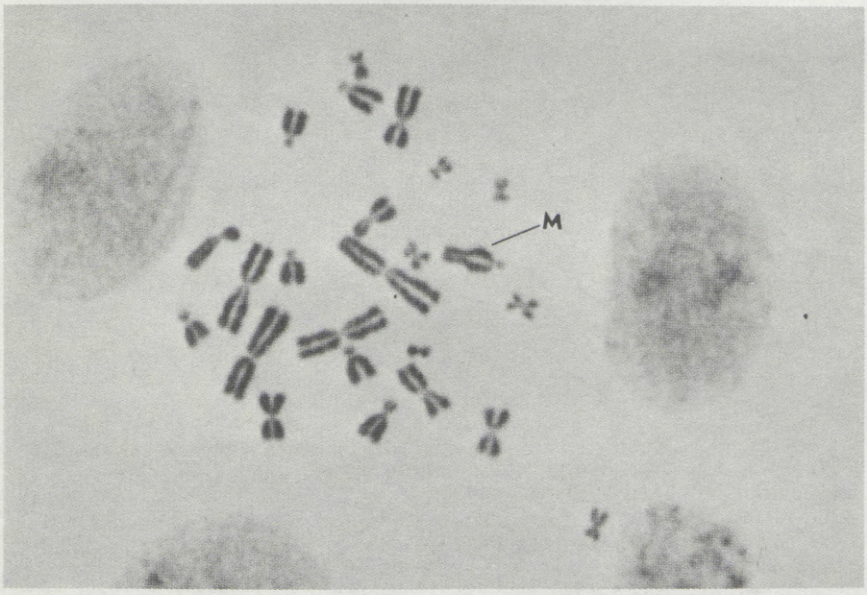


Figure 5. Marker Chromosome (M) in Cultured Chinese Hamster Thyroid Cells.

2. Effect of ^{131}I on the Incidence of Thyroid Tumors
B. C. Ward, W. Moore, Jr., W. M. Leach

In order to determine the incidence of thyroid tumors in Chinese hamsters after ^{131}I exposure, 7-10 day old animals were injected with 0.001-0.1 μCi of ^{131}I (the approximate dose to the thyroid is estimated to be 10 to 1000 rads). Hamsters were sacrificed about two years after injection, and examined for tumors.

Tumors were found in the thyroid gland, liver, and uterus. In addition brain vascular changes were found which resulted in massive cerebral hemorrhage. The hemorrhage was the greatest single cause of death to hamsters during the experiment. The number of tumors is summarized in Table 2. Incidence of lesions in the uterus, liver, and brain appeared to be unrelated to ^{131}I exposure. In the thyroid two of the 20 tumors were carcinomas and the other 18 were adenomas. In view of the small number of animals in the study, the dose-effect relationship for thyroid tumorigenesis remains unclear.

TABLE 2. TUMORS IN CHINESE HAMSTERS TWO YEARS AFTER INTRAPERITONEAL INJECTION OF ^{131}I

Injected ^{131}I, μCi/animal	No. of Animals	Tumors in			Animals with Brain Vascular Changes
		Thyroid	Uterus	Liver	
0.1	49	3	8	14	12
0.05	53	6	5	12	11
0.01	51	4	5	11	11
0.001	50	7	6	11	10
none	50	0	6	18	7
Totals (Frequency)					
^{131}I	203	20(0.10)	24(0.12)	48(0.24)	46(0.23)
Control	50	0(0)	6(0.12)	18(0.36)	7(0.14)

3. Chromosome Stickiness and Division Delay in Irradiated Cultured Cells
W. M. Leach, E. C. Beyer

Chromosome stickiness may be observed in dividing cells that were near division at the time of exposure to heat, X-rays, or hypertonic medium. Data obtained in this laboratory indicate that stickiness effects are mitigated through RNA on the chromosomes of dividing cells.

The possibility that chromosomal changes, induced by microwaves, result from stickiness effects is being explored. Chinese hamsters are exposed to microwaves from microwave ovens at various intervals after injection of Colcemid to arrest bone marrow cells at metaphase. Direct smears of bone marrow cells are made after 4-5 hours of Colcemid exposure.

In preliminary studies no chromosome aberrations have been observed. Chromosomes from irradiated animals appear not as well spread after hypotonic treatment as chromosomes from unirradiated controls. Both intrachromosomal and interchromosomal stickiness phenomena are observed in irradiated cells.

4. The Effects of X-ray Quality on Chromosome Aberration Yields
K. T. S. Yao, E. C. Beyer, W. M. Leach

Bureau interest in public health hazards of X rays produced by color television receivers has prompted comparative studies of X-ray quality on the yield of chromosome aberrations in animals and in cells cultured in vitro. Three X-ray sources operating at a 25 kVp, 250 kVp, and 3.6 MVp, are to be used. The latter source delivers X rays in a pulse lasting 10^{-3} second.

To date 14 Chinese hamsters have been flash irradiated at nominal exposures of 10, 50, or 100 R, each delivered as a single pulse of 3.6 MVp X rays. Animals were sacrificed 1, 6, 13, and 27 days post-irradiation, and kidneys and hearts were removed for tissue culture. Preliminary analysis of the slides of cultured cells reveals small differences in the aberration yields when either X-ray exposure levels or organs of the same animals are compared. The frequency of aberrations for each exposure level and for each tissue is higher than the frequency in unirradiated control animals.

5. Effects of Rat Kangaroo Hematopoietic Cell Lines on the Survival of X-Irradiated Animals.
K. T. S. Yao

Injection of normal bone marrow or spleen cells either freshly obtained or from short-term cell cultures may prolong the survival of animals which have received X-ray doses greater than the species LD 50/30. The technique has been used effectively with accidentally exposed humans. The purpose of this study was to investigate the effectiveness of long term heterologous cells on prolonging animal survival.

Chinese hamsters and mice were given 800, 1,200 or 1,600 rads of X rays (250 kVp, 15 mA, HVL 1.82 mm Cu plus 1 mm Cu and 1 mm Al

added filtration, 60 cm air distance, dose rate approximately 52 rads per minute). Within 4 hours after irradiation the animals (68 hamsters, 52 mice) were injected with cells derived from either the bone marrow or spleen of the rat kangaroo. Chinese hamsters were injected intraperitoneally with about 10^7 cells in 1 ml; mice were injected intravenously with approximately 2.5×10^6 cells in 0.5 ml. Unirradiated control animals were injected with saline. The rat kangaroo cell lines were initiated in August 1966, and had 32 subculture passages when the experiments were started.

Animals that received 800 rads showed no radiation death, with or without cell injections. All of the animals that received 1,600 rads died within 7 days after irradiation. In the Chinese hamsters receiving 1,200 rads, 12.5 percent survived at least 30 days with cell injections and 10.5 percent survived at least 30 days without the injections. In the mice receiving 1,200 rads, 35.1 percent survived at least 30 days with cell injections, but no mice survived to 30 days without cell injections.

Mice given 1,200 rads showed 31.5 percent survival after spleen cell injections and 38.8 percent survival after bone marrow cell injections. In the hamsters 5.5 percent survival followed spleen cell injections and 18.1 percent followed bone marrow injections. The data are summarized in Table 3.

TABLE 3. SURVIVAL OF MICE AND CHINESE HAMSTERS AFTER 1,200 RADS OF 250 KVP X-RAYS

	Rat Kangaroo Cell Injections						Saline Injections		
	Spleen			Bone Marrow					
Animal Species	No. of Animals	Average Survival Time, Days[a]	No. of 30-day Survivors	No. of Animals	Average Survival Time, Days[a]	No. of 30-day Survivors	No. of Animals	Average Survival Time, Days[a]	No. of 30-day Survivors
Mouse	19	15.7	6	18	18.9	7	15	10.1	0
Chinese Hamster	18	9.7	1	22	14.2	4	19	10.7	2

a. The average survival calculations included animals surviving at least 30 days. For the calculation 30 days was used, regardless of the actual duration of survival.

A relatively specific pattern of epilation and hair graying was observed in seven irradiated Chinese hamsters. Two of the seven died at 19 and 24 days postirradiation, one was sacrificed at 30 days and two others at 60 days postirradiation. The other two survived more than one year. By the 14th day postirradiation, shedding of hair started at

the top of the head. Shedding extended progressively toward the posterior, but stopped at the waistline. At about 30 days white hair appeared in the shed areas. By 60 days the white hair covered the shed areas except the top of the head. Graying of the normal agouti hair began behind the waistline about 90 days and extended progressively toward the tail. By 250 days animals were gray-white except for agouti ears, tail, a small posterior spot, and black upper lip whiskers. Two grayed and one unirradiated animal are shown in Figure 6.

Hair samples were taken from the two surviving irradiated animals and from one unirradiated animal, and were prepared for microscopic examination. Four hair types were found: Type A has a single row of medullary cells; type B has a proximal "stalk" section with a single row of cells and a distal "blade" section with 2-5 rows of cells; type C is similar to B, except that a constriction occurs between the stalk and blade sections; and type D, otherwise similar to A, has a constriction close to the tip and 2-4 bends in the hair. The degree of pigmentation of the hairs was graded as follows: Grade 1, less than 15 percent lack of pigmentation; grade 2, 15-50 percent unpigmented; grade 3, 50-85 percent unpigmented; and grade 4, 85-100 percent unpigmented. Table 4 summarizes the results of the hair measurements, with standard deviations of average values shown.

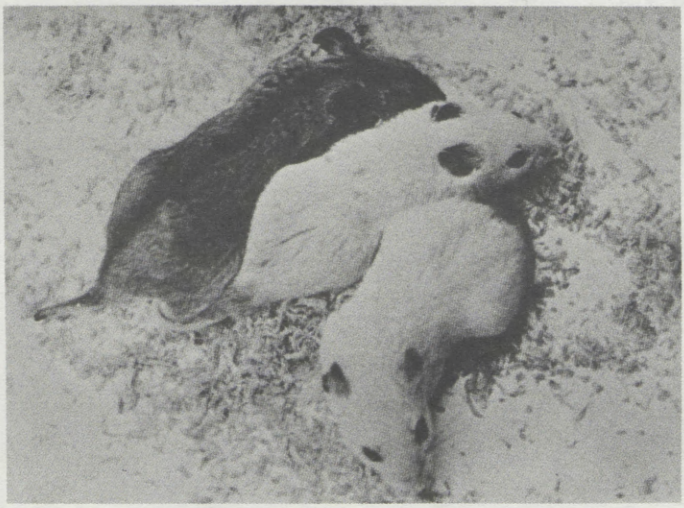


Figure 6. Two Chinese Hamsters with Gray Hair after 1,200 Rads of X Rays. After irradiation, animals were injected with cultured cell lines originally derived from the rat kangaroo. Back to about the waistline, the gray hair grew in after marked epilation. One normal agouti animal is also shown.

TABLE 4. CHINESE HAMSTER HAIR TYPE, DISTRIBUTION, AND AVERAGE MEASUREMENTS BEFORE AND AFTER EPILATION

X-Ray Dose, Rads	Body Region	Hair Type	Number of Hairs	Length[a]	Number of Constrictions[a]	Pigment Grade[a]	Frequency of White Tips, Percent
0	Shoulder	A	6	6.8 ± 0.72	0	1.3 ± 0.40	0
		B	28	7.9 ± 0.77	0	1.9 ± 0.49	0
		C	11	7.6 ± 0.76	1.1 ± 0.90	1.6 ± 0.45	0
		D	75	6.5 ± 0.70	1.6 ± 1.09	1.7 ± 0.46	0
	Haunch	A	9	8.3 ± 0.88	0	1.3 ± 0.45	0
		B	46	9.2 ± 0.97	0	1.9 ± 0.55	0
		C	13	8.9 ± 0.96	1.1 ± 0.99	1.7 ± 0.52	0
		D	52	7.8 ± 0.90	1.4 ± 1.11	1.3 ± 0.45	0
1200	Shoulder	A	10	4.9 ± 0.84	0	3.3 ± 0.65	90.0
		B	39	6.1 ± 0.93	0	3.7 ± 0.68	94.9
		C	18	6.3 ± 0.95	1.0 ± 0.85	3.8 ± 0.70	94.4
		D	53	5.5 ± 0.89	1.3 ± 0.97	3.2 ± 0.64	98.1
	Haunch	A	20	6.8 ± 1.08	0	1.6 ± 0.85	30.0
		B	27	8.5 ± 1.21	0	2.3 ± 1.02	14.8
		C	11	8.5 ± 1.21	1.1 ± 1.06	2.3 ± 1.02	9.9
		D	62	6.9 ± 1.09	1.6 ± 1.27	1.7 ± 0.88	14.5

a. Average ± one standard deviation is shown.

6. In Vitro Cultivation of the Seminiferous Epithelium of Chinese Hamsters
D. J. Ellingson, K. T. S. Yao

In order to examine directly radiation effects on spermatogenesis, we have attempted to culture germinal cells. Rose chambers have been used to contain portions of seminiferous tubules under a dialysis membrane. Eagle's minimum essential medium supplemented with 1.0 mM sodium pyruvate, 1.0 mM non-essential amino acids and 20 percent calf serum, was used. L-Glutamine (2-4 mM) plus 100 units of penicillin and 100 μg equivalents of streptomycin per ml were added. The cultures were maintained at 31°C at a pH between 6.8 and 7.0.

Tubules were flattened by the dialysis membrane. Some of virtually each cell type, and most of the spermatocytes developing spermatids and spermatozoa were pressed out from the cut ends. Most spermatogonia, Sertoli cells, and some spermatocytes remained inside the tubule. Expressed spermatocytes, as well as developing spermatids, survived 3-4 days in vitro. Spermatocytes in metaphase I or II completed one meiotic division. Spermatogonia lived 2-3 weeks in culture and underwent mitosis (Figure 7). Sertoli cells began migration out

of the tubule in about 24 hours. Sertoli cells divided actively, and overgrew cultures by 3-6 weeks of age. The Sertoli cells at culture initiation were associated rather specifically with spermatogonia (Figure 8).

Oscillation and/or rotation of nuclei and metaphase plate were observed in spermatogonia and spermatocytes. In the spermatocytes nuclear rotational movement was seen during the first 3-4 days of culture; in spermatogonia movement persisted after three weeks of culture. Movements were sporadic, uncoordinated, and either clockwise or counterclockwise. Occasionally a cell reversed its direction.

Time-lapse cinemicrographic observations of 14 cells with rotating nuclei were analyzed, and the results are shown in Table 5.

TABLE 5. NUCLEAR ROTATION FROM TIME-LAPSE CINEMICROGRAPHIC ANALYSIS

Cell Number	Number of Observed Rotations	Range of Speed of Rotation, seconds	Average Speed of Rotation, seconds
1	5	118 - 591	362 ± 181
2	16	46 - 192	96 ± 44
3	8	71 - 412	202 ± 108
4	8	108 - 342	180 ± 78
5	3	285 - 690	429 ± 226
6	3	288 - 642	450 ± 179
7	13	48 - 303	110 ± 70
8	15	48 - 288	101 ± 83
9	23	34 - 201	70 ± 25
10	13	46 - 281	117 ± 72
11	20	43 - 186	80 ± 43
12	16	51 - 184	99 ± 39
13	6	149 - 347	271 ± 63
14	23	46 - 109	68 ± 16
Total	172	34 - 690	---

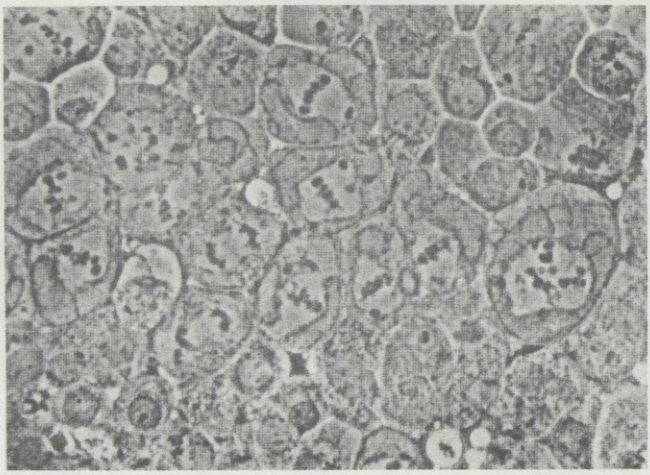


Figure 7. Mitosis in Spermatogonia Cultured from Chinese Hamsters. Cultures were in Rose chambers, where spermatogonia were recognized for 2-3 weeks after initiation of the culture.

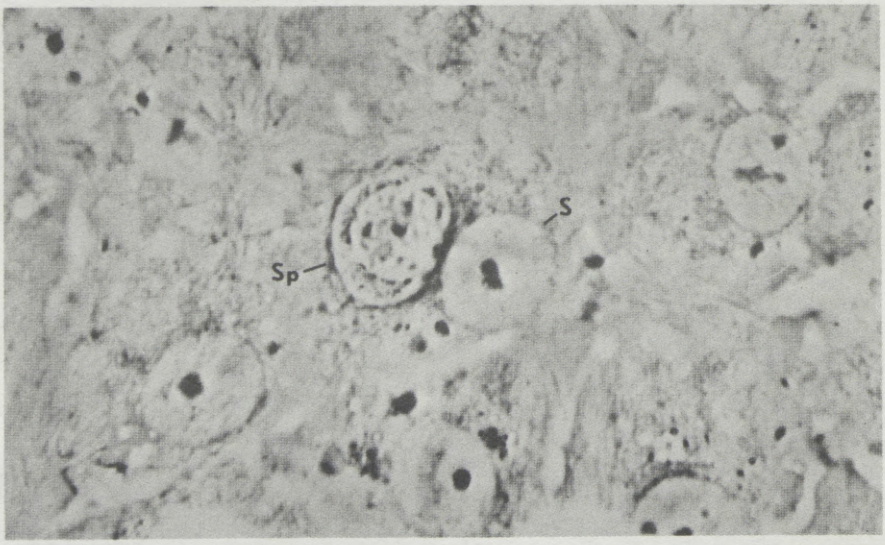


Figure 8. The Sertoli Cell-Spermatogonium Side-by-Side Orientation at the Beginning of In Vitro Culture of Testicular Tissue of the Chinese Hamster. During culture in Rose chambers, the Sertoli cells (S) may become less closely associated with some spermatogonia (Sp).

RADIATION PHYSICS LABORATORY
Mr. Harry D. Youmans, Chief

The responsibilities of the Radiation Physics Laboratory are twofold: to provide the Radiation Bio-Effects Program with irradiation, dosimetry, and related supportive services, and to conduct research studies with primary emphasis on dosimetry. During most of 1968 the Radiation Physics Laboratory has been concerned with the generation and measurement of ionizing radiations, the accurate exposure of biological specimens, and the application of results of its research studies which are primarily directed at spectral measurements and determinations of absorbed dose.

The passage of the Radiation Control for Health and Safety Act of 1968 has increased the demands upon the Radiation Physics Laboratory for detailed firsthand knowledge concerning the interaction of nonionizing radiations with biological systems, their characteristics, and their measurement. A new microwave exposure facility has been installed. New investigations germain to nonionizing radiation dosimetry will provide information on the distribution of energy absorbed in non-homogeneous tissue and molecular systems in a wide range of wavelengths, the characteristics of tissue equivalent systems at various wavelengths, and the identification of the molecules and tissues that undergo primary beam energy absorption, as well as the molecules and tissues that respond to the energy absorption.

A. LABORATORY SERVICES

1. Irradiations
W. Lee, L. Kramer, V. Yancik

The Radiation Physics Laboratory provides X and gamma irradiation of biological specimens and the dosimetry of exposures both external and internal to biological or phantom systems. The irradiation facility consists of a 1,000 curie cesium-137 irradiator, a 250 kilovolt constant potential (kVcp) X-ray generator, and a 120 kilovolt-peak (kVp) superficial therapy X-ray unit. In addition, a specially designed, high-output, low-energy (0-75 kVp) X-ray source was installed in December. The primary dosimetry for this unit is now being done.

Specimens include a variety of animal species, cultured cells, and various tissue equivalent materials and phantoms. Because of this variety, only the outlines of dosimetric procedures can be standardized.

Although dosimetry is based upon National Bureau of Standards calibrated R-meters, dosimetry is usually performed with tissue equivalent phantoms and thermoluminescent dosimeters with energy corrections based upon measured spectra. The irradiations for the year are summarized in Table 6.

TABLE 6. IRRADIATIONS AT THE TWINBROOK LABORATORY, 1968

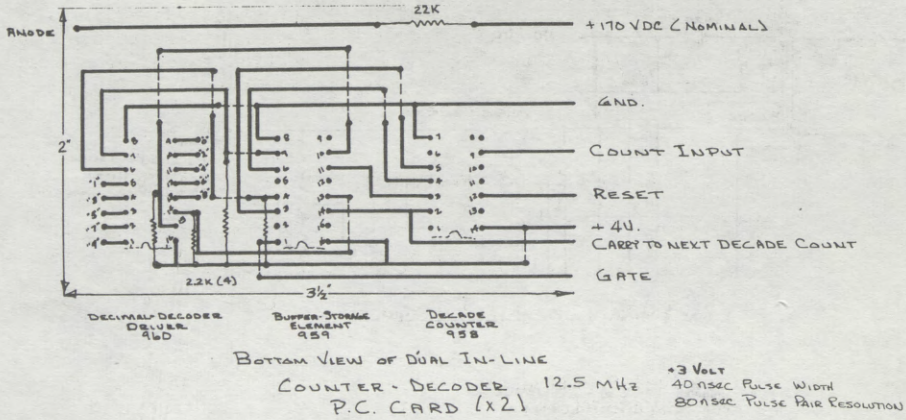
Specimen	Number	Beam On-Time, Hours
	X Irradiations	
Rats	3,626	259.5
Biological Specimens	486	34.0
Hamsters and Mice	283	8.0
Swine	2	1.1
	Cesium 137	
TLD Calibration		4
TLD Capsules		0.1
Biological Specimens	2	0.08

2. Instrumentation and Electronics
G. E. Anderson, R. A. Tell

In providing irradiation and dosimetry services to the Radiation Bio-Effects Program, the Radiation Physics Laboratory is occasionally confronted with the problem of developing instrumentation for the dosimetry work. One such device developed this year, a six-decade scaler, was developed as the readout display for a charge digitizer. The display and the digitizer are two units that will be used as part of a thermoluminescent dosimeter (TLD) system for studying the glow-curve response of lithium fluoride (LiF), a thermoluminescent material commonly used in dosimetric studies.

Each decade circuit board consists of a decade counter, a buffer-storage element, and a decimal decoder - display driver. These are all integrated circuit devices. The use of integrated circuits decreased the design time and resulted in a compact unit with dimensions of 9 by 9 by 3 inches. The circuit diagram is shown in Figure 9.

The entire unit consists of six decade boards with Nixie tube readout, two regulated power supplies, and an input gate circuit.



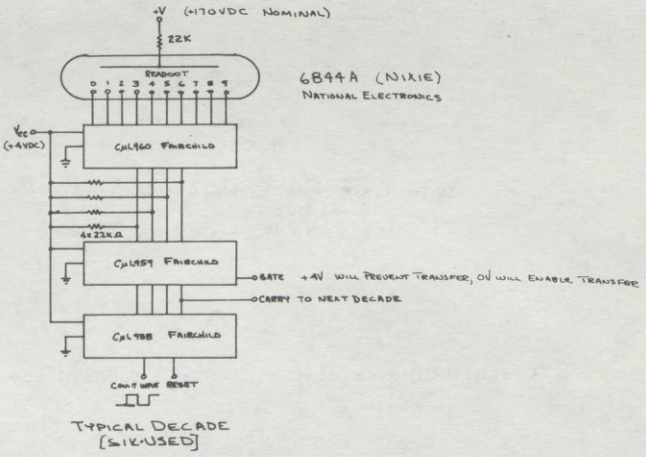


Figure 9. Circuit Diagram of Decade Circuit Board.

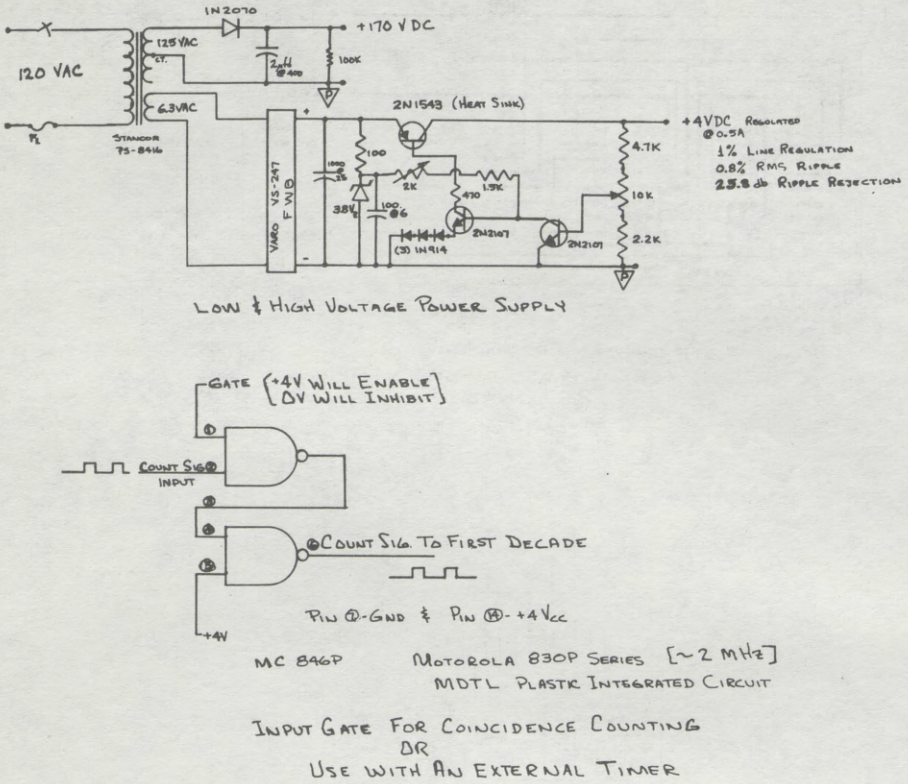


Figure 9. Circuit Diagram of Decade Circuit Board (continued).

3. Installation of Low-Energy X-Ray Machine
G. E. Anderson, R. A. Tell

During the year the Radiation Physics Laboratory installed a low energy (0-75 kVp) X-ray machine, which, with proper filtration, will be capable of simulating the X rays emitted by color television receivers. The X-ray tube employed has a 5-mil beryllium window, a platinum target, and is capable of continuous operation at 30 kV and 100 mA.

Preliminary investigations of the X-ray emission indicate that the unfiltered exposure rate is of the order of 8.6×10^6 R/min at the window under operating conditions of 40 kVp and 75 mA. Higher exposure rates are expected at the maximum tube voltage rating of 75 kV.

The high voltage power supply also produces 0 to 75 kV dc at a rated current of 100 mA dc. An overall accuracy of 1% of the desired output voltage allows precisely controlled condtions of irradiation.

To obtain constant and reproducible exposure rates from the machine, an improved milliampere stabilizer and filament power supply were developed in this laboratory. The stabilizer employs the theory of closed loop stabilization. The basic loop consists of an amplifier, bias control circuit, filament drive circuit, detector, and a summing network. These are connected so that the bias control circuit will adjust the filament drive circuit and increase or decrease the X-ray tube current until the detector produces a feedback signal that cancels the input command (the desired current flow).

In general, the performance of the loop is related to its "stiffness." If it has high gain, then only a small error signal is needed to drive the controller; the output follows the input and any perturbations are then compensated.

The mathematical analysis of this kind of mechanism is rather complex but can be reduced to an algebraic manipulation of the coefficients of a system of differential equations. It will suffice to say the loop gain is adjusted so that the frequency response crosses the zero dB axis just prior to the second pole (180 degree phase shift). The circuit diagram for the mA stabilizer is shown in Figure 10. Short term stability tests indicate a drift of 0.02% from a mean value of current over a half-hour exposure time (after a 5 minute warm up).

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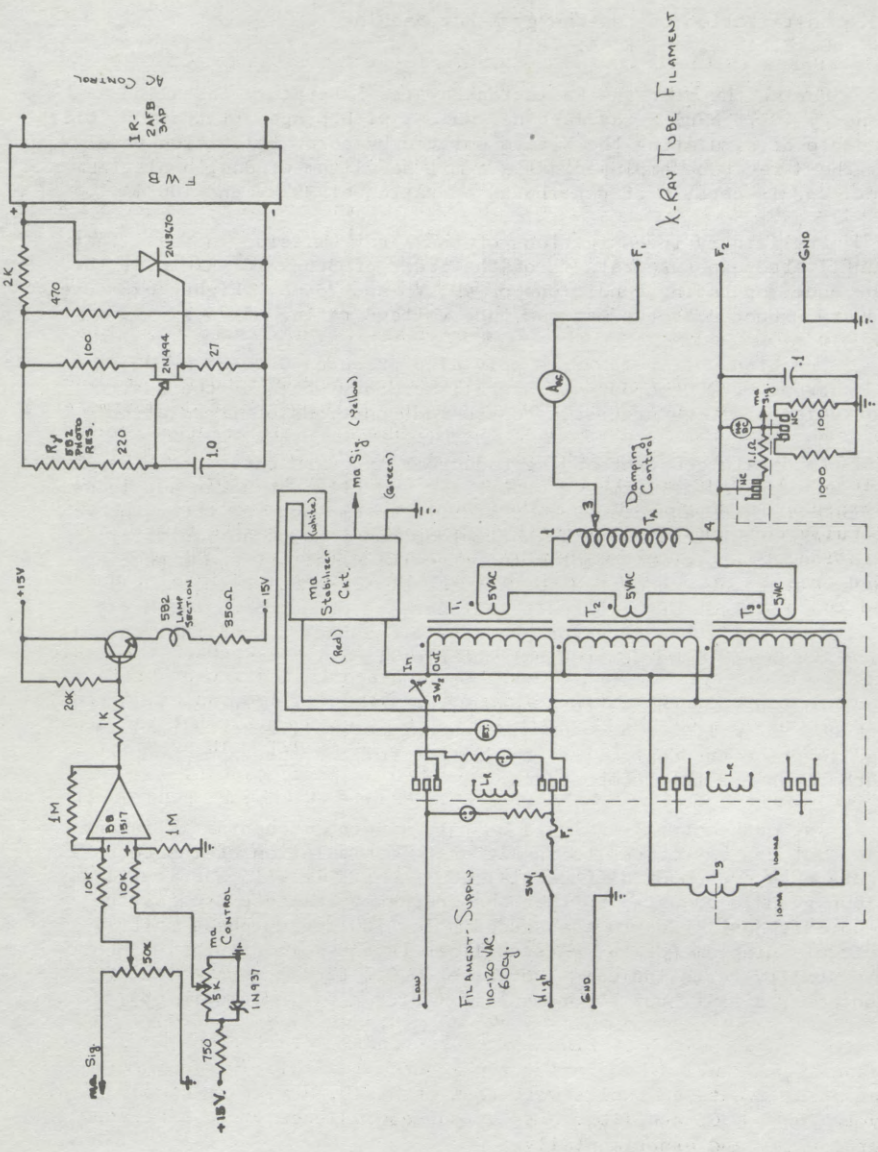


Figure 10. Milliampere Stabilizer Developed for Use with Low-Energy X-Ray Machine.

B. DOSIMETRY AND RADIATION PHYSICS

1. Doses in the Brain, Eye and Thyroid of Children from 63-112 kVp X-Ray Epilation for Tinea Capitis
W. Lee, H. D. Youmans

Tinea capitis is a fungal infection of the scalp which has occurred in epidemics among prepubescent children. X-ray epilation of the scalp was commonly used in treatment prior to the availability of griseofulvin in 1958. Recent studies indicate a relationship between X-ray epilation of the scalp and increased incidences of neurological disorders and malignancies. A collateral study by this laboratory has shown by thin layer chromatography that the lipid composition of in vivo irradiated beagle pup brain is altered by doses in this range (see page

This study was conducted to determine the distribution of dose in the brain, eye, and thyroid of children. Lithium fluoride dosimeters were used in phantoms made from mix-D and human skulls of ages 3 years, 6 years, and 12 years for exposure to 60 kVp, 90 kVp and 110 kVp X-irradiations. X-ray beam qualities were determined in air and in the phantom brain by both absorption methods and Ge(Li) spectrometry. The data were fully corrected for spectral dependence which results from heavy filtration of the incident beam by the scalp and skull. The doses ranged from 17 rad to 656 rad in brain, 11 rad to 92 rad in eye, and 3 rad to 23 rad in thyroid.

In general, the radiation treatments for "ringworm of the scalp" depended on the age of the patient (which was a reflection of brain size and cranium thickness) and the place of treatment. The radiation treatments varied from 60-120 kVp with HVT's of 0.4-4.0 mm Al, but the beams most commonly used were 75-100 kVp with 1.0 mm Al HVT. The radiation exposure ranged from 300 R to 500 R per field. Five such fields were used to obtain a uniform scalp dose (the Adamson-Kienböck technique).

In our study, three beams were used to cover the range of irradiation conditions. The qualities of the three beams were: (1) 63 kVp, HVT = 0.67 mm Al; (2) 88 kVp, HVT = 1.00 mm Al; and (3) 112 kVp, HVT = 3.90 mm Al. The X-ray tube current was 10 mA. Half-value thicknesses were determined with 99.99% aluminum foils and sheets. The attenuation curves of the three beams are presented in Figure 11.

Three children's skull phantoms (ages 3, 6, and 12 years) were selected for the dose distribution measurements. Variations in cranium thickness and skull dimensions are presented in Table 7. The brain phantoms of the three skulls were cast of Mix-D, a mixture of paraffin, polyethylene, MgO, and TiO_2. Its tissue equivalence was established theoretically and experimentally.

To gain access into the brain for dosimeter locations, the skulls and Mix-D brains were cut horizontally, dividing them in half. Two

TABLE 7. DIMENSIONS OF HEAD PHANTOMS[a]

Skull Phantom Age, Years	Maximum Diameter AP, cm	Maximum Diameter Lat, cm	Cranium Thickness Mean, mm	Cranium Thickness Range, mm
3	15.5	12.0	2.4	1.5-3.0
6	16.0	12.5	2.9	2.5-4.0
12	16.5	13.0	3.3	2.5-4.0

a. All measurements include a Mix-D scalp thickness of 3 ± 1 mm.

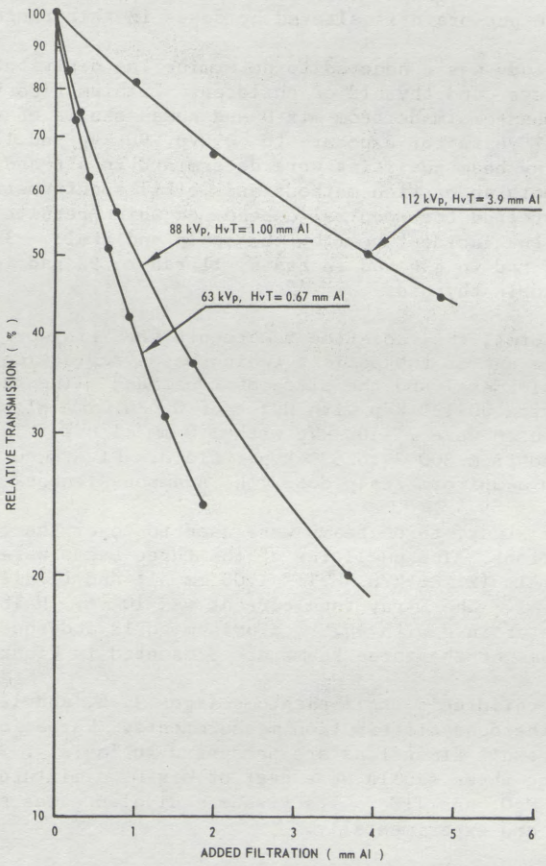


Figure 11. Attenuation Properties of the Three X-Ray Beams Used for This Study.

additional vertical cuts divided the brain into six sections. Forty-nine dosimeter locations were selected and dosimeter holes 5 mm in diameter and 12 mm deep were drilled into the six sections (Figure 12).

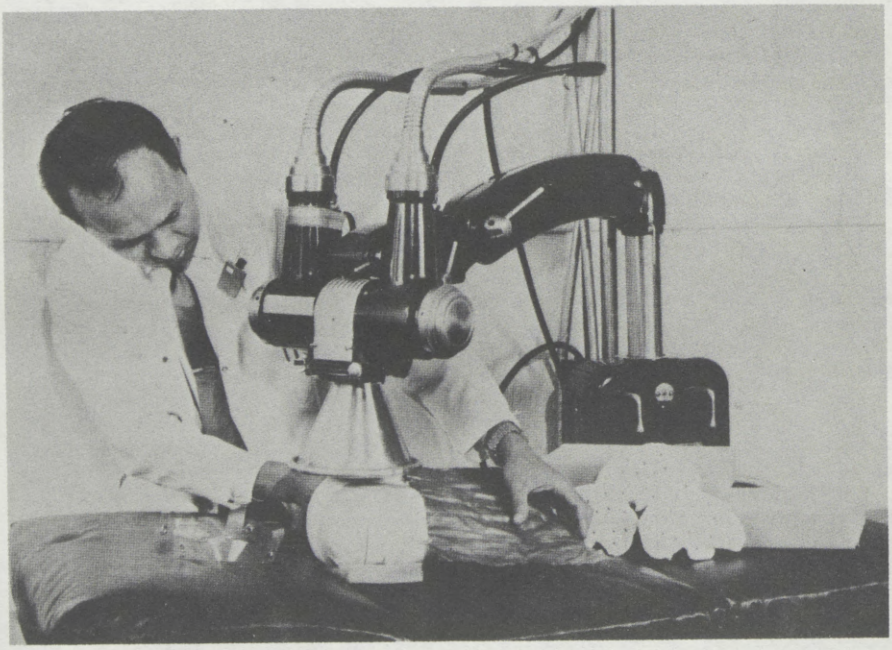


Figure 12. One of the Positions Used in Irradiating Skull Phantoms to Obtain Dose Distributions in Brain. Brain phantoms with holes for thermoluminescent dosimeters are shown at right.

Lithium fluoride (TLD-100) powder in thin gelatin capsules was employed for the dose measurements. The dosimeters were appropriately calibrated and their response as a function of exposure was determined. Since the response was linear up to 600 R, and the exposures rarely exceeded 600 R, 100 R (100 kVp, 3.5 mm Al HVT) was used for calibration.

The effective energies in the brain phantom for the three beams employed were measured with the "cap on -- cap off" method in the 3-year-old skull phantom. This method enables the quality of a beam to be estimated in any material simply by finding the ratio of exposures with an appropriate dosimeter at a point in the material when it is encapsulated in metal and when it is not encapsulated. If a set of ratios has been previously determined in air for a corresponding set of HVT's, any measurement of the ratio is equivalent to a determination of a HVT. Because two parameters are necessary to specify X-ray beam quality, such sets are not theoretically unique, but they are usually adequate when thoughtfully employed.

The qualities of the three beams in the middle of the 3-year-old head phantom were 2.1, 2.6, and 4.3 mm Al HTV for the 63 kVp, 0.67 mm HVT; 88 kVp, 1.00 mm Al HVT; and 112 kVp, 3.90 mm Al HVT, respectively. The energy responses of the dosimeters were within the experimental error.

The ratio of absorbed dose (in soft tissue) to exposure ($\bar{f}$) was relatively constant over the energy range of interest. The estimated HVT's of 2.1, 2.6, and 4.3 mm Al in brain corresponded to effective energies of 28, 30, and 38 keV. Therefore, the value of 0.88 rad/Roentgen (water) was used for all calculations of dose from exposure response.

The Adamson-Kienbock five-field treatment technique was used to irradiate the phantoms. The central axis of the X-ray beam was positioned at five points: frontal, vertex, occipital, and the left and right temporal areas. Each skull phantom was irradiated with the three beams described previously. During irradiation, a lead sheet 0.4-0.5 mm thick shielded the areas below the hair line of the phantom (Figure 12). Most lead-rubber used for patient shielding had lead equivalent thicknesses of 0.25 to 0.5 mm.

A Picker Zephyr Model NR-2 X-ray machine with an oil-cooled type CX-B X-ray tube and a 3.8 mm effective focal spot size was used. A vacuum-tube-controlled constant voltage transformer stabilized the electrical supply to the X-ray machine and the X-ray tube current was stabilized by a silicon-controlled rectifier circuit of our own design. This machine produced a field size 18 cm in diameter at a source-to-skin distance of 21.5 cm; the exposure was 400 R per field.

In general, the upper 2/3 of the brain, representing most of the cerebral cortex but excluding the lower frontal and temporal lobes of the cortex, received the highest doses. The lower 1/3 of the brain received a dose of only 60% of that received by the upper 2/3. This lower third included the cerebellum, brain stem, the lower half of the mid-brain, and

the lower frontal and temporal lobes of the cortex. Considering the whole brain, the superior lobe of the frontal cerebrum received the highest dose; the brain stem and the lower half of the cerebellum received the lowest doses.

Since additional shielding was never present over the upper portion, and the frontal lobe of the cerebrum is at right angles to four of the five irradiation fields, the dose distribution to the upper 2/3 was somewhat higher than to the rest of the brain. Dose to the upper 2/3 of the brain was quite uniform relative to the average for the whole brain.

The mean absorbed doses in the brain as functions of HVT's of the irradiating beams and the ages of the skull phantoms are shown in Figure 13 and Table 8. As expected, an increase of the HVT of a beam increased the depth dose distribution in the brain. The dose-HVT relationship in Figure 13 is a strong function. An increase in cranium thickness of only 1 mm can reduce the dose by as much as 30% in the brain, depending on the quality of the irradiating beam.

TABLE 8. MEAN DOSE TO THE BRAIN

Beam Qualities		Dose,	Brain Phantom		
mm Al HVT	kVp	Rads	3-year	6-year	12-year
0.67	63	Average Dose	80.1	76.5	67.3
		Dose Range	23-139	31-118	17-119
1.00	88	Average Dose	147	131	112
		Dose Range	50-238	61-190	33-184
3.90	112	Average Dose	432	422	416
		Dose Range	164-656	211-562	139-611

When the mean absorbed dose was used as a common denominator, our calculations showed that the upper 2/3 of the brain absorbed about 120% of the mean dose, whereas the cerebellum and the lower 1/3 of the brain received only 50% and 75%. This relationship is fairly independent of the quality of the irradiating beam and the age of the skull phantom. Therefore, once a mean dose is estimated from Figure 13 the brain dose distribution can be approximated.

Doses to the eye, pituitary, and thyroid gland are presented in Table 8. Pituitary doses in the 6-year-old skull phantom were not determined because an additional vertical cut in the skull parallel to the face of the phantom was directly over the pituitary. For vertex and the temporal exposures, the cut provided radiation leakage to the pituitary and measured values would have reflected this defect. Doses to the pituitary in the 6-year-old phantom should be very similar to those of the 12-year-old because of their similarities in cranium thickness and brain size (Table 7). The thyroid dose in the 12-year-old phantom is higher than that of the 6-year-old. This might be due to the longer face and neck of the 6-year-old phantom; consequently a longer source-to-

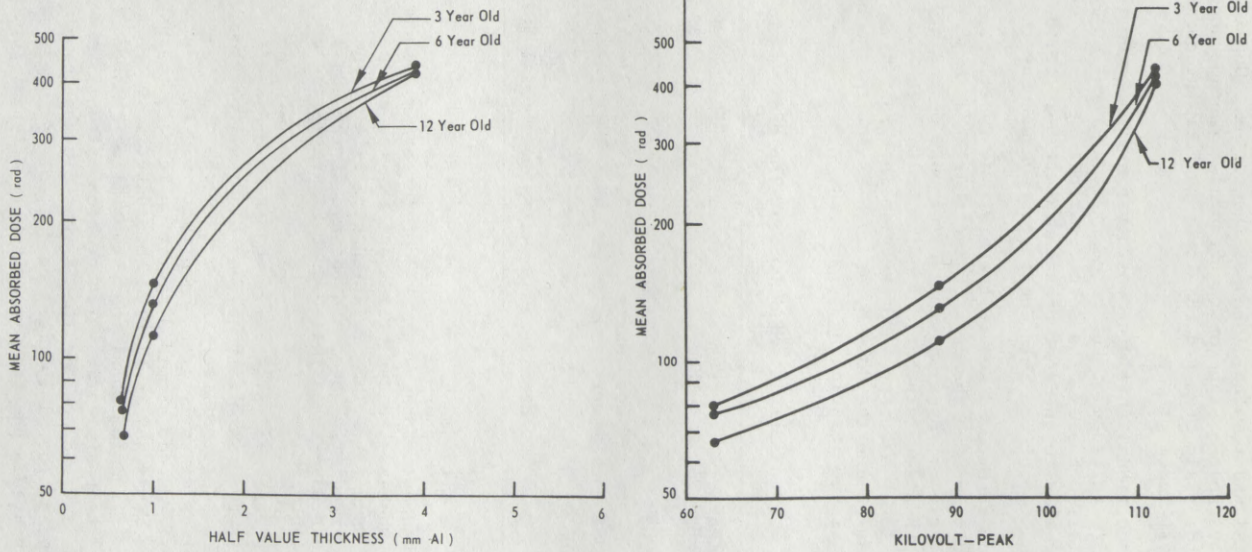


Figure 13. Mean Absorbed Dose in Brain as a Function of Half Value Thickness (left) and X-Ray Tube Potential (right).

thyroid distance. We do not know whether or not to consider this phenomenon to be unfortunate because just these variations exist in the population.

TABLE 9. DOSE TO THE THYROID, EYE, AND THE PITUITARY

Age of Phantom, Years	Beam Qualities		Dose, Rads		
	kVp	mm Al HVT	Thyroid	Eye	Pituitary
3	63	0.66	2.94	11.2	14.6
	88	1.00	5.04	23.6	34.6
	112	3.90	23.1	92.2	128
6	63	0.66	1.10	8.18	--
	88	1.00	2.40	18.4	--
	112	3.90	10.3	75.4	--
12	63	0.66	1.62	8.48	13.9
	88	1.00	3.60	17.6	29.7
	112	3.90	14.6	73.4	121

2. Spectral Transmission and Attenuation of X Radiation by Glasses and Resins used in Color Television Picture Tubes
R. A. Tell, G. E. Anderson, H. D. Youmans

A cooperative study between the Radiation Physics Laboratory, the Bureau's Electronic Products Radiation Laboratory, and Pittsburgh Plate Glass Industries was begun to evaluate the X-ray attenuation properties of certain glasses and resins used to construct color television receiver picture tubes. The attenuation coefficients of common and experimental glasses and resins and fully constructed face plates were evaluated. The results of this study will be used as a basis for selecting scientifically valid methods for assessing the attenuation effectiveness on a quality control basis.

The picture tube emission spectra of two different tubes were measured by using a NaI(Tl) detector and multichannel analyzer. Supportive data were taken with a Ge(Li) detector system. Figure 14 shows the emission spectra from the RCA 25AP22A picture tube with and without its safety panel. The bandwidth is narrow, on the order of 25 percent FWHM, and is comparable to that obtained with monochromatic X rays.

Photon intensity depends upon high voltage, and was found to vary typically from the 19th to the 30th power of the high voltage given by the empirical relation, $R = AV^k$

where R = detector response
A = constant of proportionality
V = picture tube high voltage
$19 < k < 30$

The anisotropic emission of X-ray flux was measured and is shown in Figure 15. The highest relative flux, measured 50 cm from the screen, occurred at an angle normal to the picture tube face.

After determining typical spectra from the picture tubes, an X-ray machine was adjusted so that its spectrum was similar to that of the television tubes. Using appropriate collimation, narrow beam attenuation coefficients were determined for various glasses and bonding resins. Figure 16 shows the results of these measurements. Using these values, Figure 17 was developed showing percent transmission of 25 keV X-ray photons as a function of material thickness. These data are in good agreement with the calculated values of the attenuation coefficients.

3. Dosimetry and Narrow Beam Irradiation of the Young Rat Thyroid
W. Lee, J. R. Childress, T. R. Horton

In cooperation with the Radiation Oncology and Pathology Laboratory, the Radiation Physics Laboratory has been providing radiation exposure and dosimetry services for a study examining the relative incidence of thyroid tumors in irradiated rats of different ages (see p. To examine age sensitivity, groups of 120 Long-Evans female rats, ages

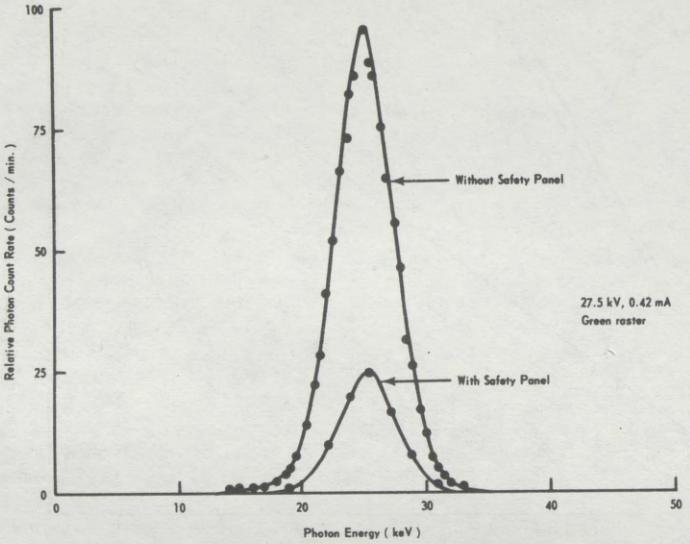


Figure 14. Emission Spectra of the RCA 25AP22A Picture Tube With and Without Its Safety Panel.

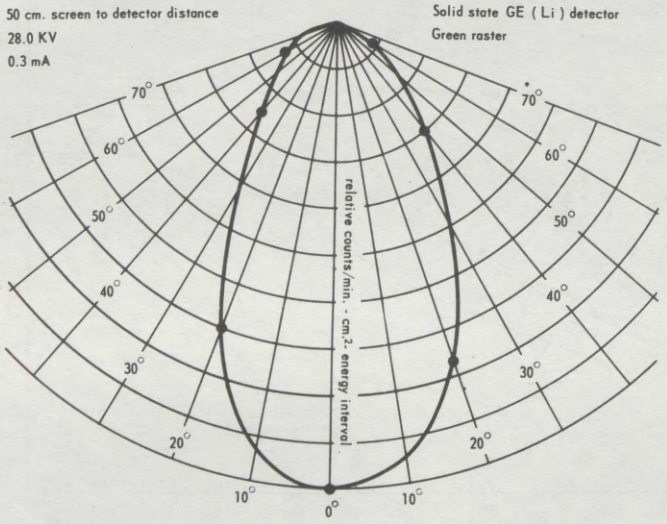


Figure 15. Spatial Distribution of X-Ray Flux at Various Angles About a Point on the Picture Tube Face.

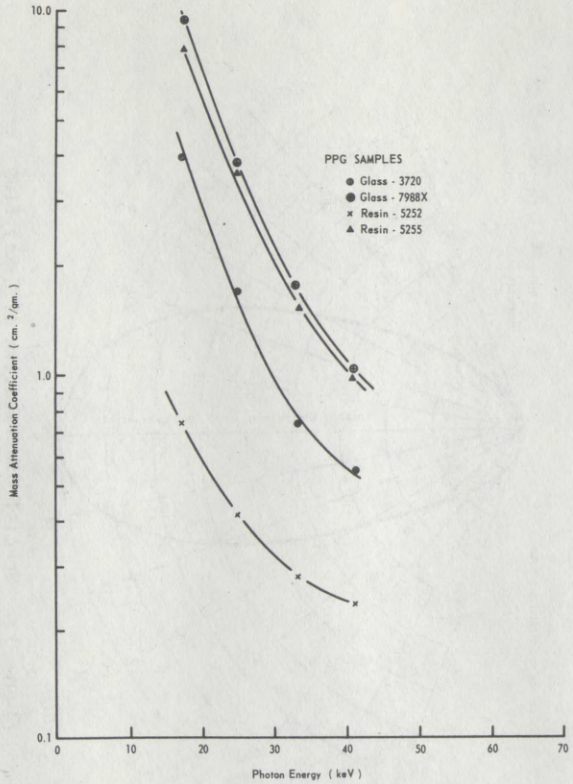


Figure 16. Narrow Beam Attenuation Coefficients of Various Glasses and Bonding Resins.

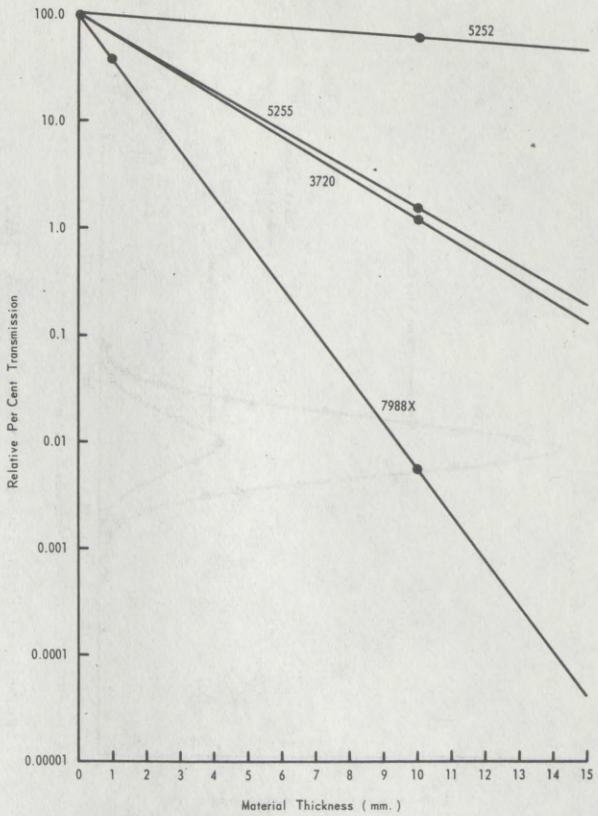


Figure 17. Relative Transmission of 25 keV X-Ray Photons as a Function of Glass and Resin Thickness.

10 days, and 1, 3, and 6 months were exposed to 1,000 rads of X radiation to the thyroid.

Because the thyroid and pituitary are functionally interdependent through hormonal biochemical mechanisms, care was taken not to expose the pituitary to the primary X-ray beam. This requirement, plus the small size of the young rat placed stringent restrictions upon exposure rate, dose uniformity, and dosimetry.

The X ray source was a 250 kVcp X-ray generator; the beam was collimated through specially designed and fabricated lead and brass collimators. Cross sectional uniformity of the beam and the positioning of the thyroid in the beam were evaluated radiographically. Depth dose, uniformity of dose, and the ratio of pituitary dose to thyroid dose were determined with encapsulated LiF rods imbedded in several sizes of rat cadavers (Figure 18).

As shown in Table 10 the absorbed dose rates varied from 1,754 rads to 1,931 rads per minute. The scattered radiation to the pituitary was only 2 to 3 percent of the thyroid dose. Thyroid dose rates of 1,900 rads per minute were achieved permitting the Class-A (NBS Handbook 88) irradiation of 240 rats in less than 2.5 hours of exposure time.

4. Dose Rate Determination in Bone Using LiF Thin Discs and Micro-Rods
U. H. Behling

A study was begun to investigate the use of LiF to determine the bone dose in cats that had been fed a steady diet of strontium 90 in equilibrium with its daughter yttrium 90. The high response, compactness, and relatively low energy dependence are characteristics of LiF that make it a desirable dosimeter. Thin discs of LiF-Teflon, 50 microns thick and 0.25 inch in diameter, and LiF extruded rods, 5.5 mm long and 0.8 mm in diameter were used.

Calibrated thin discs were taped to the exterior and to the longitudinally cut surfaces of bones; similarly calibrated LiF micro-rods were implanted in the trabecular regions of the bone (Figure 19).

As shown in Table 11 empirical exposure values of the discs ranged from 2.42 to 3.83 R/day which are in close agreement to theoretical values derived from β-fluence determination. Exposure rates for the microrods ranged from 2.44 to 3.53 R/day as determined from the response measured by the Conrad TLD Model 4 and quantitized from the calibration curve.

The exposure rates obtained from the micro-rods are not twice that of the thin discs as might be expected if the isotope were

TABLE 10. THYROID AND PITUITARY DOSES FOR FOUR AGE GROUPS

	10 days	1 month	3 months	6 months
Average weight, g	15.2	90	215	260
Anesthetic dose[a], mg	0.4	3.5	11.0	15.0
Thyroid Dose, rads	1000	1000	1000	1000
Pituitary Dose, rads	23.4	22.2	25	27
Thyroid Dose Rate, rads/min	1791	1754	1931	1869
Uncertainty, ± 1 S.D. %	3.2	5.7	2.5	3.8

a. Sodium pentothal administered per animal.

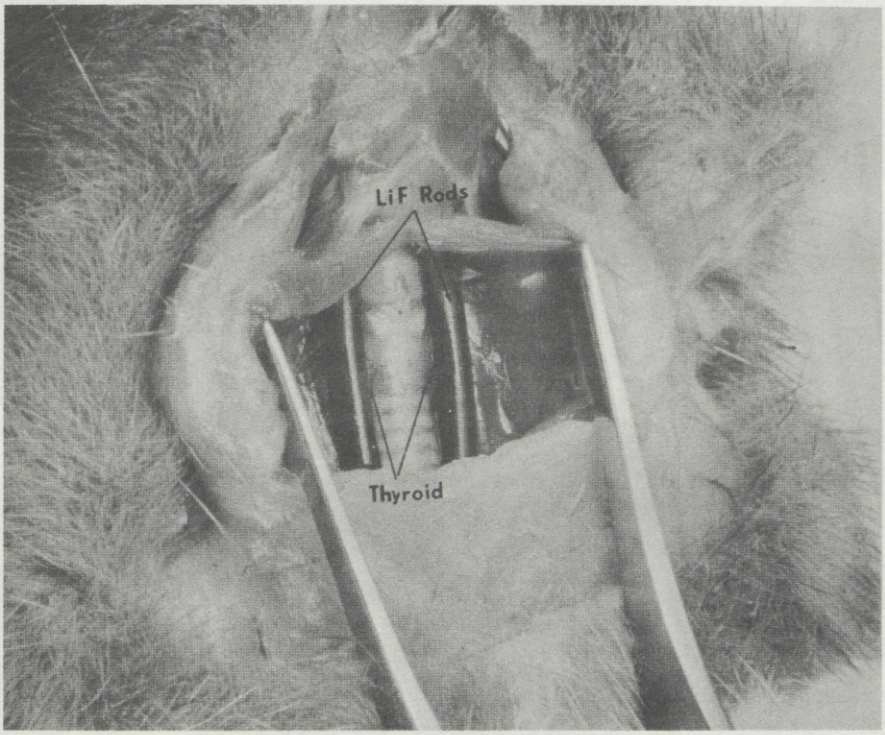


Figure 18. Encapsulated LiF Dosimeters Imbedded in Rat Cadavers Used to Determine X-Ray Dose to the Pituitary and Thyroid.

TABLE 11. LITHIUM FLUORIDE EXPOSURE DETERMINATIONS IN CAT BONES

	LiF Thin Discs			LiF Micro-Rods[a]	
Bone No.	Measured Exp. (R)	Measured Exp. Rate (R/day)	Calculated Exp. Rate (R/day)	Measured Exp. (R)	Measured Exp. Rate (R/day)
A					
Interior	9.94	2.48	3.38	20.8	3.53
Exterior	9.75	2.44	3.28	-	-
B					
Interior	11.60	2.90	3.34	14.4	2.44
Exterior	12.8	3.20	2.83	18.4	2.78
C					
Interior	-	-	-	15.8	2.54
Exterior	9.70	2.42	2.33	15.4	2.57
D					
Interior	9.70	2.42	3.29	21.7	3.51
Exterior	8.60	2.15	2.63	21.5	3.42
E					
Interior	-	3.38	3.33	16.8	2.77
Exterior	-	3.83	3.30	-	-

a. Except for the four spaces indicated, two internal measurements were made on each bone.

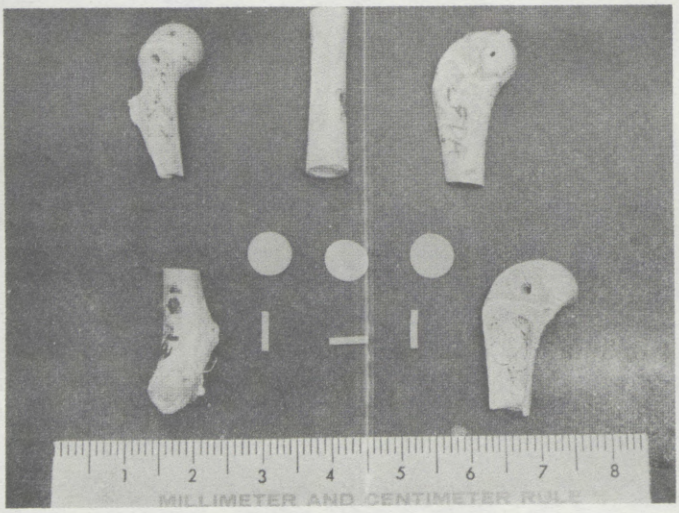


Figure 19. LiF Thin Discs and Micro-Rods Used to Obtain Radiation Doses in Trabecular Regions of Cat Bones.

uniformly distributed in a medium of homogeneous density.[1] The observed differences are probably influenced by a lower density (g/cm^3) toward the center portion of the bone and by differences in concentrations of the isotope ($\mu Ci/g$).

5. Shielding Properties of Lead-Impregnated Rubber Gloves
U. H. Behling

The increasing use of radioisotopes in research and medicine intensifies the potential radiation hazard to the users. Those who wear rubber or plastic gloves are protected somewhat from a spilled solution, but gloves offer little protection to gamma-emitting nuclides.

Commercially available, lead-impregnated rubber gloves were evaluated by the Radiation Physics Laboratory to determine their effectiveness in shielding a wearer from the 0.035 MeV emission of iodine 125.

The 0.035 MeV gamma produced by iodine 125 was simulated through narrow beam collimation of an X-ray tube (Picker type PX 6-C) driven by a Westinghouse style 980228 generator. A variac was used between the output of the autotransformer and the primary of the high voltage transformer in order to produce very low energy X rays. Beam collimators for the X-ray tube measured 0.101 inch. In addition to the inherent filtration, 0.0900 inch of Cu and 0.110 inch of Al were used to "harden" the beam of the X-ray tube operating at 35 kVp and 10 mA.

The detector was a Harshaw one inch by one inch NaI(Tl) scintillation crystal with a 0.005-inch beryllium window, optically coupled to a photomultiplier tube (RCA model 8575). The beam collimator for the NaI(Tl) detector measured 0.052 inch. The output of the photomultiplier tube was fed into a pre-amplifier (Victoreen model SPA-M). All counting data were collected with a Victoreen model SCIPP 1600 multichannel analyzer equipped with a paper tape punch readout (Teletype model BRPE).

Discs 1 inch in diameter were cut from the tips of the five fingers and four places on the palm of the glove and placed in a specially designed holder for a counting time of three minutes. The effective shielding of the sample was measured in terms of its percent transmission of integral counts in a spectrum with no sample in place for the same time period (Figure 20).

The values indicate that more than 90 percent of the photons are absorbed by the glove, which gives an equivalent thickness of about four half value layers.[2] Monoenergetic photons (gamma and X radiation) are

[1]For a medium to meet this condition it has to be an "infinite slab of infinite thickness." The lower limit of the "infinite" dimension is twice the range of R_β-max energy, which is based on the theoretical beta-energy spectrum and changes for an infinitely thick source.

[2]HVL is defined as that thickness of a given material that will attenuate 50% of the incident photons of a given energy.

attenuated exponentially, which means that additional increments in absorber thickness yield minimal changes in effectiveness; i.e., the first HVL attenuates 50% of the primary beam in comparison to 25% of the second, 12 1/2% of the third, etc. Therefore, a further increase in glove thickness would change its shielding properties very little at the expense of flexibility, and limit the use of the gloves for laboratory operations.

6. Background Gamma Spectrometry in North Carolina
G. E. Anderson, R. A. Tell, H. D. Youmans

Our study of population exposure to high natural radiation in Kerala, India, has provided estimates of mR/day ranges for different occupations, locations, ages, and sexes. The usefulness of these data is limited, however, by a lack of available accurate information on the effective photon energy of thoria background radiation. Estimates of organ dose as a fraction of an ambient field of omnidirectional gamma radiation for a range of photon energies have been published. Estimates of the average photon energy vary from 0.075 MeV to 1.25 MeV. Knowledge of the average and/or effective energy can also be used to provide a better design for the calibration of thermoluminescent personal dosimeters, such as those used in India.

To obtain knowledge of the photon energy from thoria, the attenuation characteristics of a thoria deposit in North Carolina were measured in water and in copper using a portable scintillation spectrometer. The principal deposit of thoria was exposed in a narrow vein above which the detectors and water phantoms were suspended from a wooden tripod (Figures 21, 22).

Forty-four 100-channel spectra were obtained. These data, which will provide information on the pentration of thorium gammas in water phantoms and copper sheets of various thicknesses, are presently undergoing computer analysis.

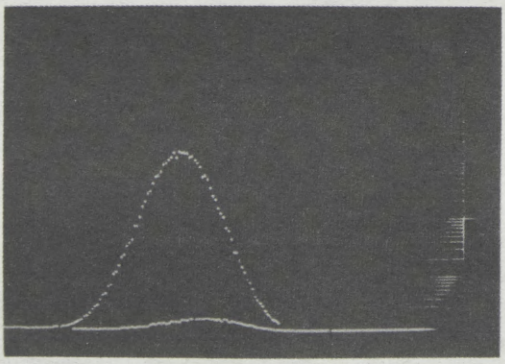


Figure 20. Spectra With and Without Sample.
Counting time 3 min; counts full scale 8 x 10^3.

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Figure 21. Portable Scintillation Detector and Water Phantom Used to Measure Pentrability of Multiply Scattered Gamma Rays from Natural Thoria Deposits in North Carolina.

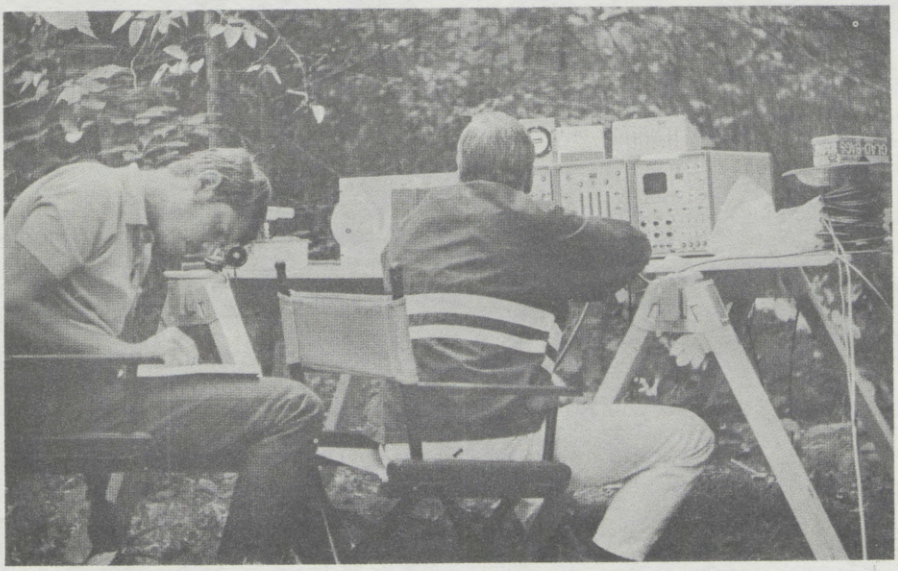


Figure 22. Portable Multichannel Analyzer used to Process and Record Radiations from Natural Thoria Deposits.

C. LIPID ANALYSIS OF BRAINS OF BEAGLES EXPOSED TO X RADIATION

J. D. Manes, R. P. Chiacchierini, H. D. Youmans

Prior to 1958, a large number of children were X-ray epilated as part of the treatment for tinea capitis, a fungal infection of the scalp. Subsequently, it was reported that a substantial proportion of the treated patients suffer from mental disorder, cancer, and permanent damage to the scalp. A previous pilot study in this laboratory with 1-year-old beagles indicated that both lipid and morphological changes might occur at the 200-rad level. The present study was conducted to measure changes in brain lipid fractions that might result from tineal X-ray exposures.

Thirteen beagle pups from four litters were included in the study. At 6 weeks of age, eight pups were irradiated with 500 R to the head only; five served as controls. At 1, 30, and 180 days postirradiation, two irradiated pups and one unexposed animal were sacrificed. At 270 days postirradiation, the remaining animals were sacrificed.

The brains of all thirteen pups were extracted. Two samples from each brain were analyzed, one from the cerebrum, and one from the pons. The brain lipids were extracted by the method of Folch et al. The extracts were analyzed on thin layer chromatograms, the results of which were quantitized by densitometry.

The analog output was digitized and the areas under each lipid peak were computed using the trapezoidal rule by electronic computer. The fraction of the total area that each lipid constituted was computed. A postirradiation time analysis and a dose analysis were carried out on the resulting fractions of lipids.

The time analysis showed the same relationships in time between various lipid fractions in both the irradiated and the control animals. These data indicate that 500 R produces no major effect on myelination over time.

The dose analysis was completed on the following four lipid classes: (1) Lysolecithin, sphyngomyelin, sulfatides; (2) lecithin; (3) cholesterol; and (4) phosphatidyl ethanolamine, cerebrosides.

The lipid fractions in two portions of the brain, the cerebrum and the pons, were analyzed separately. As indicated in Table 12 an exposure of 500 R to the head produces various responses in lipid formation in the beagle. The formation of class (1) in the cerebrum was enhanced by irradiation, but in the pons it was retarded. Irradiation enhanced the formation of lecithin in the cerebrum, but produced no significant change in the pons. The levels of cholesterol were not changed by irradiation in either the cerebrum or the pons. The formation of class (4) lipids was unaffected by irradiation in the cerebrum, but was enhanced by the treatment in the pons.

TABLE 12. SIGNIFICANCE OF LIPID FORMATION IN IRRADIATED AND UNIRRADIATED DOG BRAIN

Lipid Class	Treatment	Mean	95% Confidence Limit Lower	Upper	Significance Level
		Cerebrum			
Lysolecithin Sphyngomyelin Sulfatides	Control	0.1801	0.1746	0.1856	0.01
	Irradiated	0.1963	0.1919	0.2007	
Lecithin	Control	0.1793	0.1727	0.1859	0.01
	Irradiated	0.1912	0.1859	0.1965	
Cholesterol	Control	0.2378	0.2287	0.2469	not
	Irradiated	0.2313	0.2241	0.2385	significant
	Overall	0.2338	0.2282	0.2394	
Phosphatidyl ethanolamine Cerebrosides	Control	0.3046	0.2956	0.3136	not
	Irradiated	0.2995	0.2924	0.3066	significant
	Overall	0.3015	0.2959	0.3071	
		Pons			
Lysolecithin Sphyngomyelin Sulfatides	Control	0.2322	0.2252	0.2392	0.01
	Irradiated	0.2138	0.2048	0.2228	
Lecithin	Control	0.1516	0.1481	0.1551	not
	Irradiated	0.1509	0.1482	0.1536	significant
	Overall	0.1512	0.1491	0.1533	
Cholesterol	Control	0.2128	0.2043	0.2213	not
	Irradiated	0.2236	0.2170	0.2302	significant
	Overall	0.2196	0.2144	0.2248	
Phosphatidyl ethanolamine Cerebrosides	Control	0.3250	0.3166	0.3334	0.05
	Irradiated	0.3425	0.3316	0.3534	

RADIATION ONCOLOGY AND PATHOLOGY LABORATORY

Dr. Norman C. Telles, Chief

The primary research of the Radiation Oncology and Pathology Laboratory has focused on the pathogenetic mechanisms involved in radiation-induced tumors. The approaches continue to be largely morphological and biochemical, with great emphasis being given to studies of host-virus relationships, the importance of the immune response to carcinogenesis, and the effect of co-insultive agents on radiation induction of tumors. Recently nonionizing radiation effects have been included as part of the Radiation Oncology and Pathology Program, but these efforts are still too preliminary to be reported at this time. Several studies that have been completed in sufficient detail are reported further on in this section.

The study on radiation enhancement of SV40 transformation in 3T3 and human cells is particularly significant because it opens a new approach to assessing radiation effects on cells and tissues which should be of interest to radiobiologists, virologists, radiotherapists, and those concerned with the epidemiological and clinical aspects of radiation-induced disease.

Thus, an effort to obtain lung tissue from former uranium miners, and others exposed to ionizing radiation has already been started in this laboratory. Using the approach outlined in the report by Pollock and Todaro (Nature 219:520-521, 1968) we plan to explore the possibility that cells derived from cultures of these tissues may be more readily transformed by virus than non-exposed cells derived from similar tissues.

A. THYROID AGE SENSITIVITY STUDY IN YOUNG RATS

J. R. Childress, W. Lee, T. R. Horton

As a result of a nuclear test in the Pacific in 1954, 19 children on the island of Rongelap under 10 years of age were exposed to about 170 roentgens of external γ rays and an estimated 700 to 1,400 rads from ingested radioactive iodine. In this young Rongelap Island group an incidence of 78% thyroid nodularity developed within 12 years after exposure. The incidence of abnormalities in older age groups was only slightly higher than that in nonradiated individuals.[1] Epidemiologic investigation indicates a risk on the order of one case of thyroid

[1]Conrad et al. 1966. New Engl. J. Med. 274:1392.

abnormality per million children per rad per year for thyroid doses over 100 rads.[2] Hempelmann estimates an incidence of palpable thyroid nodularity for nonradiated control populations of 0.36 to 1.7%.[3] It appears that in a given irradiated population, children develop more thyroid tumors than other members of the group.

Considerable investigation has been given to the effect of radiation on the rat thyroid. Lindsay, et al reported a 54% incidence of thyroid adenomas and a 31% incidence of alveolar carcinomas in Long-Evans rats two years after treatment with 1,000 R to the thyroid gland.[4] However, the incidence of thyroid adenomas and alveolar carcinomas was based on only 24.4% of the original experimental group of animals. Doniach found no gross difference in sensitivity between weanling and adult rats as measured by a thyroid weight response to a goitrogenic challenge four months after injecting a 0.5 - 5.75 μCi range of ^{131}I. Doniach has indicated that radiation acts to initiate, and cellular proliferation acts to promote, carcinogenesis of the thyroid in rats.[5]

The present thyroid age sensitivity study allows animals of different age groups to experience a common post-exposure risk period over which tumors might develop. Particular attention has been given to preventing death of the animals in the age sensitivity study for more accurate statistical evaluation of thyroid tumor incidence.

Briefly, 960 female, random-bred, Long-Evans rats were placed on the study. The anesthetized animals were given a highly localized dose of 1,000 rads of X radiation (250 kVcp, 15 mA) to the thyroid (see page Radiation scatter was minimized with specially designed brass and lead collimators (Figure 23). The brass reduced the primary beam to 1/30 of the original 1,000 rads; the lead reduced the beam by another 1/16 for an approximate 2-rad whole-body dose to the rat. Doses were determined with plastic-coated lithium fluoride rods imbedded in various sizes of rat cadavers (see page

The thyroids were located by palpating the cricoid cartilage. Anesthetized rats were positioned on a wooden board and the center of the irradiation field was marked with a small piece of white paper tape (Figure 24). A thin paper pointer fastened to the center of the collimator hole was used to position the thyroid under the center of the irradiating beam and to mark the predetermined source-to-thyroid distance.

After the Long-Evans rats had been on the study about eight months, 82 animals had died. Pneumonia was responsible for 72% of all deaths. Other causes of death included pleuritis (10%) and malocclusion, leukemia, encephalitis, and urolithiosis (7%). Because of postmortem

[2]Conti et al. 1960. Radiology 74:386.
[3]Hempelmann. 1968. Science 160:159.
[4]Lindsay et al. 1961. Cancer Res. 21:9.
[5]Doniach. 1957. Brit. J. Cancer 11:253.

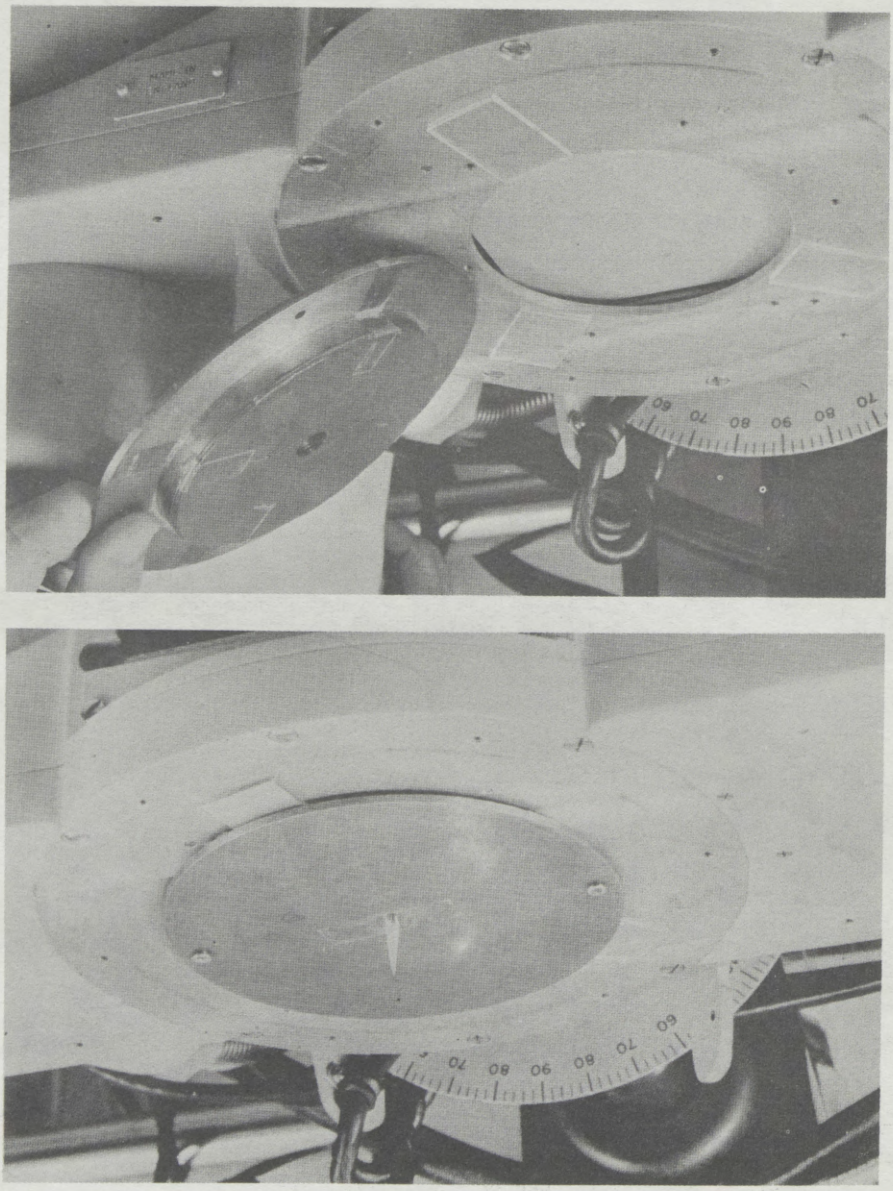


Figure 23. Brass and Lead Collimators Used in Narrow-Beam Irradiation of Rat Thyroid Glands. Bottom photo shows collimator in place with paper pointer used to align X-ray beam and thyroid.

autolysis, cause of death could not be established in 11% of the rats. No microscopic or gross thyroid irregularities have been found thus far. Table 13 shows percent deaths at each age. Owing to the high rate of mortality due to respiratory disease, tetracycline has now been added to the drinking water of the rats. This has reduced considerably the rate of death due to preliminary disease.

TABLE 13. DEATHS OF RATS IRRADIATED AT VARIOUS AGES

Age Group[a]	Deaths in Group (percent)	
	Irradiated	Control
6 months	12.5	11.7
3 months	13.3	5.8
1 month	10.0	5.8
10 days	7.5	1.7

a. There were 240 animals in each age group, 120 per treatment.

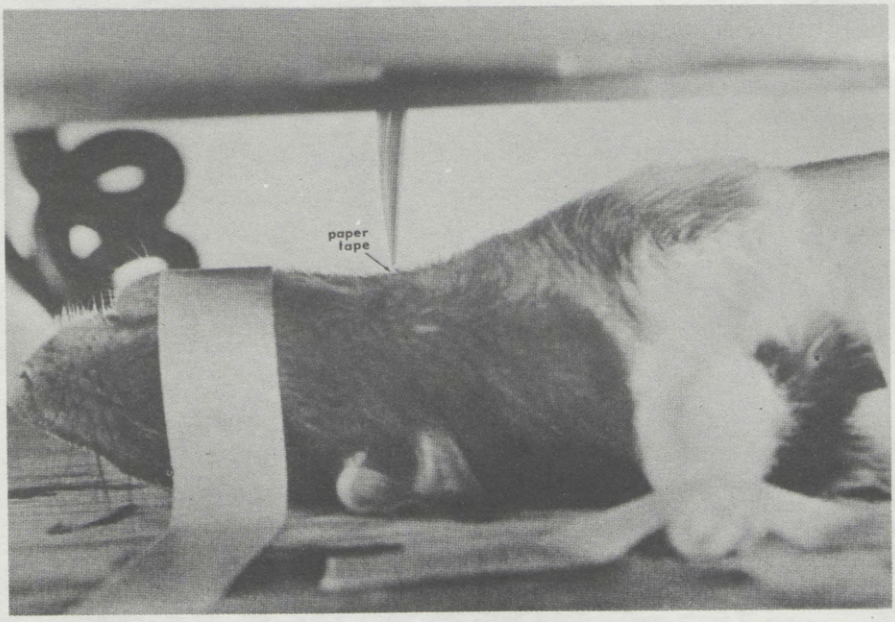


Figure 24. Position of Anesthetized Rat During Thyroid Irradiation.

B. SPONTANEOUS LESIONS IN A COLONY OF CHINESE HAMSTERS
B. C. Ward

In a study designed to determine the tumorigenic effects of ^{131}I on the thyroid gland in Chinese hamsters, a high incidence of hepatomas, uterine adenocarcinomas, and cerebrovascular lesions were found (Table 14). No statistical relationship between these lesions and treatment with ^{131}I could be shown.

Cerebral hemorrhage was observed in 20 percent of the hamsters in the study. The hemorrhage was found, in every case, to be associated with inflammation and necrosis of the anterior cerebral artery (Figure 25).

More than 25 percent of the animals developed liver tumors which upon histologic examination were found to be benign hepatocellular tumors (Figure 26). The tumors sometimes were as large as 1.5 cm.

Uterine tumors were found in 30 of the 120 females examined. The tumors were usually found in the cervical area of the uterus and may have originated there; however, due to the large size of the tumors it was difficult to ascertain the point of origin. Histologic examination showed the tumors to be adenocarcinomas (Figure 27).

None of these lesions have previously been reported in other colonies of Chinese hamsters. Further work will be done to investigate the hamsters in the Bureau of Radiological Health colony.

TABLE 14. INCIDENCE OF LESIONS IN RELATION TO DOSE OF ^{131}I

Treatment μCi ^{131}I	No. of Animals		Brain Lesions	Liver Tumors	Uterine Tumors
	Male	Female			
0.1	26	23	12	14	8
0.05	25	28	11	12	5
0.01	27	24	11	11	5
0.001	24	26	10	11	6
0	31	19	7	18	6
Total	133	120	51	66	30

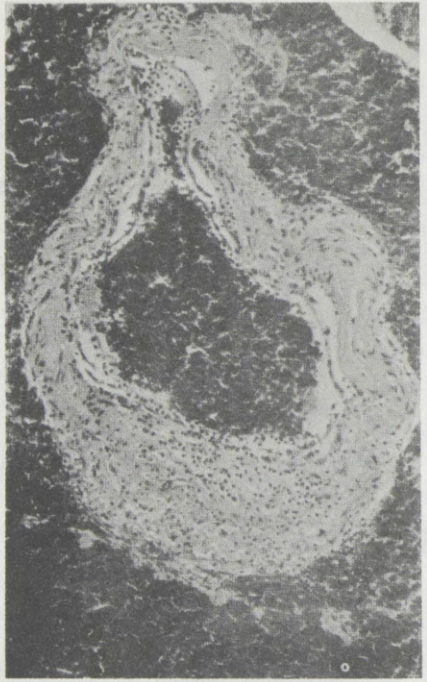


Figure 25. Microscopic View of Anterior Cerebral Artery in the Brain of a Hamster with Acute Massive Cerebral Hemorrhage. Inflammatory cells are present within the wall of the vessel. Hematoxylin and eosin. 125X.

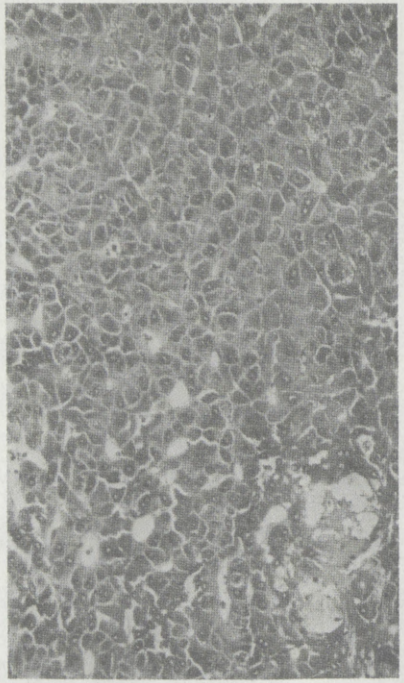


Figure 26. Liver. The liver tumors are composed of large hepatocytes growing in a disorganized manner. Hematoxylin and eosin. 40X.

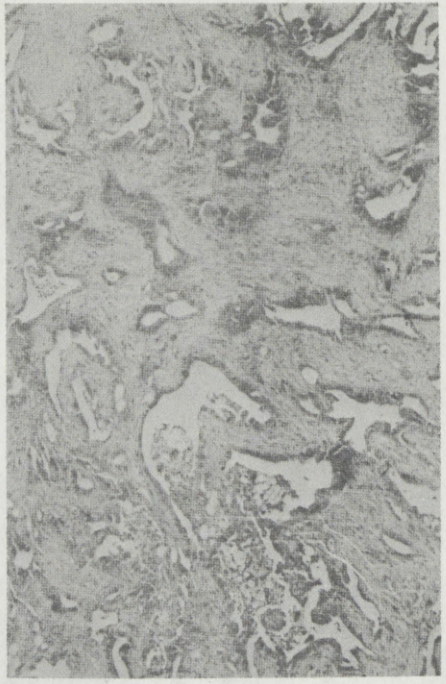


Figure 27. Uterus. Neoplastic glandular tissue amid abundant fibrous stroma characterized the uterine tumors.

C. STUDIES OF RADIATION - VIRUS INTERACTIONS

E. J. Pollock

Ionizing radiation produces both somatic and genetic effects. Carcinogenesis is one of the most perplexing and significant somatic effects. However, if cancer is regarded to be the result of a genetic change induced by radiation, then it can also be thought of as a non-heritable genetic effect. Our work has focused on the examination of genetic factors which could be altered by radiation and thereby lead to carcinogenic changes in cells or tissues.

We have considered the DNA strand-breaking effects of radiation. If cancer-inducing viruses are present in a cell when broken DNA strands are present or are being repaired, there is an increased probability that these cells will incorporate the viral DNA and presumably result in a transformed cell. This effect has recently been supported by studies in this laboratory in which irradiated cultured cells (3T3) were exposed to a transforming virus (SV40).

In another investigation, we have devised a method for studying both early and late viral functions in the same cell strain. Although it is well known that radiation can differentially inactivate various virus functions, transformation frequencies and infectivity have not been studied in the same cell strain. Studies are currently in progress to examine the inactivation of several tumor virus functions using the method.

There have been conflicting reports concerning the transformation of cultured cells by radiation. We have attempted to resolve some of the conflict areas in our own work. A line of contact-inhibited mouse fibroblast cells was developed from inbred BalbC mice. These cells were irradiated with 1,500 rads, and the surviving cells were subcultured. Colonies that did not appear to be contact inhibited were subcultured and grown in large numbers. Irradiated weanling BalbC mice were then inoculated with these cells. Four months have elapsed since the inoculation and no tumors have yet developed. No tumors have developed in control animals inoculated with the same but unirradiated cells. These animals are still under observation.

1. Radiation Enhancement of SV40 Transformation in 3T3 and Human Cells[6]

Radiation and viruses are implicated in carcinogenesis in man and animals. It has been shown that in C57B1 mice a virus present in the animal's tissues is the causative agent and has been implied that radiation increases an animal's susceptibility to tumor production by a virus. We have examined the direct effect of radiation on the susceptibility of individual cells to tumor viruses in tissue culture.

[6]The full article by Pollock and Todaro was published in Nature 219:520-521, 1968.

Human cells and mouse cells were grown in tissue culture. Cell monolayers were infected with an oncogenic virus, SV40, either prior to or after exposure to X rays. Radiation doses varied from 75 rads to 1,200 rads. The transformation frequencies of irradiated cultures were compared to those of unirradiated cultures. The relative increase in transformation frequency noted in the irradiated cultures was called the enhancement of transformation, which was found to be an exponential function of the radiation dose (Figure 28). Results were similar for mouse and for human cells.

This work contributes to the understanding of the mechanism of radiation carcinogenesis. Radiation increases the probability that an oncogenic virus will produce tumors in animals. Depression of immunological defenses plays a part in this process. The above experiments, however, show a direct effect of radiation on cellular susceptibility to transformation and suggest a second role of radiation in enhancing viral oncogenesis.

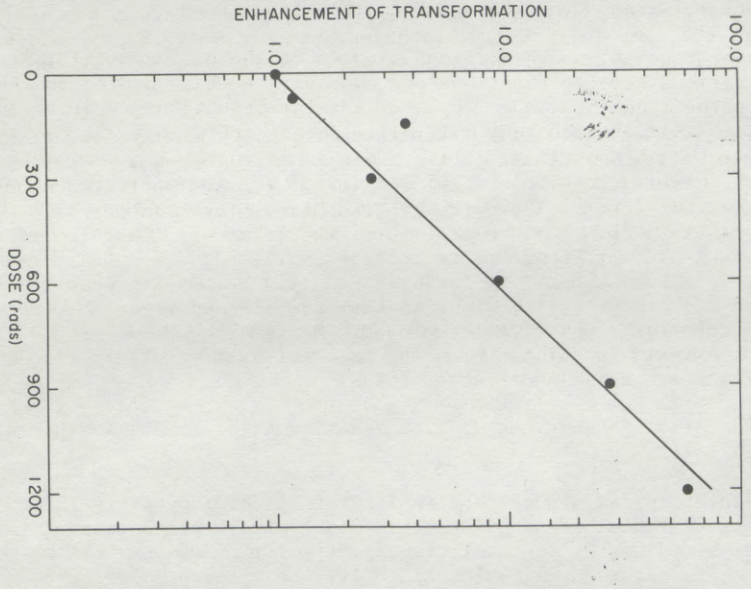


Figure 28. Data from Three Experiments Show the Enhancement of Cell Transformation after Irradiation and Infection with SV40.

2. Infectivity and Transformation Relationships of Ultraviolet-Irradiated SV40 Virus

Several genetic functions of tumor viruses are differentially inactivated by ultraviolet radiation. For example, transformation and oncogenecity are inactivated less rapidly by ionizing radiation than is infecting capacity. In these experiments, however, the transformation frequency in one cell strain was compared to the infectivity in a different cell strain, and different multiplicities of infection were used to determine each of the viral functions.

We have used several strains of cultured human cells and have devised methods where, in the same cell and at the same multiplicity, we can compare T-antigen inducing capacity, V-antigen inducing capacity, infectivity, and transformation. Irradiation with ultraviolet light differentially inactivates these functions. The rate of inactivation of V-antigen induction is 30 percent less than the rate of inactivation of infectivity.

The slopes of the inactivation curves for V-antigen are 5- to 6-fold greater than those for transformation. The curve for inactivation of T-antigen inducing capacity falls along a line with a slope midway between that for transformation and V-antigen induction.

The conclusions of previous studies of the differential inactivation of various genetic functions of tumor viruses have had to be interpreted in the light of comparing early and late functions in different cell strains and at different multiplicities of infection. Since the synthesis of coat protein is a late viral function, it is reasonable that this should be related to and necessary for the production of complete infectious virus, another late function. This has permitted us to compare early and late functions in the same cell line using the same multiplicity of infection.

Since ultraviolet radiation is used in sterilization procedures and in vaccine preparation, this work becomes significant because in a heavily irradiated virus a significant oncogenic potential may exist while infectivity may be undetectable. If infectivity is used to identify the virus, then its presence may go undetected.

D. RADIATION-ETHIONINE ULTRASTRUCTURE STUDIES - A SERIAL SECTION EVALUATION

N. C. Telles, D. W. Coble

We have previously reported some electron microscopic observations of a number of hepatomas developing in female Osborne-Mendel rats treated with radiation and ethionine. We concluded that a large number of the nuclei in the hepatomas contained cytoplasmic inclusion bodies and surmised that these were true inclusion bodies and not sectioning artifacts. We have modified this view based on the serial-sectioning work reported below.

The structure and configuration of intranuclear cytoplasmic inclusions occurring in rat hepatomas produced by X radiation and/or ethionine has now been studied by means of consecutive serial sections (Figure 29). Such intranuclear inclusion bodies have been described previously[7-11] but it has not always been clear whether the inclusions are true inclusions or simply psuedo-inclusions; i.e., simple invaginations of the nuclear membranes. Also, the manner of formation of such structures has not been determined.

Studies of serially sectioned hepatoma nuclei have shown that the greater proportion of intranuclear cytoplasmic inclusions are due to the invagination of the nuclear membranes, with continuity maintained between the cytoplasm and the invaginated cytoplasmic material (Figure 30). Rarely, an apparent break or discontinuity in the wall of the invaginated inclusion has been observed (Figure 31) leading to an admixture of cytoplasmic contents and nucleoplasmic material such as is illustrated in Figure 32.

Careful evaluation of serial sections of many nuclei containing these invaginations has revealed that the invaginatory pores tend to be fairly uniform in size. Furthermore, a single invagination may also give rise to one or more "satellite" invaginations (Figure 29). The nuclear membranes do not appear to be stretched or torn by the invagination. Also, the dimensions of the nuclear pores appear unaltered during the process of invagination.

Mechanical distortion of the nuclear membranes has been suggested as a possible mechanism of formation for intranuclear invaginations.[11] The uniformity of size of the invaginatory pores as well as their channel-like structure would seem to argue against this means of formation. Furthermore, extrinsic pressure on the nuclear wall would seem unlikely to give rise to satellite invaginations, even if intrinsic "weak" spots were to exist in the nuclear membranes. Traction forces appear equally

[7]Kleinfeld et al. 1956. J. Biophys. Biochem. Cytol. 2:435-439. Sup. 4.
[8]Leduc and Wilson. 1959. J. Biophys. Biochem. Cytol. 6:427-439.
[9]Brandes et al. 1965. Science 149:1373-1374.
[10]Mori and Onoe. 1967. J. Electronmicroscopy (Tokyo) 16:137-142.
[11]David, H. 1964. Submicroscopic Ortho- and Patho-Morphology of the Liver (Text Volume), Pergamon Press, Oxford, England. p. 234.

unlikely as an explanation for such invaginations.

We suggest that nuclear invaginations may result from a regional or localized increase in the total nuclear membranes. The enlarging membranes bulge in toward the nucleoplasm following a path of least resistance. Ultimately the invaginated wall may tear or open, discharging cytoplasmic contents into the nucleus.

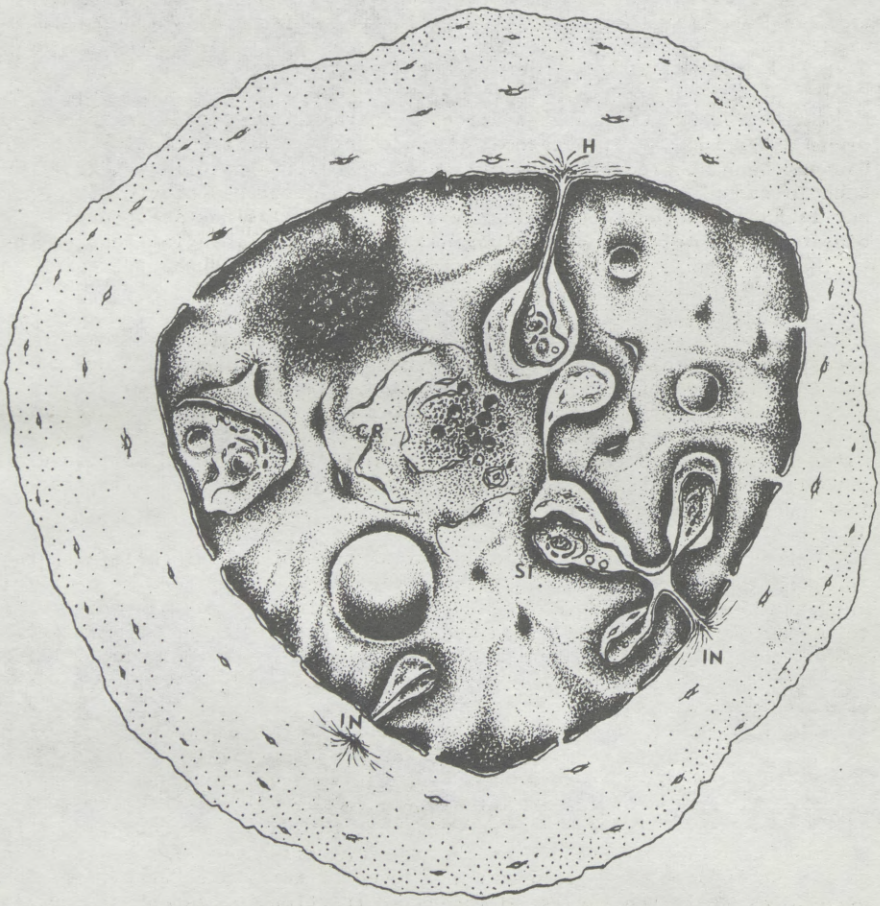


Figure 29. Artistic Representation of the Structure of Nuclear Cytoplasmic Invaginations. Note that the nuclear membranes have invaginated at several points (IN) and "satellite" invaginations (SI) are also present. Cytoplasmic remnants (CR) from a degraded cytoplasmic inclusion are present in the nucleoplasm. Regional increases in the nuclear membranes are represented by the stress lines in the nuclear surface (H).

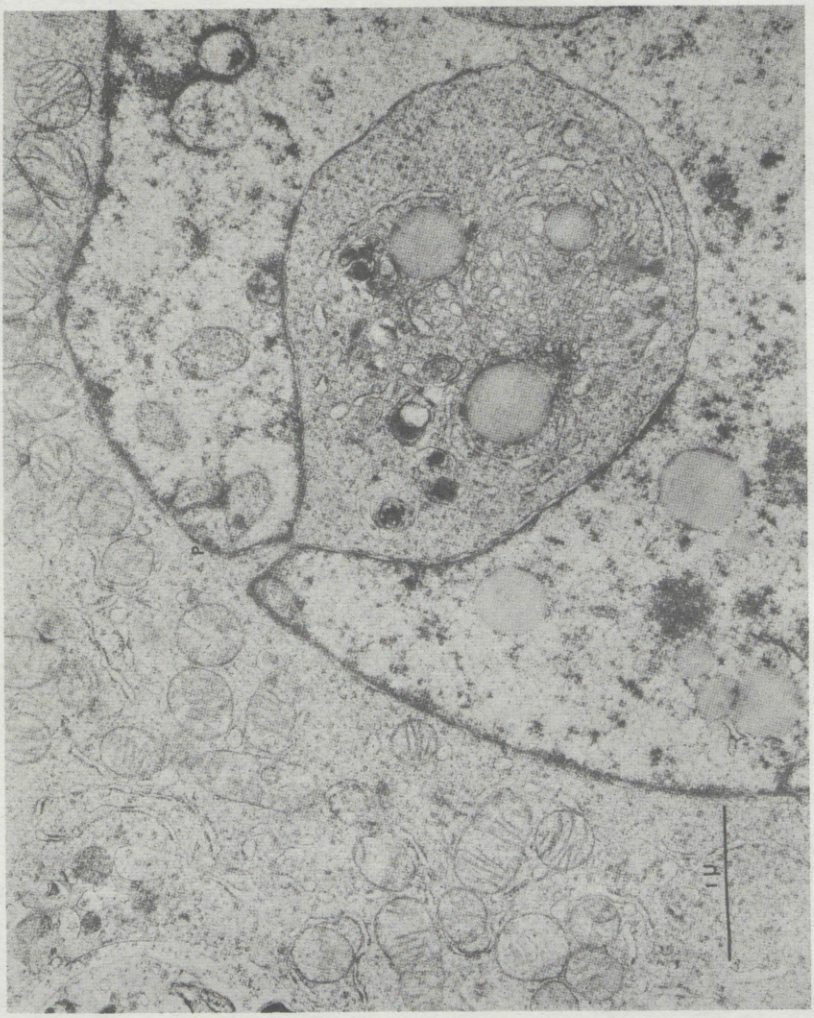


Figure 30. Invagination of Nuclear Membrane Showing Channel-Like Pore (P) which Provides Continuity Between the Cytoplasm and the Invaginated Material.

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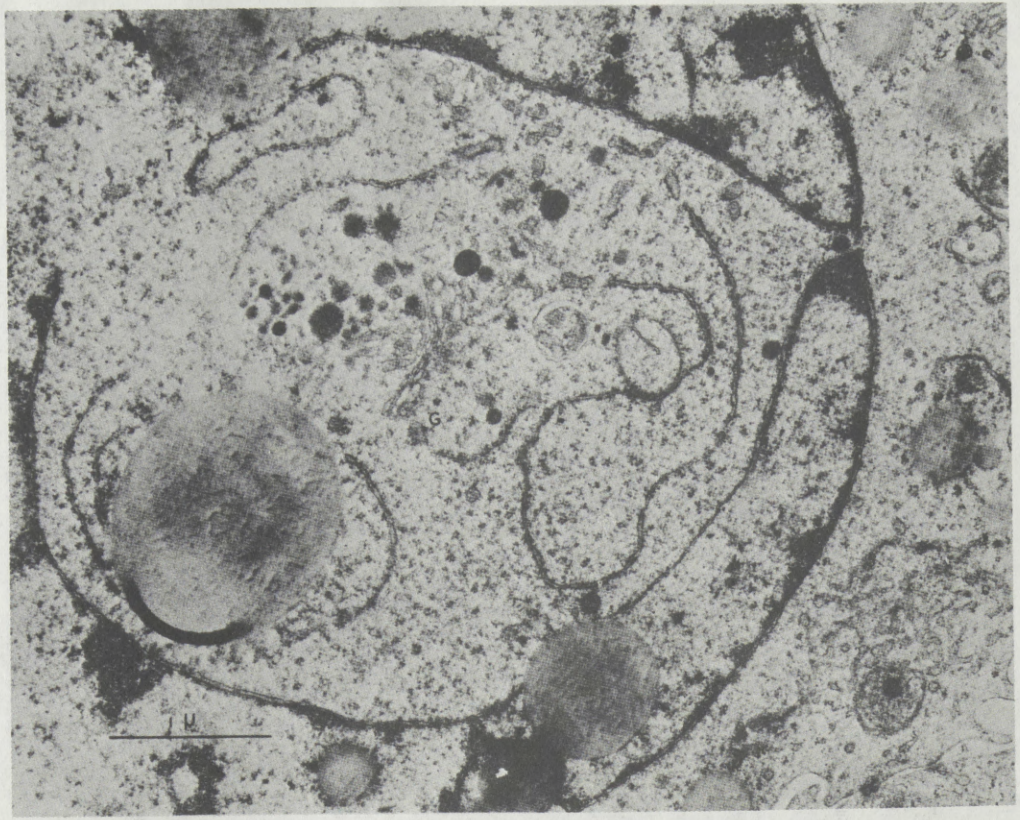


Figure 31. Apparent Opening or Break (T) in the Wall of the Invaginated Nuclear Membrane. Admixture of cytoplasmic and nuclear contents presumably occurs at this point. Note the Golgi apparatus (G) within the inclusion.



Figure 32. Hepatoma Nucleus Showing Nuclear Cytoplasmic Inclusions (CI) as Well as Cytoplasmic Remnants (CR). Invagination of the nuclear membrane is indicated at IN.

RADIONUCLIDE TOXICOLOGY LABORATORY
Dr. Jerry F. Stara, Chief

During 1968 the Radionuclide Toxicology Laboratory studied primarily the toxicity or other biological effects of specific hazardous radionuclides. The core project "The Effects of Strontium-89 on the Hematopoietic System of the Cat -- With Special Consideration to Leukemogenesis and Age Sensitivity," was given special emphasis. Its research objectives are to:

a) Determine and identify the time (or tissue) that may be uniquely sensitive to radiation-induced lymphoproliferative or myeloproliferative disorders associated with ^{89}Sr ingestion during development and growth of the cat;
b) Assess the radiation dose (rads) delivered to the bone marrow and other organs in several age groups of Felis domestica that have received dietary ^{89}Sr, and the relationship between the effective doses in cats and ^{90}Sr doses incriminated as leukemogenic in dogs and miniature swine;
c) Systematically investigate all leukemia cases for the presence of a viral agent, and study the transmissibility of such an agent in cats and possibly other mammalian species.

These efforts included several prerequisite and ancillary studies to obtain physiological, embryological, and radiological parameters for the core project, as well as initial experiments with cats subjected to high chronic dietary doses of ^{89}Sr.

A major change in the structure and planning of the Radionuclide Toxicology Laboratory was reflected in a decision to relocate the laboratory from Cincinnati, Ohio, to the Washington, D. C. area. The preparations for the transfer of the laboratory required much effort during the year to arrange suitable housing for the cat colony, and to provide for the transfer of the laboratory and its personnel with the least amount of interruption of the ongoing scientific endeavor.

Aside from the ^{89}Sr long-term project, the laboratory staff continued their investigations concerned with: (1) Evaluation of radiopharmaceuticals - specifically ^{131}I-tetracycline - as a promising aid in diagnosis of tumors, and sodium alginate as an agent for reducing strontium uptake and retention under chronic intake conditions; and (2) metabolism of heavy radionuclides, especially translocation studies following ingestion of chemical forms of ^{210}Po and ^{210}Pb found in the diets of guinea pigs and cats, in order to develop models related to ^{210}Po and ^{210}Pb exposure of selected populations, such as uranium miners or Alaskan Eskimos, from natural sources.

A. STATUS AND PRODUCTION OF THE CAT COLONY

J. F. Stara, N. S. Nelson, E. Berman, M. J. Replogle

The feline colony maintained by the Radionuclide Toxicology Laboratory consists of 235 male and female cats, a number lower than in normal times. The size of the colony was reduced to facilitate the transfer from the present location in Cincinnati to a location near the Rockville, Maryland, laboratory. A number of animals which had a poor reproductive record or unsatisfactory genetic traits were culled and used for short-term studies to provide required prerequisite or ancillary data for the long-term strontium-induced leukemia study.

Only 34 animals are presently on experimental status; the remainder are breeding animals. About 200 animals will be transferred. As a part of the preparation for transfer and initiation of a large cat colony, genetic and clinical histories for individual animals are being compiled to characterize the individual animals. Animals designated for transfer have been subjected to an extensive hematological examination; serum samples have been examined for specific diseases such as toxoplasmosis, with two positive cases yet unconfirmed.

The health of the colony during the past year was good. The 5% mortality rate was limited to young animals with few exceptions. During an extended period of cold damp weather, three cats developed pneumonia, which was caused by an erythromycin sensitive staphylococcus. The good health of the colony was primarily due to strenuous sanitary practices, effective prophylaxis, and personal dedication and careful handling.

The numbers of kittens produced, kittens per litter, and litters produced have been recorded for the past six years. During 1965-1968, 238 breedings were observed. Of these, 178 fertile breedings carried to term giving a 74.0 $\pm$ 5.5% conception rate in the colony for the four years.

Table 15 summarizes the production record of the colony. The data show that the greatest number of pregnancies produced four kittens (23.2% of the pregnancies). Except for litters of two kittens, the number of litters of various sizes born each year varied considerably. Most litters were biased in favor of males, but the sex was equally divided in the litters having one and six kittens. Overall, the colony produced 55% males and 45% females.

A large sample of the kittens (60%) were weighed at birth, either immediately after birth or within 8 hours of the time of birth. The mean weight distribution shows that individuals in litters of 1 to 4 kittens weigh approximately 100 grams. For litters of five kittens or more, the mean weight decreases somewhat as the litter size increases.

The weights at birth have not been adjusted for the length of gestation period. Since the duration of pregnancies in this colony varied between 62 and 68 days, with an average of approximately 65 days, it is possible that the rather large observed spread of weights reflects more the length of gestation period than the expected size of neonates. However, a sufficient number of litters of different gestation times were not available to demonstrate litter size vs. duration of pregnancy.

TABLE 15. KITTEN PRODUCTION DURING 1963-1968

Kittens/ Litter	No. of Litters	No. of Kittens Born			Birth Weight,[a] Grams	
		Male	Female	Total	Mean	Range
1	30	15	15	30	99.0	69.4-128.6
2	38	43	33	76	98.7	66.1-131.3
3	62	108	78	186	98.9	59.1-138.0
4	68	138	134	272	100.4	72.6-125.2
5	47	140	95	235	95.7	61.1-130.3
6	30	90	90	180	90.5	56.7-124.3
7	10	38	32	70	84.5	60.3-106.7
8[b]	-	-	-	-	-	-
9	1	4	5	9	85.6	75.8-95.4
Total	286	576	482	1058		

a. A sample of kittens from about 60% of the litters were weighed within 8 hours of birth.
b. No litters of eight kittens were born.

B. QUALITATIVE EVALUATION OF THE EMBRYONIC SKELETON IN CATS

E. Berman, J. F. Stara

In order to develop satisfactory estimates of skeletal dose in the embryo, accurate morphological data regarding time sequence of skeletal tissue formation throughout embryonic life is necessary. To study this problem, feline embryos are collected from normal pregnant dams by cesarotomy and treated with alizarin stain. This technique produces a fetal specimen whose soft tissues are almost completely transparent, while calcified tissues are stained red and purple, and are readily visible. The study was designed to determine the embryonic age at which bone tissue first appears in the fetus, the age at which calcium initially deposits in various areas of the body, and the relative rate at which each bone develops. This study will provide necessary information in investigations of bone-seeking radioisotope incorporation into feline embryos, as well as specific information in studies of mammalian development.

The embryos are collected at one-week intervals after confirmation of normal pregnancy, and from three weeks through nine weeks of life. Because of biological variation within a litter, at least three embryos each, from three different litters must be collected for each observation point. So far we have used 14 normal pregnant queens, considered as colony surplus, to produce the 26 embryos now in our collection. An additional eight embryonic litters must be collected at appropriate times to obtain a minimum set of samples.

Although this method of soft tissue clearing and bone staining is not completely quantitative as to the volume or the amount of calcified tissues, it allows gross measurement and morphological observation of the developing skeleton. After clearing and staining, the embryonic specimen is projected on a screen so that the embryos of various sizes are projected as equally sized images. Analysis of bone appearance and relative bone size is made from the tracings of these images. A special projector and tracing screen which will allow proper visualization of the entire embryo is being constructed. In small embryos, or for body areas which require greater magnification, camera lucida microscopic drawings will be made. Using a method of rotating the embryos along their mid-line axes, quantitative measurements of size and volume of selected bones can be made from the tracings.

C. PLACENTAL TRANSFER OF STRONTIUM AND CALCIUM IN THE FELIS DOMESTICA
N. W. Nelson, R. G. Wolfangel, J. F. Stara

The work involving placental transfer of strontium and calcium in the cat is part of a larger effort to elucidate the placental transfer of divalent cations in mammals. The results of this work also provide information that will be used in a study of radioactive strontium-induced leukemia in cats. Preliminary observations plotted in Figure 33 show weight and radioisotope content in embryos from two weeks of gestation to birth. The observed embryonic uptake curves were obtained from a group of embryos born of dams on ^{85}Sr chronic uptake regimen and a second group which received a mixed dose of ^{85}Sr and ^{45}Ca, intravenously 24 hours before removal of the embryos by cesarotomy. Predicted calculated values for chronic uptake using single dose data from another experiment were also plotted.

The ^{85}Sr chronic uptake curve shows values from 2 to 8 weeks of gestation, since embryos were not available from 8 weeks of gestation to birth. In animals given a single dose, the strontium curve roughly parallels the calculated curve. The calcium uptake was about 5 to 20 times greater during the first five weeks of gestation, but then leveled off more rapidly than the strontium values; at 8 weeks of gestation the calcium level is only about 50% higher than that of strontium. In addition, the strontium uptake in cronically dosed animals exhibited a much steeper slope than the curve for single-dosed animals, particularly during the last 9 days of pregnancy. Calculated values for chronic uptake were higher than the observed chronic uptake dose by a factor of two during the first 6 weeks of gestation, but were closely parallel during the last 2-1/2 weeks of pregnancy.

The data in Figure 34 indicate that for cats given a single dose, the strontium content of the placenta is proportional to its weight. The calcium content rises to a peak at about 5 weeks of gestation and then drops to a relatively constant level. The change in the radiocalcium uptake curves at 5 weeks of gestation (as demonstrated both in Figure 33 and Figure 34) suggests that there is either a change in the placental permeability or a total calcium pool at this time. Further investigation with particular reference to specific activity of maternal blood is necessary to evaluate these observations.

The curves for total strontium, calcium, and inorganic phosphorus (Pi) in the embryos are compared with weights in Figure 35. The phosphorus content seems to be directly related to embryonic weight; calcium and strontium content are more or less related to age (length of gestation). The high rate of deposition of the latter elements beginning at 5 weeks of gestation, indicates largely the increase of bone mineralization in the developing embryo. The data also point out that from 7 weeks of gestation to birth, the amount of phosphorus in the skeleton was between 60% and 75% of total body phosphorus; the skeletal strontium was between 70% and 85% of total body strontium; and the skeletal calcium was between 80% and 95% of total body calcium.

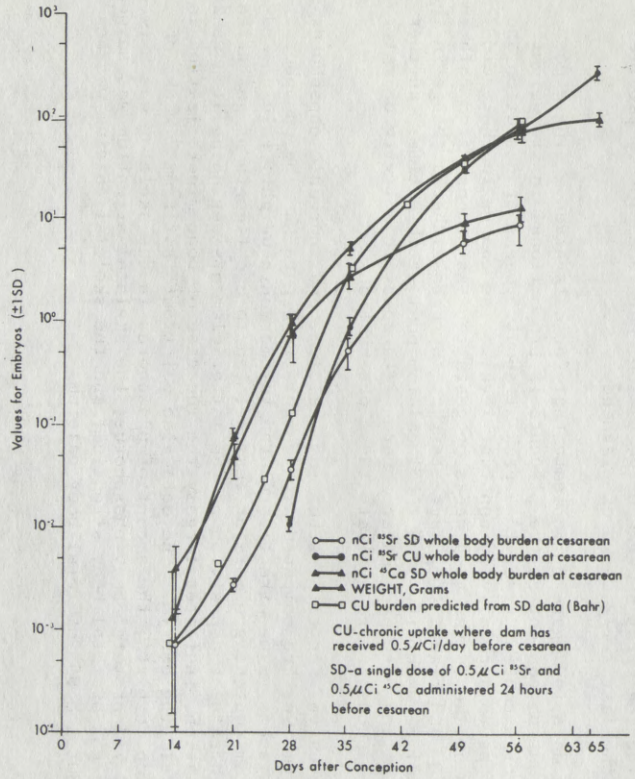


Figure 33. Weight and Radioisotope Content in Embryos.

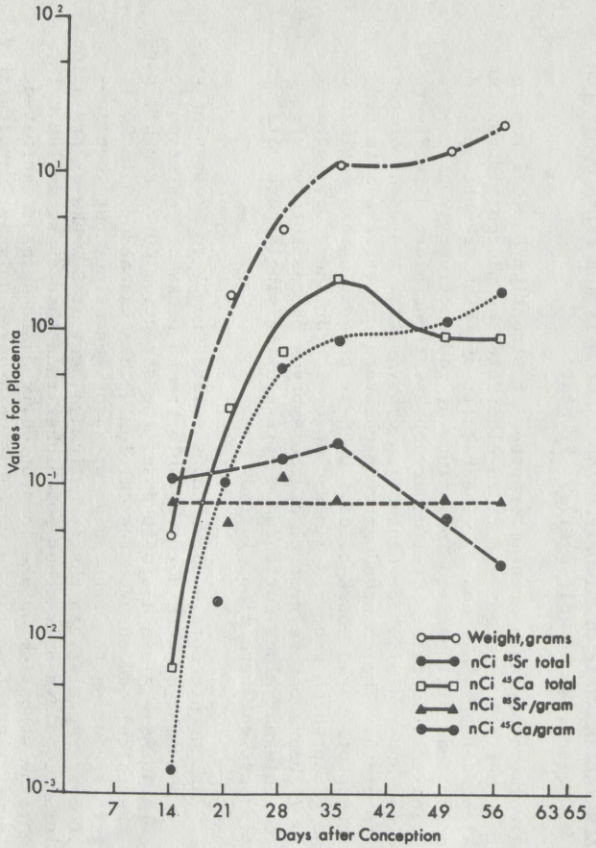


Figure 34. Weight and Radioisotope Content of Placenta.

These data and their interpretation are preliminary estimates, since they are based on single pregnancies at each observation point, even though two or more embryos were obtained from each pregnant dam. The minimum average values needed for each point are three pregnancies, representing nine embryos, before any statistically valid conclusions can be made.

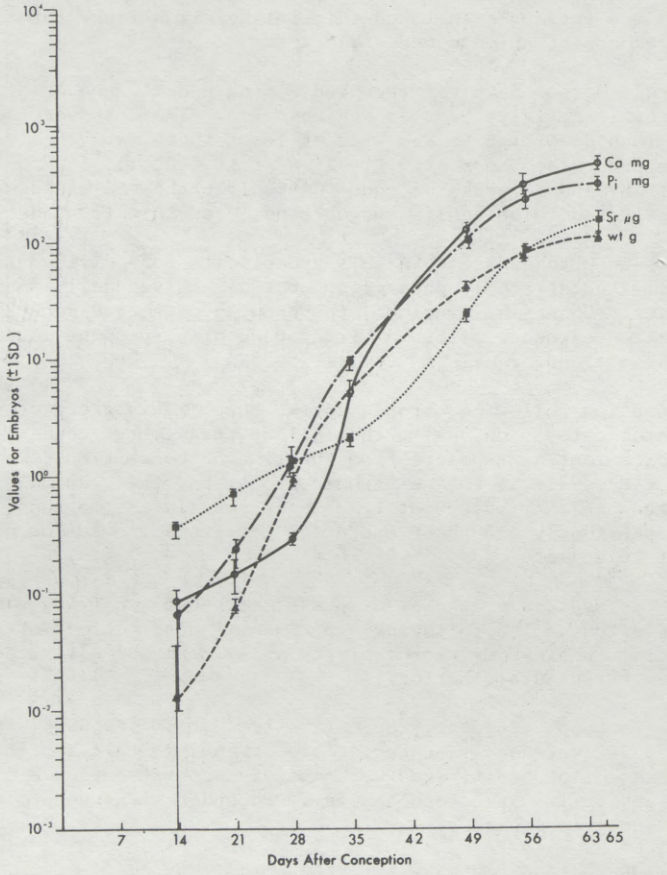


Figure 35. Radioisotope and Phosphorus Content and Weights of Embryos.

D. METABOLISM OF ^{85}Sr IN CATS

1. Methodology

J. F. Stara, R. G. Wolfangel

For the past four years, our laboratory has conducted an extensive investigation of ^{85}Sr metabolism in the cat. In order to "fill in the gap" which is present in much of the published literature regarding strontium metabolism, especially when acute single dose investigations are extrapolated to chronic intake situations, three experimental groups of animals were selected:

Single dose: Each cat received a single oral dose of high specific activity ^{85}Sr as the chloride. The cats were subdivided according to age with at least three cats receiving the prescribed dose at 0, 1, 2, 4, 6, 8, 10, 12, 16, 20, 24, 32, 48, and 56 weeks of age. Cats older than 56 weeks were considered to be adults and were not used in this study.

Chronic uptake dose: In this group, cats were divided similarly to the single-dose group, but were given daily ^{85}Sr oral doses. Under this regimen, the growing cats received ^{85}Sr radiation exposure prior to birth or weaning, via the maternal placenta and/or milk.

Excretion following chronic uptake dose: This group of experimental cats is unique in that all of its members began receiving radiostrontium exposure from the time of conception. This group received ^{85}Sr as in the chronic group, but these animals were taken off the isotope at time intervals similar to those described previously and their excretion pattern followed for approximately a year.

Regardless of the study phase, each cat receiving radiostrontium was subjected to the following experimental observations at prescribed intervals: Whole-body radioactivity assay, excreta assay, blood analyses, and ^{85}Sr tissue distribution.

To supplement the ^{85}Sr metabolism data, various tissues--especially bone--were analyzed for stable strontium, calcium, and phosphorus. Ashed samples of the tissues were analyzed for strontium and calcium by atomic absorption spectrophotometry. Phosphorus was determined by ultraviolet spectrophotometry.

2. Whole-body Radioactivity Assay

J. F. Stara, R. G. Wolfangel, G. L. Jessup

For each experimental cat, the ^{85}Sr body burdens were analyzed in terms of initial experimental age. The tabular whole-body data were further treated and analyzed. The following equation adequately describes

radiostrontium elimination from cats following both single oral dose and chronic uptake dose:

$$R(t) = A(t + d)^{-b}e^{-ct}$$

where R = whole body retention at Time = t

A and b and c = constants

The equations obtained for each cat were averaged for all members of a respective age group using appropriate computer subgroups. Since animal-to-animal variations were seen, it decreased the reliability of the single equation describing radiostrontium metabolism for the particular age group. However, the equation representing a particular age group should be considered the best estimate of ^{85}Sr metabolism in cats; treatment of the data is under way at the present time.

Figure 36 represents the excretion of ^{85}Sr in different age groups of cats which received a single oral dose. The older cats appeared to eliminate a significant quantity of the ^{85}Sr in a relatively brief period. Later, elimination of the remaining radiostrontium proceded at a rate nearly equal to the younger animals. In younger groups, the early rapid ^{85}Sr elimination pattern was nearly or completely absent.

Figure 37 shows the plots of ^{85}Sr retention values generated from the average group excretion equations of chronically-dosed cats. There appeared to be little or no rapid excretion of radiostrontium in any age group, demonstrating a significant difference from cats labeled with a single dose.

3. Excretion Data
R. G. Wolfangel, J. F. Stara

The quantity of ^{85}Sr appearing in 24-hour collections of urine and feces of the experimental cats has been computed from the available data. Figure 38 illustrates excreta values from cats on chronic uptake dosage versus cats on chronic excretion status. During the chronic dosage phase, the feces to urine ratio approached 100 and followed a stable trend. During the excretion phase, radioisotope levels were reduced significantly with the feces to urine ratio averaging about 10 during this phase. During the transition from the chronic uptake phase to chronic excretion phase, ^{85}Sr content in the feces decreased from approximately 1,000 nCi/day to 10 nCi/day, a factor of 100. In contrast, the amount of isotope in the urine decreased from 10 nCi/day to about 1 nCi/day during the same transition period.

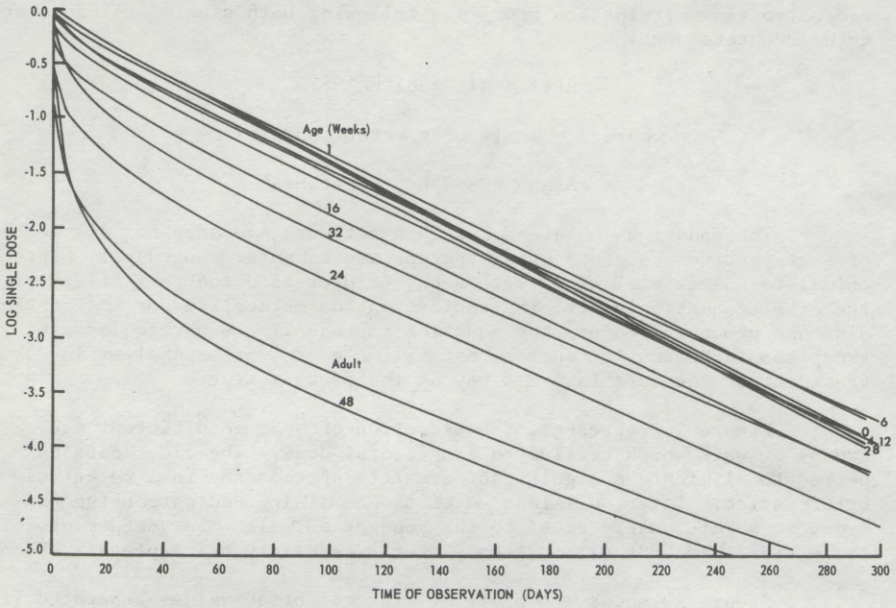


Figure 36. Excretion Curves of Cats Given a Single Oral Dose of ^{85}Sr.

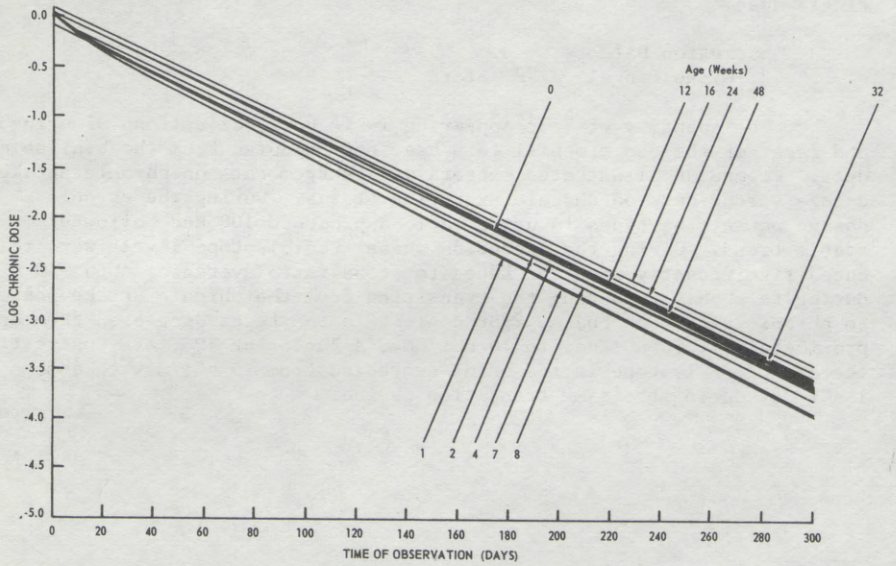


Figure 37. Retention Values Generated from Excretion Equations of Chronically Dosed Cats.

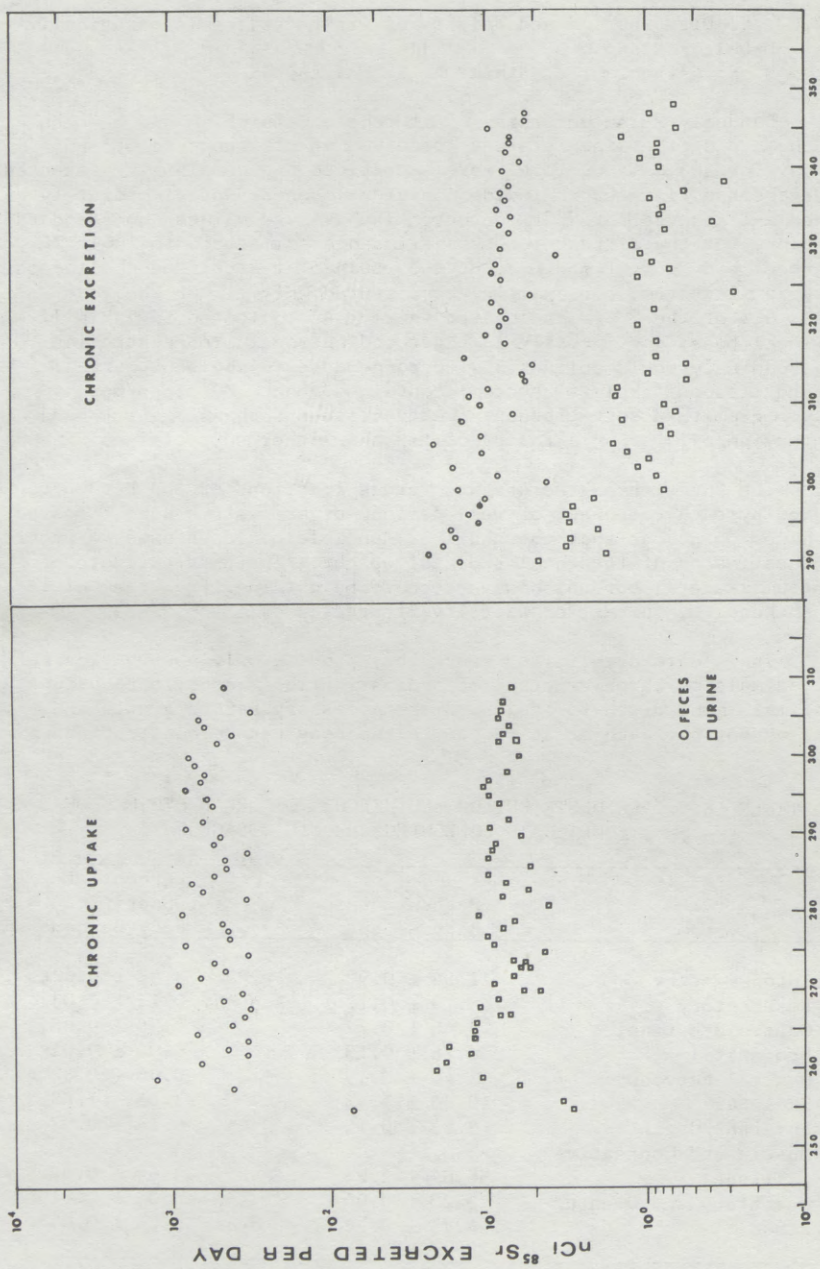


Figure 38. Feces and Urine Values for Cats on Chronic Uptake and on Chronic Excretion Regimens.

4. ^{85}Sr Distribution and Weights of Organ Systems in Chronically-Labeled Cats
N. S. Nelson, J. F. Stara, R. G. Wolfangel

Randomly selected, three adult female cats which had been on ^{85}Sr chronic uptake kinetic study (received an oral dose of 0.5 μCi ^{85}Sr/day for 365 days or more) were sacrificed and completely dissected. All organs and tissues, including individual bones, were immediately weighed and assayed for ^{85}Sr content. The average values and standard deviations for the different body systems are summarized in Table 16 by percent body weight and percent body burden at sacrifice. Although the skeletal system, for example, represented only 11% of the body weight, 91% of the ^{85}Sr was located there. As indicated in Table 17 individual bones vary greatly in their radiostrontium concentration and accordingly would deliver a wide range dose to the bone marrow. The hard tissues (skeletal system) contained about 100 times more ^{85}Sr per gram than soft tissues. Fatty tissues such as omentum and mesentery were lower by a factor of ten than other soft tissues.

The functions of the weights versus fractions of the burden contributed by each component of well-defined organ systems were compared. The values point out that the skull or mandible could be used to provide a good estimator of the total skeletal weight. The best estimate of strontium skeletal burden, however, could be obtained from the pelvis or the thoracic, lumbar, or sacral vertebrae.

These data are limited since they provide only observation for adult animals on chronic uptake of radiostrontium. Additional values for animals from birth to adulthood are necessary before growth and uptake curves for each organ in the feline body can be constructed.

TABLE 16. ^{85}SR DISTRIBUTION AND WEIGHTS OF ORGAN SYSTEMS OF ADULT CATS FOLLOWING CHRONIC DOSAGE

System	Percent of Body Weight	Percent of Sacrifice Body Burden
Integumentary	12.84 ± 0.90	3.42 ± 0.62
Respiratory	0.79 ± 0.17	0.15 ± 0.03
Gastrointestinal	3.48 ± 0.22	0.38 ± 0.08
Urogenital	0.78 ± 0.15	0.04 ± 0.01
Central Nervous	1.40 ± 0.19	0.06 ± 0.02
Skeletal	10.65 ± 1.43	91.05 ± 1.83
Internal Organ	3.68 ± 0.15	0.14 ± 0.02
Muscle and Connective Tissue	56.69 ± 2.24	3.69 ± 0.98
Mesentery and Omentum	3.20 ± 0.64	0.05 ± 0.01
Blood	4.75 ± 0.22	0.24 ± 0.06

TABLE 17. WEIGHT AND ^{85}SR DISTRIBUTION IN CAT SKELETON

Bone	Percent of Skeletal System Weight	Percent of Skeletal System Burden
Skull	12.45 ± 0.77	19.34 ± 3.46
Mandible	2.73 ± 0.04	3.50 ± 0.72
Vertebrae Cervical	5.53 ± 0.72	5.46 ± 0.77
Thoracic	8.59 ± 0.67	9.14 ± 0.51
Lumbar	10.06 ± 0.88	11.80 ± 1.20
Sacral	2.38 ± 0.67	2.68 ± 0.12
Coccygeal	3.98 ± 0.26	1.60 ± 0.50
Scapula	3.49 ± 0.12	6.15 ± 1.36
Humerus	6.05 ± 0.24	4.65 ± 0.74
Radius	1.92 ± 0.11	1.22 ± 0.53
Ulna	2.46 ± 0.14	1.95 ± 0.67
Carpals	0.533± 0.12	0.25 ± 0.09
Metacarpals	1.25 ± 0.30	0.51 ± 0.14
(F) Phalanges	1.54 ± 0.05	0.54 ± 0.01
Pelvis	4.72 ± 0.17	7.88 ± 0.74
Femur	7.42 ± 0.12	5.65 ± 2.65
Tibia	6.41 ± 0.13	4.87 ± 1.43
Fibula	0.805± 0.32	0.49 ± 0.25
Tarsals	2.91 ± 0.22	1.13 ± 0.23
Metatarsals	2.52 ± 0.22	1.05 ± 0.41
(R) Phalanges	2.14 ± 0.57	0.72 ± 0.34
Ribs	8.42 ± 0.24	7.67 ± 0.24
Sternum	1.53 ± 0.28	1.60 ± 0.32

5. Analysis of Stable Elements in Skeletal Tissues of Cats
R. G. Wolfangel, J. F. Stara, J. M. Cooper

Tissues of selected cats, which were sacrificed as a part of the radiostrontium metabolic studies, were analyzed for levels of Sr^{++}, Ca^{++} and Pi (inorganic phosphate). Ashed tissue samples were analyzed for Sr^{++} and Ca^{++} using an atomic absorption spectrophotometric technique. Phosphorus (Pi) was determined using an ultraviolet spectrophotometer. A high-speed digital computer was utilized to compute and sequentially arrange the data according to age groups.

The results (Figure 39) showed a gradual increase in the percent ash (ash weight/wet weight x 100) in skeletal tissues with increased animal age. The Ca^{++} and Pi levels in bone ash were virtually independent of age, ranging between 34-37% for Ca^{++} and 16-18% for phosphorus. The strontium to calcium ratios were low (0.5) in the neonates, but were elevated quickly to a maximum at about 10-15 weeks of age; thereafter the ratios gradually declined with increasing age. The percent strontium in ash generally followed the same trend. To date, nearly all stable chemistry data have been computed and summarized in the manner described; statistical evaluation of the data is in process.

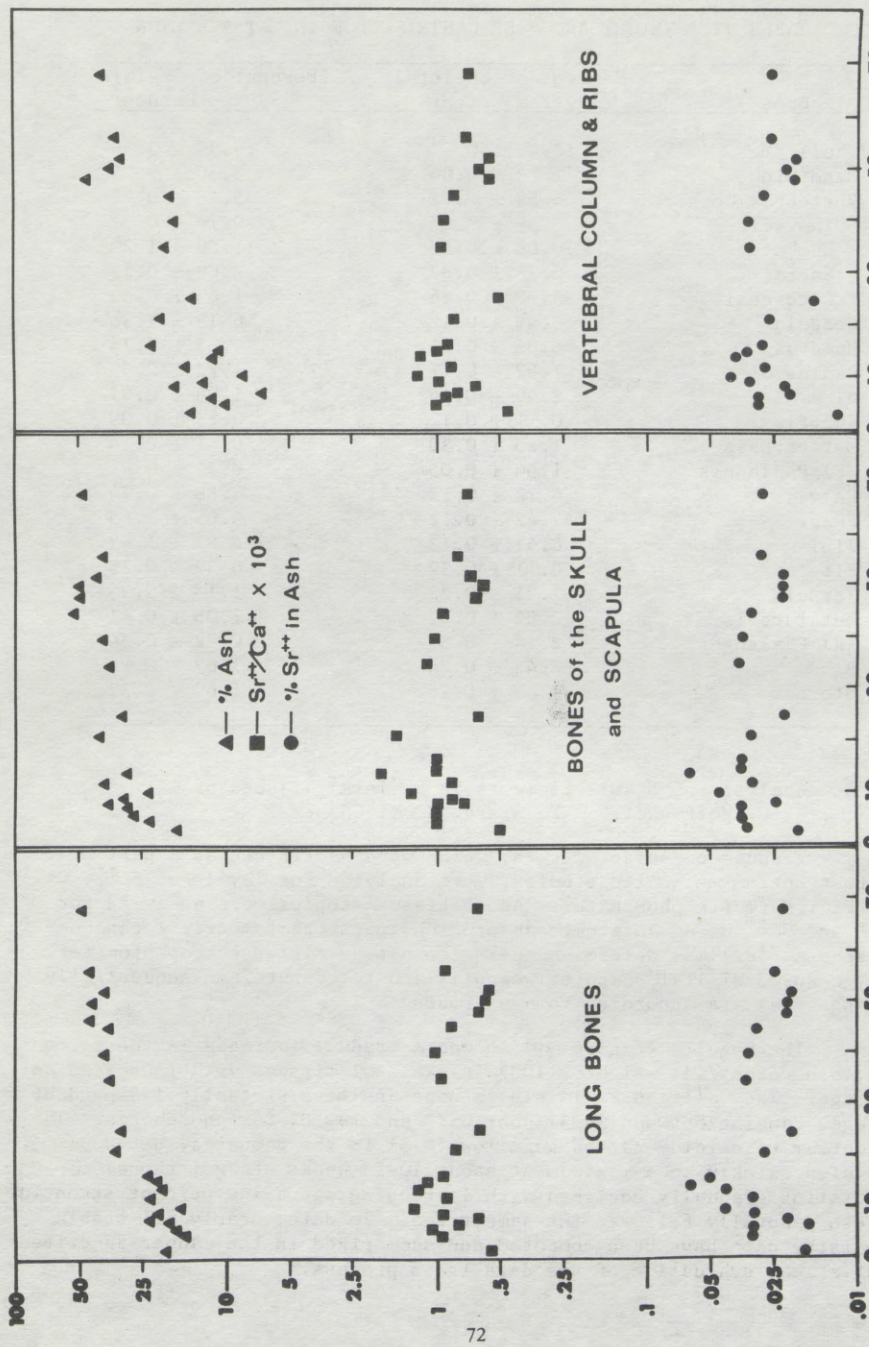


Figure 39. Strontium Levels in Three Types of Skeletal Tissue as a Function of Age.

E. DOSIMETRY OF RADIOSTRONTIUM IN SKELETAL TISSUES OF CATS

1. Nuclear Emulsion Characteristics and Calibration

L. S. Rosenstein, N. S. Nelson

In depth observations on Eastman Kodak Nuclear Tract plates were continued this year. Studies were restricted to those emulsions which could be of potential value for autoradiographic quantitation. These included Kodak NTB and NTB-2 emulsions both of which are extremely suitable for recording of charged particles. NTB-2 nuclear emulsions are the more sensitive of the two.

Fading and sensitivity tests were repeated to ascertain the effects of seasonal changes on the performance of nuclear emulsions. As expected, no difference could be detected in either NTB, or NTB-2 emulsions stored with dessicant at -10°C (freezer). For nuclear emulsions stored under ambient conditions with no dessicant, the image loss and sensitivity changes were far more critical in the early summer months (under high-humidity conditions) than under low conditions of saturation found in January and February. Batch differences were eliminated by using each nuclear tract plate as its own control.

The results of the above study indicate that exposure of quantitative autoradiograms can best be accomplished under deep-freeze conditions. It was concluded that, under conditions of prolonged exposure, NTB-2 presented the most stable reaction as far as minimal image fading and sensitivity changes are concerned. Its greater sensitivity allowed for reductions in exposure time by as much as a factor of two.

Work has been continuing on the calibration of nuclear emulsions for quantitative autoradiography. By employing the method of Marshall et al., standard sources of radiostrontium ($^{90}Sr + {}^{90}Y$) have been used in conjunction with absorbers to derive calibration curves for less than thick sources. These calibrations have been applied to bone sections to determine bone concentration ($\mu Ci\ ^{90}Sr/gram$) and further to describe the distribution of radioactivity within a bone sample.

2. Strontium-90 Dose Distribution in Chronically Labeled Cats of Different Ages

L. S. Rosenstein, J. F. Stara

Pregnant dams received daily doses of ^{90}Sr in their diet from conception. With this method the skeletal tissues of kittens were uniformly labeled at the time of sacrifice, whether the isotope was transferred to the developing offspring through the placenta, maternal milk, or in their own diet. Kittens were sacrificed at 0, 25, 50 and 200 days of age. The dams eventually were sacrificed and served as an adult subgroup. Selected bones were dissected, fixed, and embedded in bioplastic or methacrylate for sectioning, autoradiography, microradiography, and microdensitometry.

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An example of autoradiographic quantitation is illustrated in Figure 40. The sample is an infinitely thick, cortical cross section taken from the femur of an adult cat (504 days of age), chronically labeled with strontium-90 via the diet. The autoradiogram showing evidence of short-term exchange on periosteal and endosteal surfaces, and the long-term diffuse exchange processes, is shown (40a). The resulting X-ray and Isodensitracer analog output are shown in b and c, respectively. An overlay reflecting the contours of absorbed dose rates have been included for a more adequate interpretation (40d). A photomicrograph of the identical femoral section of several magnifications is included in Figure 41 to illustrate the fine structure of adult feline bone. The dark circular bodies represent the osteons with Haversian Canals in the center. Evidence of accretion and resorption can be seen at the periosteal and endosteal surfaces, respectively.

In order to determine the distribution of absorbed dose rates in trabecular regions, an autoradiogram of an infinitely thick, longitudinal section of a young cat femur was scanned in the usual manner on the Isodensitracer (Figure 42). In addition, the analog output was not only graphically displayed 42b, c), but also digitized on magnetic tape. The area recorded has been outlined 42a). There were approximately 225,000 observations made on each plane 12.5 microns (abscissa) by 25 microns (ordinate). The data are being used to fit response surfaces and also to graphically display bone areas of interest to a much finer grid than could be obtained from the original response patterns 42b, c).

3. Development of Bone--A Review of Literature
L. S. Rosenstein

A very extensive literature search has been conducted into those areas that relate to isomorphic exchange and nucleation mechanisms at the level of the hydroxyapatite crystal. This review along with some aspects of calcium/strontium metabolism at the level of the crystal has been prompted by the demands of future investigations involving effects of localized deposition of ^{89}Sr, or ^{90}Sr occupying a lattice position.

Any mechanism resulting in the calcification of a mineralizable matrix obviously influences the building of a crystal structure in which calcium at its lattice position can be replaced by a radiotoxic element (any pertinent member of the alkaline earth series). Although the concept of crystal orientation (epitaxy) in most cases is rigid, there are some conflicting views as to how crystal growth initially begins.

Neuman and Neuman[1] first postulated nucleation mechanism in which crystallization occurs on sites to which minerals may be bound, thus forming nucleation centers. Later work showed that the site of calcium or phosphate binding may be in the collagenous fibrils in the ground substance. Furthermore, it was demonstrated that only collagen fibrils

[1]The Chemical Dynamics of Bone Mineral, Univ. of Chicago Press, Nature 218:1262.

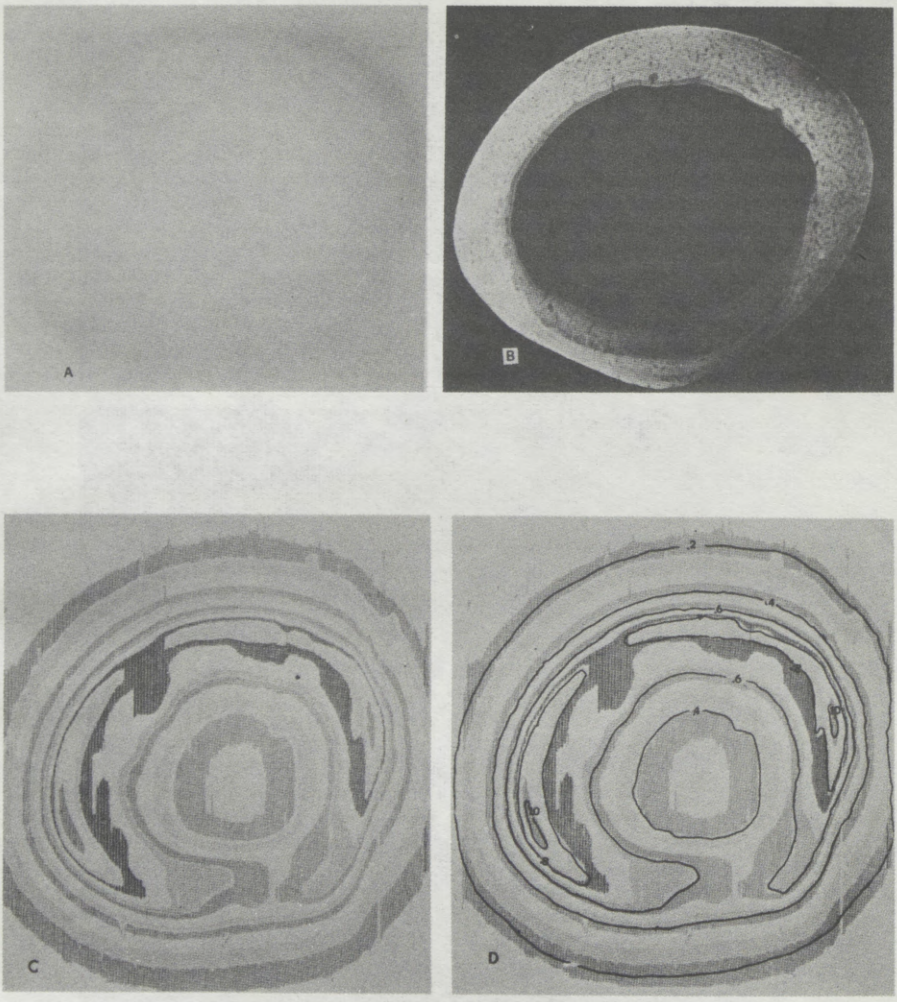


Figure 40. Cross Section of an Adult Cat Femur Showing Associated Autoradiograph (A), X Ray (B), and Absorbed Dose Rates in Rads per Day (C, D). The radionuclides are ^{90}Sr + ^{90}Y.

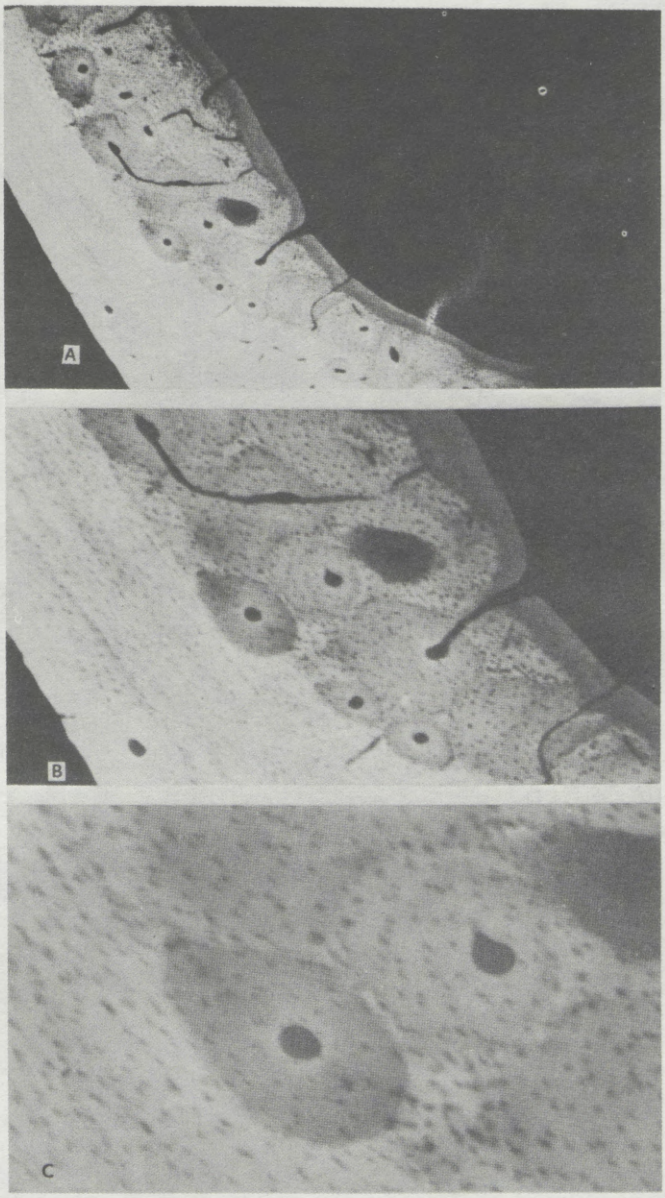


Figure 41. Photomicrographs Showing Cellular Detail of Adult Cat Femur Shown in Figure 40.

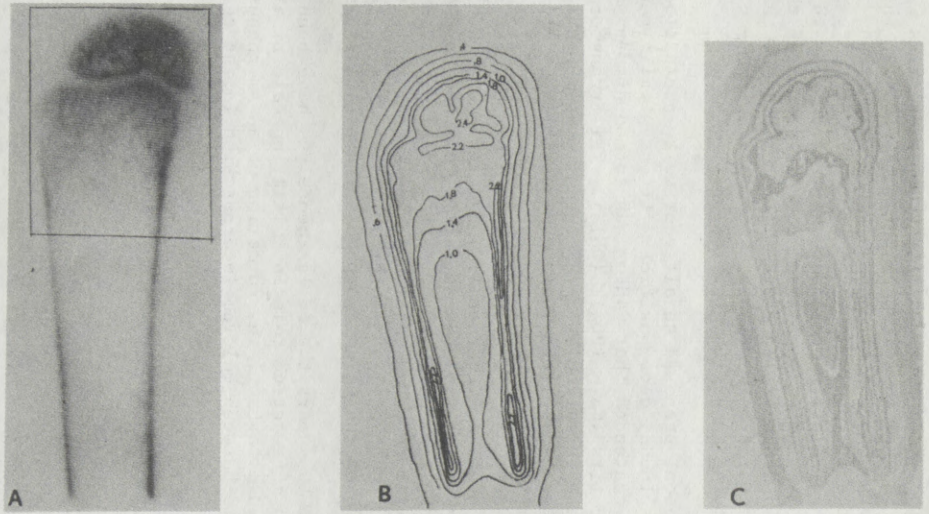


Figure 42. Longitudinal Section of Weanling Cat Femur Labeled with ^{90}Sr + ^{90}Y. The dose response surfaces (rads per day) were determined for the enclosed area in (A) and are shown in (B) and (C).

possessing certain periodic and stereochemical characteristics were able to mineralize. It was further suggested that ATP may provide the energy and phosphate groups (orthophosphate) necessary for nucleation. One other study stated that the ground substance (sulfated mucopolysaccharide) may interact with collagen fibrils and induce nucleation. In this instance, the binding of calcium was necessary for activation of the nucleation process. In pre-osseous tissue another study indicated that nucleation may occur by a reaction between calcium and tissue protein with the ground substance acting as an ion distributor.

In 1968, Samachson[2] proposed an alternative to nucleation and further growth called spinodal decomposition. It essentially reflects the views of those who contended that $CaHPO_4$ was formed first and later modified into hydroxyapatite (Ca_{10} $(PO_4)_6$ $(OH)_2$). This transformation involved the intermediate formation of an amorphous phase of calcium phosphate which was later redeposited in a form resembling hydroxyapatite. The initial formation of $CaHPO_4$, however, has no need for the collagenous template. Only where transformation to hydroxyapatite has occurred is the matrix necessary. Generally, Samachson's method involves the addition of Ca^{++} to the organic matrix followed by HPO_4^-. The removal of H^+ then follows allowing PO_4^- its proper position on the template. Ca^{++} or OH will be added until the hydroxyapatite is formed. Crystal growth will continue until an inhibitor is encountered (such as pyrophosphate) or the formation of an amorphous precipitate is incurred.

Within the past two years the cells themselves have been implicated as playing a much more active role in initiating calcification than formerly considered. In fact, the formation of an amorphous phase may well be intermediate between calcium incorporation in the cell and formation of hydroxyapatite.

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[2]Nature 218:1262.

F. LETHAL EFFECTS OF ^{89}SR IN CATS

J. F. Stara, N. S. Nelson, R. G. Wolfangel

The original objective of this study was to assess the ^{89}Sr dose effect on feline embryos at five different chronic dose levels administered to the dams from day of breeding until deliveries. An attempt to obtain embryonic mortality probit curves from this pilot experiment was not entirely successful. Dams were fed ^{89}Sr in their diet at dose levels of 10, 62.5, 125, 250 and 500 μCi per day from conception to parturition. Levels producing over 50% mortality in embryos resulted in mortality rates of more than 50% in the dams prior to, or at the time of delivery. Several important observations were made, however, which will be of definite use in developing the long-term ^{89}Sr study.

At birth, the average weights of the kittens delivered of dams fed 10 μCi of ^{89}Sr per day were comparable to the average weights of controls in the same size litters. There was a slight downward trend in the average weights of offspring of cats receiving 62.5, 125 or 250 μCi/day. Offspring born from dams receiving 500 μCi/day showed a marked reduction (30%) in weight at birth. Most kittens born from radioactive mothers (in all dose groups) showed a slight retardation of growth during the first 4-7 weeks of life, but later caught up with the colony norms. Several resorptions and abortions occurred in the pregnant queens. Most pregnancies resulted in births with kittens alive and growing, but the general opinion of trained colony personnel was that the ^{89}Sr kittens were not "doing well." This observation was later borne out by a high death rate among the growing kittens. In dams on the highest level (500 μCi ^{89}Sr per day) a cannibalism occurred which is a well-known behavioral syndrome in cats, as well as certain other mammalian species, in cases when the mother delivers abnormal offspring.

The most severe effect seen in dams receiving ^{89}Sr was the depletion of the peripheral blood elements. The formed blood element responses are shown in Figure 43. The cause of death of the three queens which died at parturition, or shortly thereafter, was an uncontrollable hemorrhage, an apparent defect in the clotting mechanism. This hemorrhage could not be controlled by an injection of clotting agents such as adenochrome isonicotinic acid hydrazone nor by n-butyl alcohol. All queens receiving 250 or 500 μCi of ^{89}Sr per day exhibited a generalized anemia with PCV greatly reduced, as well as general cachexia. Only one queen (915) survived for 140 days post conception from the group receiving 500 μCi per day. Her blood count was precipitously dropping and her condition progressively worsened until she was sacrificed at 170 days after conception. At this time the RBC was 480,000 with a PCV of 6, and WBC of 2,500. In all adult females on high dose levels the adverse response was observable primarily in the hematopoietic system and the general body condition (cachexia).

The ^{89}Sr body burden, specific activity, and rad dose were calculated for selected dams and their offspring. In Table 18, the observed body burden of ^{89}Sr was compared with values predicted from pregnant animals

TABLE 18. PREDICTED AND OBSERVED ^{89}SR IN KITTENS FROM CONCEPTION TO 1 YEAR

Dose,	nCi/g At Birth		Rad Dose from Birth to 1 Year		Rad Dose from Conception to 1 Year	
μCi/d	Predicted[a]	Assayed[b]	Predicted	Assayed	Predicted	Assayed
10	58.80	8.08	30.01	4.20	44.57	6.24
62.5	361.25	33.03	187.70	16.89	287.70	25.08
125.0	722.50	177.18	375.15	93.99	557.15	139.29
250	1445.0	866.53	750.55	450.33	1114.55	668.73
500	2890.0	1546.37	1501.09	810.59	2283.09	1203.71

a. Predicted from pregnant animals which received daily dose of 0.5 μCi of ^{85}Sr for 1-3 years.
b. Average for all kittens assayed.

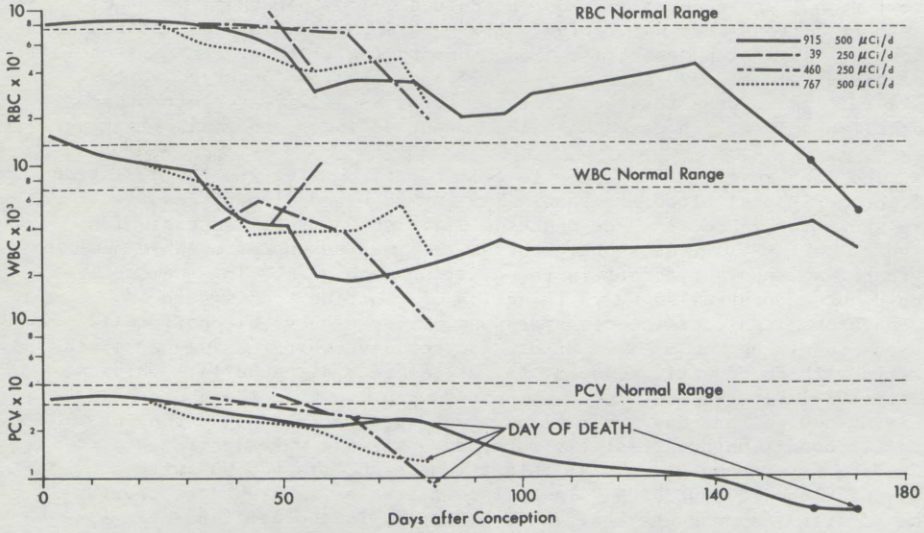


Figure 43. Blood Element Responses of Four Animals That Received ^{89}Sr Doses at Rates of 250 and 50 μCi per Day.

that received a daily dose of 0.5 μCi of ^{85}Sr for a 1-3 year period. The average body burden in the kittens labeled with ^{89}Sr differed from the predicted dose by a wide margin at the lower levels, and by about 50% at the higher dose levels.

Cat embryos were obtained by cesareotomy from dams receiving 0.5 μCi ^{85}Sr per day by pill prior to and during pregnancy. For the five different dose levels, the integrated dose from conception to birth was calculated. The calculated data from 14 to 35 days of gestation included the rad dose from the placenta. During this period of development the fetus is within the range of ionizing radiation originating in the placenta. At that time the placenta exhibits a higher concentration of radiostrontium than the fetus.

The observed and predicted integrated body burdens for each dose level of ^{89}Sr fed, appropriately corrected, are also given in Table 18. These data suggest that about 40% of the total predicted rad dose will be received by the embryo during gestation, and that the remainder will be received from birth to one year of age.

G. LOCALIZATION OF ^{131}I-LABELED TETRACYCLINE IN TUMORS USING SCINTI-SCANNING

R. G. Wolfangel, J. F. Stara

Various investigators have implicated tetracycline to be a potentially reliable agent for diagnosing neoplasms. In most cases this conclusion was based upon observation of yellow fluorescence arising from excised tumor tissue when irradiated with ultraviolet light. To evaluate and extend the use of tetracycline in diagnosis of tumors in vivo, radioiodinated tetracycline was synthesized and injected into cats and dogs which showed clinical symptoms of neoplasia; subsequently, scans of the affected animals were obtained using the scintillation camera.

Radioiodine-labeled tetracycline was produced in our laboratory by reacting ^{131}I-labeled N-iodosuccinimide with a deoxytetracycline in concentrated acid. Results of chromatographic, ultraviolet spectral absorbance, and optical rotation determinations on the final product were compared with published values. The analytical data indicated that small amounts of unreacted deoxytetracycline were present. However, 99% of the ^{131}I residing in the final product was found to be present as ^{131}I-tetracycline. These results were obtained by autoradiography of finished chromatograms and secondly by sectioning the chromatograms and counting each section. The specific activity of the tetracycline was assayed and found to be 1 μCi/mg of tetracycline.

Labeled tetracycline for animal injection was prepared by dissolving the antibiotic in sterile balanced electrolyte solution at a level of 20-25 mg/ml and filtering the preparation through a Millipore filter (0.22 micron using a "swinny" adapter).

Three experimental animals showing clinical symptoms of neoplasia were used in this experiment: A male Siamese cat (Kit) with a tumor in the submandibular area; a female dog - terrier (Petunia) - with a breast tumor; and a female dog - a red-bone hound (Lady) - also with a tumor of the breast. Both Kit and Petunia were injected with 5 mg of iodine, as potassium iodide, one hour prior to tetracycline administration because previous investigations in other species have shown slight thyroid uptake of ^{131}I activity; this is probably unbound radioiodine stemming from the 1% radiochemical impurity in our reaction products. Lady did not receive this treatment.

The prepared solution of tetracycline was in all cases injected intravenously, with Kit and Petunia receiving 80 mg and Lady receiving 12 mg. Since Lady weighed approximately 90 pounds, she was not subjected to scanning and was used only for tetracycline tissue concentration study; i.e., distribution analysis of dissected tissue. For the scinti-scanning procedure, both animals were anesthetized and the radiotetracycline injected immediately before the first scan. Each animal was scanned in several positions and at various times during three days following tetracycline administration. Polaroid photographs of the scintillation scans

were taken each time. The serial determinations over the three-day period were to investigate the optimal time distribution relationship and body position which would be most beneficial for the tumor diagnosis.

After scanning was completed, each animal was sacrificed by exsanguination, dissected, and samples of major organs and neoplastic tissues were collected for radioassay. The levels of tetracycline in the various tissues were normalized and corrected for physical decay. In the case of Kit, high tetracycline levels were found in the tumor tissue, the spleen, and the liver; in the case of the two dogs, the level of tetracycline in mammary tumors did not surpass that in normal healthy tissues.

On the scinti-scans, Kit showed similar accumulations of high level radioactivity in the area of the neck, liver, spleen, and urinary bladder, demonstrating a good agreement with the distribution analysis. Pathological examination confirmed the diagnosis of lymphosarcoma in a submandibular region which had metastasized and produced visible neoplastic nodules in the spleen and the lymph nodes.

Scinti-scans of Petunia showed ^{131}I tetracycline penetration into the mammary tumor, but not in a greater concentration than normal health tissue such as liver. In all cases distribution data corroborated the scans. Pathological findings diagnosed a squamous-type tumor in the mammary gland which was well circumscribed and localized. Results obtained from Lady were essentially the same.

The small number of animals studied presents obvious difficulties in interpretation of the results. Diagnosis of the type of tumors present in the two dogs does not appear possible using tetracycline administration and scintillation methods. The fact that the tetracycline scanning procedure did provide excellent interpretative illustrations of lymphocytic neoplasm in the affected cat warrants further evaluation of this agent as a potential cancer diagnostic aid in vivo.

H. EXPERIMENTAL MYXEDEMA IN CATS PRODUCED BY ^{131}I

J. F. Stara, N. S. Nelson

A cooperative study was initiated with the National Heart Institute to investigate the effects of myxedema on heart musculature in the cat. Fifty-three adult felines (25 males and 28 females) were dosed with high levels of ^{131}I to produce partial ablation of the thyroid with resulting myxedema. Prior studies of iodine retention in felines indicated that a single dose of 500 μCi of ^{131}I/kg would produce a hypothyroid state.

Serum samples were initially obtained from all animals to provide baseline protein bound iodine (PBI) values. Normal PBI values averaged 5.0 μg percent with a range of 1.8 to 8.9. The I.V. dose of 500 μCi/kg depressed the PBI values by approximately 50% at 90 days. However, the NHI laboratory assayed six animals at 120 days post-dose and found no myxedematous conditions and subsequent changes in heart muscle.

Based on this finding, a second dose of ^{131}I at an increased level of 1 mCi/kg was administered to all remaining animals. Serum samples obtained at 30 days and 60 days after dosing demonstrated PBI values below 2.0 μg percent, a reduction from normal values by 60%. There was a severe change in the behavior and daily activity of the cats. The majority gained weight, exhibited lethargy, stiffness, and awkward movements, and displayed changes or complete elimination of voice signals.

To confirm reduced thyroid function, ^{123}I was administered to six of the experimental animals. The ratio of thyroid uptake values was 20:1 in the control vs. experimental animals.

The clinical findings combined with the ^{123}I thyroid uptake values and the PBI values produced sufficient evidence of severe hypothyroidism and myxedematous conditions in these animals. Investigators at the NHI confirmed these results and found altered conditions in cardiac musculature. Testes, ovaries, thyroid, adrenal, and heart muscle from selected animals are presently undergoing histopathological examination.

I. MATERNAL-FETAL ^{131}I RELATIONSHIPS IN THE GUINEA PIG

N. S. Nelson, J. F. Stara

Investigations of maternal-fetal relationships of ^{131}I metabolism in the guinea pig have shown that the pattern of iodine deposition in the thyroids of 26 and 30 day embryos resembles that of mature animals in that follicular deposition has occurred. Iodine deposition in thyroids of 21 day embryos was somewhat more diffused. Apparent deposition of iodine in tissues of the embryonic eye was observed in 21, 25, and 30 day embryos. This deposition occurred apparently in the tissue which would become, in the adult, tapetum lucidum. Although some deposition of iodine occurred in other tissues, its magnitude was greatest in the tapetum lucidum and in the thyroid.

J. DISTRIBUTION OF CARRIER FREE AND ^{99}MO-LABELED MILK IN CATS

R. G. Wolfangel, J. F. Stara

Because of recent interest in ^{99}Mo, the Environmental Surveillance group asked this laboratory to conduct a pilot study of the metabolic behavior of this radionuclide. They supplied ^{99}Mo as an aqueous molybdate solution ($^{99}MoO_4^=$), and in labeled milk; the milk was obtained from a dairy cow which had ingested a dose of the $^{99}MoO_4^=$. The ^{99}Mo in the milk was non-ionic or protein bound as indicated by passing the milk through anionic and cationic ion exchange columns. Three cats were administered the aqueous solution by intravenous injection, and three others were fed 60 ml of the labeled milk. Whole body measurements were obtained on all animals for 36 hours; at the end of this period, the animals were sacrificed and dissected. The mineralized tissues of animals that received the labeled milk contained 7 or more times the amount of ^{99}Mo than the aqueous solution-dosed cats. The soft tissues showed the same trend, although the ratio was somewhat lower. The preliminary data strongly suggest major differences in the metabolism of the aqueous ^{99}Mo versus the ^{99}Mo biologically labeled in milk not withstanding the fact that different routes of administration were utilized.

After 36 hours, the milk-fed cats retained nearly 90% of the administered ^{99}Mo; cats given aqueous ^{99}Mo by capsule retained less than 20% of the initial dose. The milk-fed cats displayed a urine to feces ratio of 0.40; those given the capsule showed a value of 2.5.

The results of the pilot study indicate that ^{99}Mo ingested in the form of labeled milk is metabolized differently than aqueous molybdate solution. The internal radiation exposure resulting from ingestion of contaminated dairy products would therefore be appreciably greater than that resulting from administration of an aqueous solution where molybdenum is in the ionic state.

K. CARCINOGENIC EFFECTS OF DEPOSITED RADIOACTIVE PARTICLES IN THE LUNG[3]

R. E. Stanley, H. J. Monie

The study to assess the potential human health hazard associated with the inhalation of respirable, highly radioactive particles emitted in the effluent from reactor engines began at the Southwestern Radiological Health Laboratory (SWRHL) in 1967. The project was designed to be conducted in three phases. The expected results from the first phase, production of primary lung cancer in the rat, would serve as an indication of the existence of potential hazard and of the need for proceeding with the second phase projected for the dog. Failure to produce primary carcinoma in the rat with exposure levels likely to be encountered in the environment would terminate the project at the conclusion of the first phase.

Progress to date has been limited to the completion of an extensive survey of the literature on inhalation toxicology and to three preliminary studies. The third preliminary study was started in July. In this study, field-collected radioactive particles from reactor effluent were injected via the trachea into the lungs of five rats. We have found, as in the two previous preliminary studies, that the clearance of radioactive particles from the rat lung is best described by a two-phase curve. The first phase represents the initial clearance and varies with the individual animal. It is probably dependent upon the dispersion of the particles in the lung and the individual efficiency of the ciliary escalator. The clearance half time for this phase is from 1 to 5 days. The second part of the curve apparently is primarily influenced by physical decay of the retained isotopes and varies with the age of the particles injected. In a previous study, fresh particles containing both short- and long-lived isotopes were used and a 7-day half time was observed in the second phase of the clearance curve. The present study uses particles 3 weeks old, the clearance half time is 11 days indicating a predominance of long-lived components. Gross and microscopic effects data for the limited studies are not yet available.

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[3]This study conducted at the Southwestern Radiological Health Laboratory, Las Vegas, Nevada.

L. INVESTIGATION OF ALPHA PARTICLE AND TOBACCO SMOKE SYNERGISM[3]

S. C. Black, E. W. Bretthauer

This investigation was conducted in two distinct phases. Phase I consisted of the quantification of not only ^{210}Po but also ^{210}Pb and ^{226}Ra in tobacco and mainstream smoke over a wide range of parameters, i.e., locale of tobacco growth, variability in smoking patterns, effectiveness of commercial cigarette filters, etc. If the exposure due to smoking could not be easily eliminated or significantly reduced as suggested by such a parameter evaluation, then Phase II, animal studies to determine whether the amounts of radiation derived from Phase I actually produce lung carcinoma, was to proceed. The laboratory work on Phase I has been completed.

Phase II of the Project began in early January, 1967. A literature search revealed that an inhalation chamber for introducing cigarette smoke at comparable conditions (temperature, particle size, and concentration) to human smoking did not exist for small animals. A series of experiments was undertaken to provide data useful for the design of an inhalation chamber which would meet the above criteria. A prototype chamber was fabricated, tested and modified until it exhibited acceptable agreement with the desired criteria.

To successfully test this chamber several problems were solved which should enhance future progress: (1) a method for uniformly adding ^{210}Po to cigarettes to enhance concentration in smoke, (2) development of an animal restrainer to minimize trauma during exposure, and (3) a method of removing ^{210}Po from mainstream cigarette smoke. A large scale smoking device (exposure of 20 rats simultaneously) was completed in November. Experiments are now in progress to determine dose ranges to be used for the long-term experiments which will be designed to determine whether the quantities of alpha radiation present in cigarette smoke actually produce lung carcinoma.

PHYSIOLOGY AND BIOPHYSICS LABORATORY

Dr. Moris L. Shore, Chief

In evaluating the hazards of ionizing radiation, a number of approaches have been taken by the Physiology and Biophysics Laboratory. One approach is based on the hypothesis that ionizing radiation produces its most significant long-term effects through alterations in DNA, the structural integrity of which is essential to the maintenance of all normal cellular activity and thus the functional viability of any living organism. Any radiation-induced alteration, produced directly or indirectly in the normal base sequence of DNA, constitutes a mutation. Such mutations are generally considered to be deleterious, and even if not, constitute damage produced by ionizing radiation. Mutations may be expressed in such obvious ways as birth abnormalities, decreased lifespan, tumor induction, or cataract formation. Mutations may also find more subtle expression as decreased functional capacity of specific organ systems, alterations in immunological competency that may decrease resistance to bacterial or viral infection, or alterations in the synthesis of proteins whose synthesis is directly dependent on the integrity of DNA, Messenger RNA, and the translation process.

Other studies have examined the effects caused by radiation delivered in utero. These studies have dealt with protein synthesis in general, specific enzyme systems, possible effects on immunological processes, and effects on components of the peripheral blood.

This past year, the Physiology and Biophysics Laboratory integrated studies related to the effects of microwave radiation into many of its projects. The first study, summarized in the following section, relates to the biological effects of microwaves. Additional emphasis on nonionizing radiation studies and low-energy X-ray studies are planned for next year.

A. EFFECTS OF MICROWAVE RADIATION ON CHINESE HAMSTERS

D. E. Janes, W. M. Leach, W. A. Mills, R. T. Moore, M. L. Shore

Increased concern has developed recently over the possible biological hazard of electromagnetic radiation in the microwave frequencies. The scientific literature indicates that microwave radiation produces significant effects on a number of biological systems, including the nervous system, the eye, the circulatory system, and the reproductive system. At the cellular level, observations have shown that microwaves (1) produce lenticular opacities, (2) can arrest the process of differentiation in embryos without necessarily arresting cellular proliferation, (3) can produce testicular damage (even when such irradiation is effected below temperatures necessary to cause injury with infrared exposures), and (4) can produce irregularities in the mitotic process.

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The present study, using Chinese hamsters, investigates the biological effects of microwaves on the mitotic process of bone marrow cells, and on the in vivo incorporation of ^{14}C-labeled phenylalanine into protein of liver and testis. The cytogenetic studies provided suggestive evidence for increased chromosomal stickiness after microwave radiation. However, no chromosomal or chromatid aberrations were observed. Studies on protein synthesis indicate that microwave radiation causes a marked decrease in the in vivo incorporation of labeled amino acid into protein both in liver and testis.

Unanesthetized Chinese hamsters weighing 25-35 grams were used in this study. Experimental animals were exposed to radiation produced by a microwave oven operating with the door open at a frequency of 2450 MHz (12.25 cm wavelength).

The irradiation was not performed under unequivocal far field conditions and the average power density of the microwave field at the point of exposure could not be effectively determined with instruments available for the measurement of average power density. Thus two approaches were employed for the relative characterization of the field; one, biological, employed lethality as an endpoint, the other, physical, employed calorimetry techniques using spherical water loads.

For the lethality studies, animals were irradiated for 3 minutes followed by no radiation for 1 minute until the time of expiration. The duration of microwave exposure which resulted in deaths of the hamsters ranged from 9 to 36 minutes. Rectal body temperatures in hamsters at the end of the irradiation period during which mortality occurred ranged from 37.9° C to 47° C with a mean of 43.6° C.

Data were obtained on the absorption of microwave energy in spherical phantoms filled with distilled water. The phantoms had volumes of 500 ml and 200 ml and radii of 4.92 and 3.63 cm respectively. The pyrex containers used for the phantoms were assumed to be in thermal equilibrium with the water mass of the phantom. The calorimetric technique showed an average temperature rise per minute in the 500 ml water phantom (4.92 cm radius) to be $0.178 \pm 0.002^{\circ}$ C per minute; in the similar 200 ml (3.63 cm radius) phantom, $0.198 \pm 0.001^{\circ}$ C per minute. The average rates of energy absorption, expressed per unit of cross sectional area of the phantom were 87.1×10^{-3} (500 ml) and 71.3×10^{-3} (200 ml) joules sec^{-1} cm^{-2}. These values are useful as a point of reference, but cannot readily be extrapolated to measures of the average power density of the microwave field since the absorption cross section for these phantoms is not known.

1. Chromosomal Effects

Cytogenetic studies were performed in animals exposed to the microwave field for a total of 12 minutes. Two chromatid breaks were

observed in a total of 50 analyzable cells. In the control animals, one chromatid break was observed in 100 cells that were examined. Five of the 100 control cells were aneuploid; four had a small acrocentric chromosome missing, the other cell contained two extra submetacentric chromosomes. Aneuploidy was not observed in the irradiated cells.

A substantial proportion of metaphase cells from irradiated animals showed gross chromosomal anomalies, similar in appearance to the "early physiological" or "stickiness" effects observed in dividing cells after X irradiation. Because of the complexity in stickiness effects after X radiation, it may be of questionable value to attempt, at the present, a quantitation of stickiness in cells exposed to microwaves. Stickiness phenomena may be observed either between parts of one chromosome (chromatid stickiness) or between two or more chromosomes (chromosome stickiness). In the present study only metaphase cells were evaluated for chromosome stickiness and chromosomal aberrations. In the controls up to 20 percent of the metaphase spreads contained what appeared to be chromatid stickiness, but no chromosome stickiness. In the cells from animals irradiated two hours after Colcemid injection, over half of the metaphases showed chromatid stickiness. Chromosome stickiness varied from preparation to preparation in a range from about 25 percent to 67 percent of the metaphase cells. The cells from animals injected after irradiation were essentially similar to control cells. Almost 50 percent of cells from animals injected just prior to irradiation showed chromatid stickiness, but chromosome stickiness was not observed.

In preparations obtained from animals irradiated two hours after injection, we found evidence that cells were escaping from the Colcemid block, and attempting to complete mitosis and cytokinesis. Detectable cytokinesing cells were those in which stickiness interfered with daughter chromosome separation. Long chromosomal bridges connected the daughter nuclei in about 10-15 percent of the dividing cell population. Similar bridging was observed in cells from animals exposed immediately after injection (4-5 percent), as well as cells from animals injected after exposure or control cells (less than 1 percent in either case). It is apparent that stickiness may interfere with the completion of cytokinesis. Since chromosomal material is in the bridge between the daughter nuclei, it is possible that chromosome rearrangements may be detected in subsequent cell divisions. Experiments to examine this possibility are in progress.

2. Effects on Amino Acid Incorporation

The in vivo incorporation of ^{14}C-labeled phenylalanine (^{14}C Phe) into liver and testis protein was examined in Chinese hamsters after microwave irradiation. Since animals were injected with ^{14}C Phe intraperitoneally, variable amounts of the labeled amino acid may have been available within the tissues of interest for incorporation into protein. Thus both acid soluble ^{14}C Phe in liver and testis as well as acid insoluble ^{14}C Phe were determined. The data on incorporation are expressed

as relative activity -- % injected dose ^{14}C Phe in tissue protein/% injected dose ^{14}C Phe in tissue acid soluble fraction.

Animals received a total microwave exposure of 12 minutes as previously described. Controls were sham irradiated. Rectal temperature was obtained with a thermistor probe on completion of exposure or sham exposure. The mean increase in rectal temperature as a result of microwave irradiation was 4.2 ± 0.6^{o} C.

Table 19 presents the average relative activity in liver and testis at 80 minutes and 20 hours after the midpoint of exposure. Since liver value for irradiated animals is not significantly different from zero at 80 minutes, it appears that labeled amino acid incorporation into liver protein was essentially abolished by 80 minutes after microwave exposure. A similar effect, though not as pronounced was seen in testis 80 minutes after exposure. The value of relative activity in testis of irradiated vs. control animals was decreased by approximately 45 percent. The difference between sham controls and irradiated animals was significant ($P < .05$).

TABLE 19. RELATIVE ACTIVITY[a] OF AMINO ACID INCORPORATION AT VARIOUS TIMES AFTER MICROWAVE IRRADIATION

Time After	Liver		Testis	
Irradiation	Irradiated	Control	Irradiated	Control
80 minutes[b]	0.564 ± 0.334	4.73 ± 0.328	0.331 ± 0.065	0.609 ± 0.093
20 hours[c]	5.368 ± 0.603	5.689 ± 0.455	0.539 ± 0.082	1.092 ± 0.231

a. $\frac{\text{\% injected dose } ^{14}C \text{ Phe in tissue acid insoluble fraction}}{\text{\% injected dose } ^{14}C \text{ Phe in tissue acid soluble fraction}}$

b. Average of 11 animals.

c. Average of 12 animals.

Table 19 also shows that incorporation of amino acid into protein, which was essentially abolished 80 minutes after exposure was restored to normal values 20 hours later. The relative activity of sham irradiated controls was not significantly different in either the liver or the testis group although a tendency toward lower values is suggested 80 minutes after sham irradiation relative to the 20 hour controls.

In contrast to the recovery of amino acid incorporation into liver, the value for testis remained depressed relative to sham controls 20 hours after exposure to microwaves. The factors underlying this difference are not readily apparent, but hormonal stresses associated with the sham irradiation may be involved. It is apparent, however, that in all cases exposure to microwave radiation did decrease the incorporation of labeled amino acid into testicular protein. This effect was apparent

as early as 80 minutes after irradiation and lasted at least through the 20th hour after exposure.

The finding of decreased amino acid incorporation into protein in liver and testis after microwave exposure cannot be equated to decreased protein synthesis without qualification. For instance, if microwave radiation causes an increase in the amino acid pool in tissue, then the specific activity of the amino acid precursor (labelled Phe/total Phe) will be lower in irradiated relative to sham control animals. Under this condition the incorporation of equivalent amounts of phenylalanine in both groups of animals will lead to a decreased incorporation of ^{14}C Phe in the irradiated animals. The degree to which incorporation of label was reduced in liver 80 minutes after irradiation, as well as the persistent effect in testis 20 hours after irradiation, however, suggest that increase in the size of the precursor amino acid pool may not be the mechanism underlying this effect. Further experiments will have to be performed to establish the mechanisms underlying altered amino acid incorporation into proteins in tissues of microwave irradiated animals. The mechanism may be either thermal or nonthermal. If thermal, however, it is probably an indirect rather than a direct effect, since temperature rises such as those observed in this study are not normally associated with protein denaturation. Thus, a molecular effect is implied which may be mediated by hormonal or other factors.

B. HEMATOPOIETIC CHANGES ASSOCIATED WITH IN UTERO IRRADIATION
D. G. Hazzard, R. A. Budd

Small amounts of irradiation to blood forming organs cause arrest of hematopoiesis and changes to the peripheral blood. Most sensitive of all blood cells are the lymphocytes and their precursors. We are studying the changes produced by irradiation at various embryonic stages of development, at various total exposures, and from energy sources in the 250 keV and 25 keV regions on total white cell count, total red cell count, nucleated red cell count, hematocrit, and body weight of the offspring of irradiated rats.

Figure 44 shows the results of irradiating pregnant rats with 180 rad from a 250 keV source days 13 through 21 of gestation on the total white counts of pups 24 hours after birth. Figure 45 shows the effects of similar irradiation on day 15 of gestation on the recovery of the white cell counts of the pups from birth to 10 days of age. It appears that there are marked decreases in the WBC of those irradiated in utero for the first 2-3 days after birth, but that by the fourth day the WBC of the survivors recovers to approximately normal levels. Effects on survival are shown in Table 20.

Figure 46 shows the effect of various doses on the white count of 24-hour-old pups when they were irradiated in utero on day 15 of gestation. Because of the wide variance in counts, statistically significant difference as measured by "Student's t test" were noted at only the 180 and 240 rad dose levels, both being different from the control ($P < 0.01$). The intraperitoneal injection of 40 μg of endotoxin per 100 g of body weight 24 hours prior to irradiation resulted in a significant increase in white cell count ($P < 0.01$).

Figure 47 shows the dose effect of irradiation at 15 days gestation on total red cells and nucleated red cells; Figure 48 similarly shows the response on hematocrit and body weight. All these criteria except hematocrit show marked effects in the pups 24 hours after birth as a result of in utero irradiation of the mother at 15 days gestation.

TABLE 20. EFFECT OF IRRADIATION DOSE AT 15 DAYS GESTATION ON LITTER SIZE AND SURVIVAL OF PUPS BORN

	Average Litter Size	% Survival 24 hr.	% Survival 2 wk.	% Survival 30 days
No Irradiation	10	100	100	100
60 rad	9.5	100	100	100
120 rad	10	100	100	100
180 rad	12	97.2	86.1	86.1
180 rad + endotoxin	8	100	81.2	81.2
240 rad	9.3	39.3	28.6	0
240 rad + endotoxin	9.6	44.8	27.6	27.6

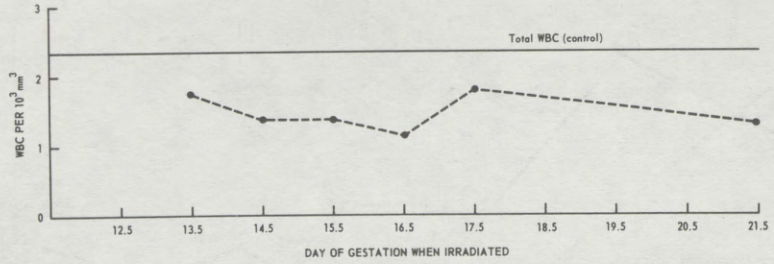


Figure 44. Effect of X Rays at Various Gestation Times on White Cell Count Taken at 24 Hours of Age.

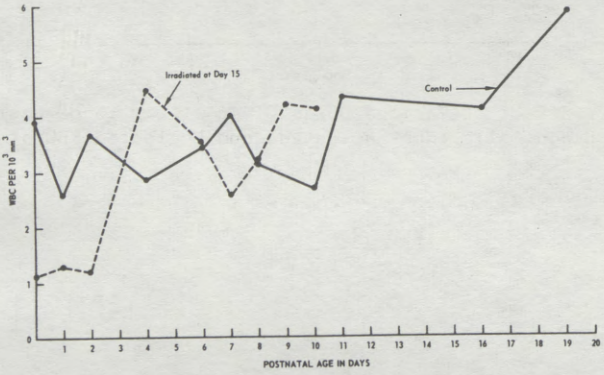


Figure 45. Effect of Irradiation at Day 15 of Gestation on White Cell Count at Various Ages After Birth.

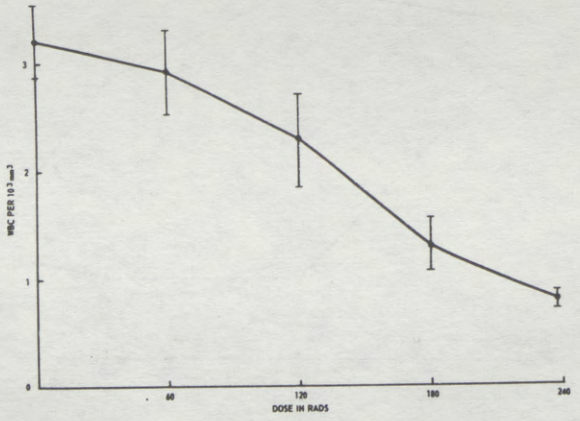


Figure 46. Effect of Various Doses Given at Day 15 of Gestation on the White Cell Count Taken at 24 Hours.

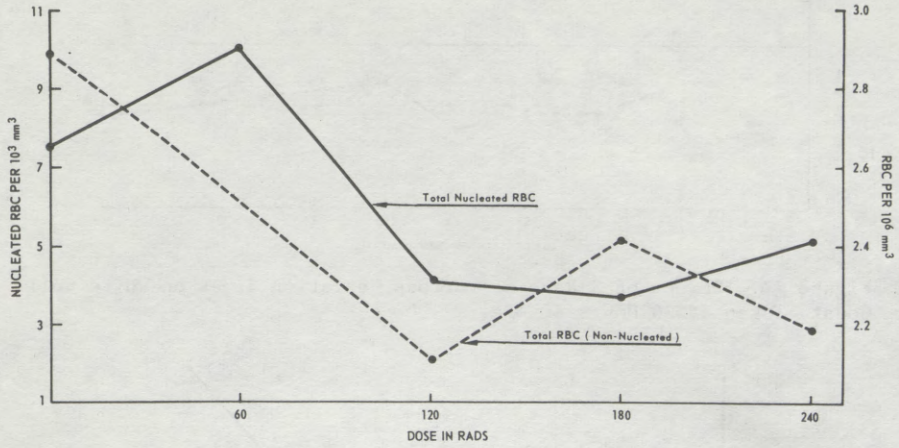


Figure 47. Effect of Various Doses Given at Day 15 of Gestation on Total Red Blood Cells (Non-nucleated) and Nucleated RBC at 24 Hours.

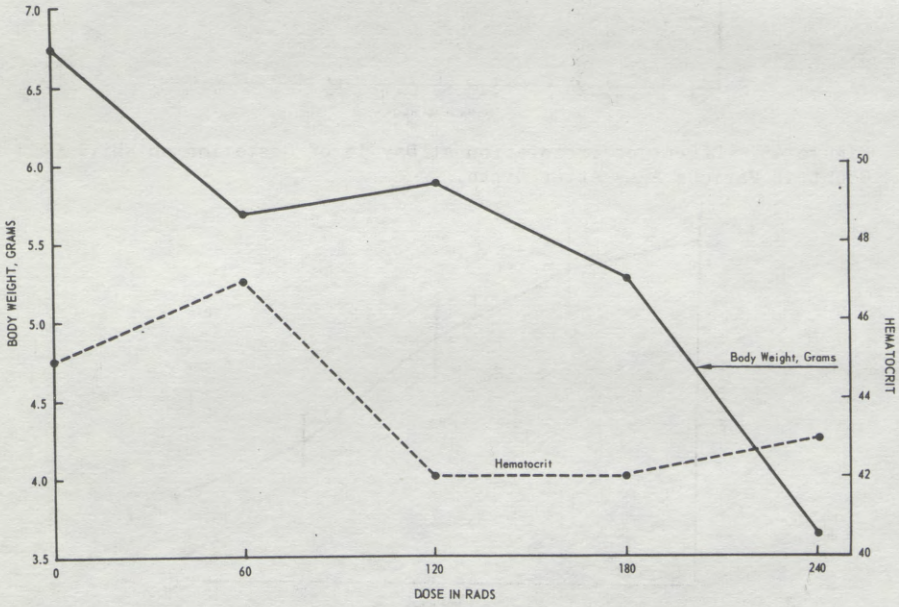


Figure 48. Effect of Various Doses Given at Day 15 of Gestation on Body Weight and Hematocrit at 24 Hours.

C. IN UTERO IRRADIATION WITH HIGH AND LOW ENERGY X-RAYS AT VARIOUS DOSE RATES

D. G. Hazzard, R. A. Budd, T. J. Withrow, C. Ronayne

This study examines the dose effects of irradiation at varying embryonic development stages to find: (1) if biochemical effects of irradiation are more pronounced when irradiation occurs very early in embryonic development, (2) to find the developmental stage-dose relationship exhibiting the most sensitive period for in utero irradiation, and (3) to compare the relative effects of radiation obtained from low energy source to that from high energy source.

Rats at varying stages of gestation received 180 rads of 250 keV X rays to study the effects on lactic dehydrogenase (LDH) and total protein. In one series of studies representing 186 animals, no differences were observable in liver LDH levels of pups 24 hours or 6 days after birth when their dams had been irradiated on the 15th day of gestation. Neither were any differences found at 24 hours after birth when irradiation occurred on day 5 or 10 of gestation. The corresponding total protein values for these animals did show a 7% increase ($P < 0.02$) at 24 hours after birth, but no differences at 6 days or when irradiation occurred on day 5 or 10 of gestation.

Studies involving 180 rad exposures to the pregnant females on day 13, 14, 15, 16, 17, and 21 of gestation have shown considerable variation in LDH and total protein levels. However, the variation about each point was so great that none of these values was statistically significant ($P < 0.05$) from the control value.

D. EFFECT OF X-RAY RADIATION AND MICROWAVE RADIATION IN VITRO AND IN VIVO ON HUMAN AND RAT GAMMA GLOBULINS

G. P. Kamat

Pregnant rats were X irradiated on day 13 of gestation with a dose of 180 rads and killed 24 hours later. Serum was separated from each rat. Gamma globulins were precipitated with 18%, 14% and 12% sodium sulphate. The same procedure was repeated with non-irradiated control rats.

The serum of the offspring of X irradiated pregnant rats was individually collected and gamma globulins were precipitated with 18%, 14%, and 12% sodium sulphate. Gamma globulins were also prepared from rats after exposure to microwave irradiation for 9 minutes and 15 minutes. High-titre antisera were prepared in rabbits against human gamma globulin (Cohn Fraction II) and normal rat gamma globulins using Freund's complete adjuvant.

The various gamma globulins of rats exposed to X and microwave radiation will be tested for the changes in their antigenic structures by using acrylamide gel electrophoresis, Ouchterlony's gel diffusion technique, immunoelectrophoresis as well as the other chemical methods to study properties after denaturation such as release of sulphydryl groups, increase in optical levo rotation, and precipitation with the homologous antisera.

Human gamma globulin (Cohn Fraction II) was fractionated on Sephadex-G-200 using 0.01 M phosphate buffer pH 7.6 containing 0.15 M NaCl. The first peak of IgM gamma globulin was separated and recycled on the same column using the same buffer. A single peak of IgM was obtained. Similarly the peak containing the IgG human gamma globulin was fractionated on DEAE cellulose column using 0.0175 M phosphate buffer pH 6.3. A single peak of IgG was obtained. The results showed that human gamma globulin (Cohn Fraction II) from Pentex Corporation contains 91.9% IgG and 8.1% IgM.

Optical rotation of human gamma globulin in H_2O and 0.9% NaCl was determined at specific wavelengths (365 mμ, 405 mμ, 436 mμ, 546 mμ, and 578 mμ). Lambert-Beer plots for human gamma globulin (Cohn Fraction II) from Pentex Corporation were determined for four wavelengths, 260 mμ, 278 mμ (peak), 280 mμ and 290 mμ. The spectra for human gamma globulin at a concentration of 0.1 mg/ml in 0.15 M NaCl were determined for wavelength range 200 mμ-310 mμ. The nature of aggregation of human gamma globulin (Cohn Fraction II) for native form and heat denatured form in 0.9% NaCl solution were determined with modified Coulter Counter apparatus.

The method for the quantitative determination of sulphydryl groups using 5,5'-dithiobis (2-nitrobenzoic acid) was standardized for human gamma globulins. Pure samples of IgG and IgM human gamma globulins will be irradiated with X-rays and microwaves in vitro. The configurational

changes occurring in IgG and IgM after X-ray irradiation and microwave irradiation will be studied by determining the four parameters of optical rotation:

1) (a) specific rotation
2) a_o, constant for helical and intrinsic residue contributions
3) b_o, constant characteristics of helix and
4) λ_c, optical rotatory dispersion constant.

The changes in the functional properties of IgG and IgM human gamma globulins such as precipitation with the homologous antiserum, and complement fixation will be studied. The mechanism of denaturation of IgG and IgM human gamma globulins after exposure to X-ray radiation and microwave radiation will be studied by separating the aggregates on Sephadex G-200, determining their sedimentation constants, and their amino acid composition. These studies should help in explaining the following question: Can radiation cause human auto-immune diseases and if so, how?

E. THE ISOLATION OF KUPFFER CELLS FROM RAT LIVER AND STUDIES OF CELLULAR RESPIRATION DURING PHAGOCYTOSIS

R. K. Fred, T. G. Zaremba

Previous studies in this laboratory have indicated that sublethal irradiation of mice causes a decrease in the phagocytic capacity of the reticuloendothelial system. To determine the site of radiation damage, it is necessary to study the effect of radiation on phagocytosis at the cellular level. This may be accomplished by isolating the phagocytic cells of the liver (Kupffer cells), determining the biochemical pathways during phagocytosis, and studying the effect of radiation on the pathways.

We have developed a method for isolating Kupffer cells from rat liver which, unlike previous methods, yields sufficient material to study cellular respiration using the Warburg apparatus. Briefly, a suspension of intact liver cells is prepared using a modification of the method of St. George; the suspension is incubated in dilute trypsin at 37° C, and finally the cells are purified by centrifugation of the trypsinized suspension in a density gradient and washing. This method yields approximately 150-200 mg of Kupffer cells from each 10 grams of rat liver. Figure 49 is a typical phase micrograph of cells obtained in this manner.

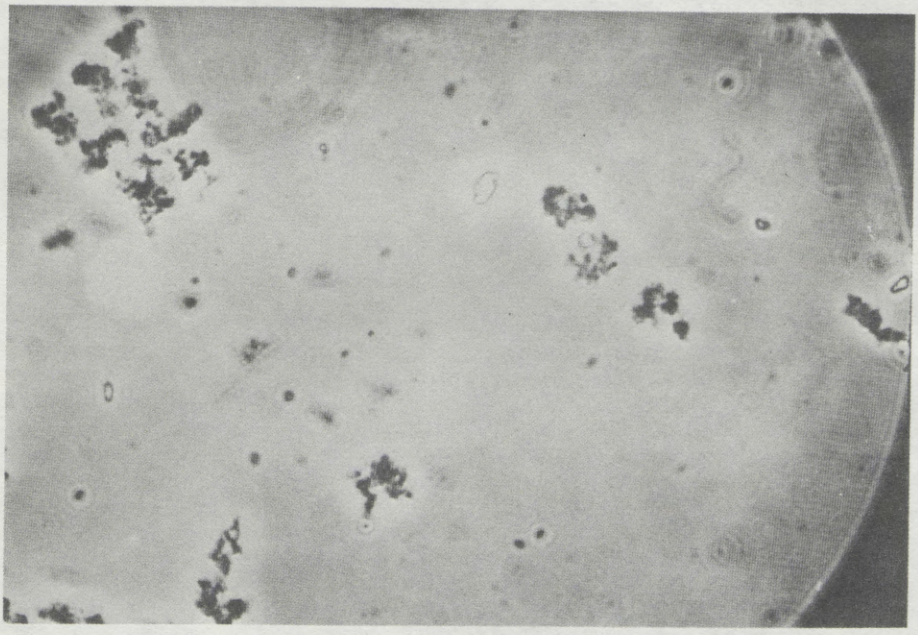


Figure 49. Phase Photomicrograph of Unstained Kupffer Cells.

To determine if these small irregularly shaped cells were Kupffer cells, rats were injected with carbon and the Kupffer cells were later isolated at various times. If the cells were isolated a few hours following the carbon injection, small irregularly shaped cells, which appeared to have carbon uniformly dispersed in the cytoplasm, were obtained. If the cells were isolated several weeks following the injection, they appeared to be the same size and shape, but the carbon was noted to be distributed into aggregates.

Respiration studies were performed using four different types of liver cell preparations: (1) A liver mince, prepared by chopping the liver with a razor blade to a fine mince; (2) whole liver cells prepared by passing the liver through a tissue press, suspending in tissue culture media and passing this suspension through a 100 mesh filter to remove large clumps of cells; (3) "washed liver cells" prepared simply by washing the whole liver cell suspension with tissue culture media; (4) Kupffer cells, isolated as previously described. The oxygen uptake of each of these four liver preparations was measured over a 2-hour period at 37^{o} C on a Warburg apparatus. The results, presented in Figure 50 are typical oxygen uptake curves and show that duplicate values agree well for the first 60 minutes. However, the slopes tend to decrease by variable amounts after 60 minutes, so only the first 60 minutes were used in the calculations. The rate of oxygen uptake of washed liver cells is approximately 60% lower than that of the whole liver cells. Recent experiments have indicated that debris associated with the whole liver cell suspension is responsible for a large portion of the oxygen uptake. Therefore, of the values obtained for unwashed and washed liver cells, the values for the washed cells are probably a better indication of the rate of oxygen uptake of liver cells. The Q_{O_2} of the Kupffer cells was not significantly different from that of the washed liver cells. Approximately 7×10^{9} polystyrene particles were added to the Kupffer cell suspension; although the rate of oxygen uptake was 29% higher than that of the Kupffer cells without particles, this difference was not found to be statistically significant.

To determine if the Kupffer cells had ingested the polystyrene spheres the suspension was washed several times and viewed with phase and electron microscopy. Figure 51 is a phase micrograph showing the Kupffer cells with polystyrene particles. It is difficult to determine if the particles are inside of the cells or only attached to the outer surface. Figure 52 an electron micrograph of a section from the same suspension, shows that the polystyrene particles are associated with cytoplasmic constituents such as mitochondria and endoplasmic reticulum. These microscopic observations strongly suggest that the polystyrene spheres had been ingested by the in vitro suspension of Kupffer cells.

Since there was no significant increase in oxygen uptake by Kupffer cells during in vitro phagocytosis, it was of interest to determine the rate of oxygen uptake by Kupffer cells which already contained particles. Therefore, rats were injected with 72 mg of a carbon suspension and

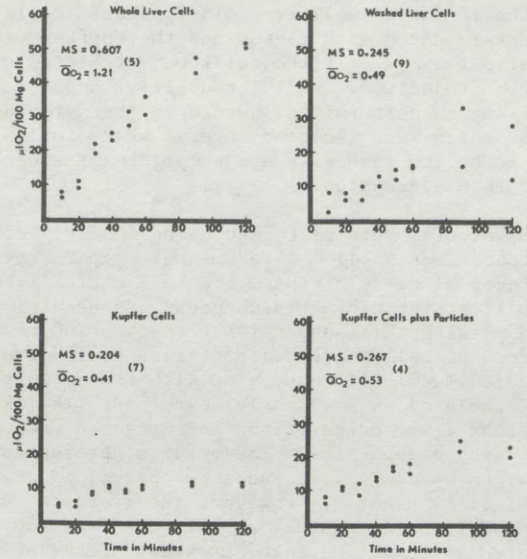


Figure 50. Oxygen Uptake Curves for Various Types of Liver Cell Preparations. MS = mean slope in µl O_2/100 mg wet tissue per minute; QO_2 in µl O_2mg dry tissue / hour; numbers in parentheses refer to the numbers of duplicate experiments.

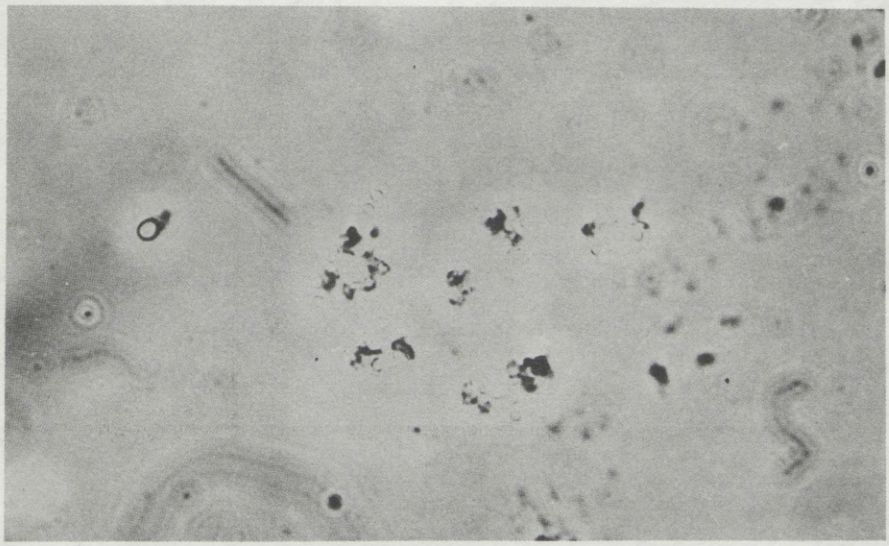


Figure 51. Phase Photomicrograph of Unstained Kupffer Cells that Had Been Incubated with Polystyrene Particles In Vitro.

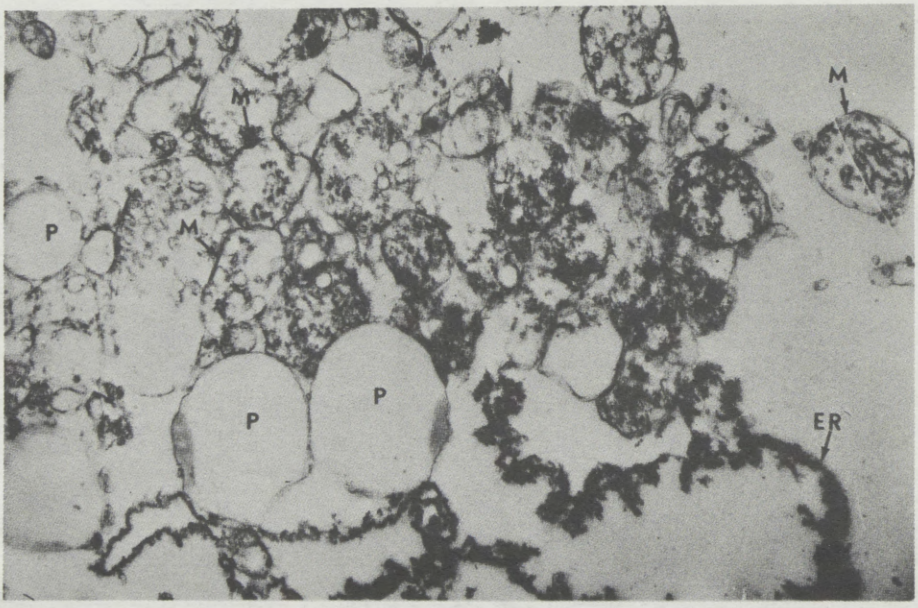


Figure 52. Electron Photomicrograph of Kupffer Cells That Had Been Incubated with Polystyrene Particles In Vitro. P = polystyrene particles; M = mitochondria; ER = endoplasmic reticulum.

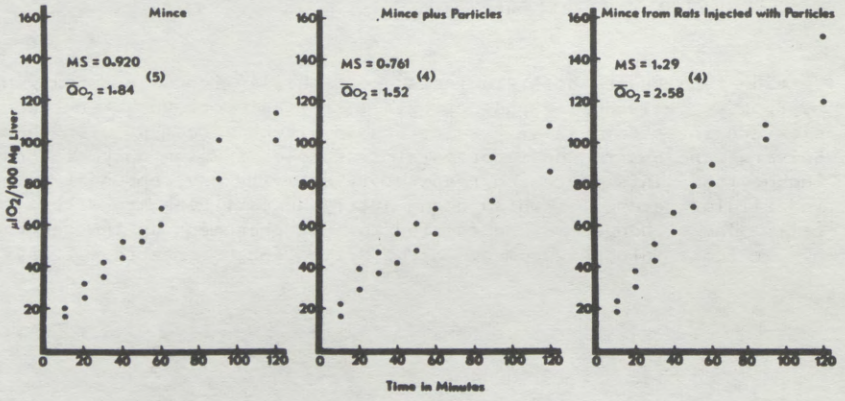


Figure 53. Oxygen Uptake Curves for Liver Mince. MS = mean slope in µl O_2/100 mg wet tissue / minute; QO_2 in µl O_2/mg dry tissue / hour; numbers in parentheses refer to the number of duplicate experiments.

sacrificed 15 minutes later. Initially, the respiration studies were performed using liver mince; the results are shown in Figure 53. These graphs, as those in Figure 50, are typical oxygen uptake curves with the duplicates closely agreeing for the first 60 minutes. Twenty milligrams of carbon were added to the liver mince (this is approximately equal to the concentration of carbon initially present in the blood of rats injected with 72 mg of carbon). There was no significant difference in the rate of oxygen uptake between the liver mince with particles and that without particles. However, the liver mince from rats injected with carbon exhibited a 40% increase in the rate of oxygen uptake compared with controls. In order to determine whether the large increase in oxygen uptake exhibited by the liver mince from carbon-injected rats was attributable to the Kupffer cells, the experiment was repeated using isolated Kupffer cells instead of liver mince. The results of these studies are shown in Table 21. The oxygen uptake of Kupffer cells from control rats and from carbon-injected rats were compared on a daily basis because of a large day-to-day variation. The Kupffer cells which had previously ingested carbon particles exhibited a 120% increase in the rate of oxygen uptake compared with controls.

TABLE 21. RATE OF OXYGEN UPTAKE OF KUPFFER CELLS[a]

Experiment	Kupffer Cells from Control Rats	Kupffer Cells from Rats Injected with Particles	Increment
1	0.1722	0.2484	0.0762
2	0.0865	0.1910	0.1045
3	0.0	0.1281	0.1281
Mean	0.0862	0.1892	0.1029

a. The numbers refer to the slope for 0 - 60 min (expressed as μl O_2/100 mg wet tissue/min).

The results of these studies suggest that an increase in oxygen uptake by Kupffer cells during phagocytosis most likely occurs after the particles are ingested. These results are in direct agreement with those of Selvaraj and Sbarra who reported similar results using polymorphonuclear leukocytes. This increased respiratory activity may represent changes in cellular metabolism which occur after the particles are within the cell. These changes may be related to such phenomena as the segregation of particles into phagosomes, enzyme activation, or membrane repair.

COLLABORATIVE RADIOLOGICAL HEALTH LABORATORY
Dr. R. John Garner, Director

A. THE BARRIER-MAINTAINED COLONY[1]

The cesarian-derived, barrier-maintained (CDBM) beagle colony provides the experimental material for the Collaborative Radiological Health Laboratory. The Colony is currently comprised of approximately 1,300 animals, a reduction of about 400 over the course of the year. This reduction has become possible following establishment of breeding programs appropriate to the needs of the long-term work. Culls were either absorbed by short-term studies in this laboratory or were used to fill requests from other laboratories.

The conception rate in the colony rose slightly during the course of the year but is still rather low, averaging 78%. Undetected infertility in the male is believed to be a primary factor. A program has therefore been introduced for selection of breeding males: preliminary results suggest that its adoption may help to raise the conception rate to approaching 90%.

In an attempt to meet budgetary stringencies, measures have been introduced to improve economy of routine operation without loss of efficiency. A drastic change has been made in the hitherto time-consuming process of disinfecting all bags of food entering the barrier-maintained area. Bacteriological tests reveal no significant increase in contamination of the feed as a result. Routine fecal examinations for parasite eggs have also been reduced in number by limiting individual sampling to pregnant females and otherwise using composite samples. There has been no change in the vaccination program.

Reduction in size of the colony presented an opportunity to examine apparently clinically normal mature dogs for pathological changes as well as animals culled because of clinical abnormalities. A finding of some significance was the high incidence of thyroiditis with or without clinical and pathological evidence of hypothyroidism. It is becoming evident that thyroid dysfunction may be a major problem in long-term studies.

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[1]Current research conducted at the Collaborative Radiological Health Laboratory is reported in the Annual Report for 1968, Colorado State University - U.S. Public Health Service Collaborative Radiological Health Laboratory, Fort Collins, Colorado (Contract PH 86-62-135).

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Spontaneous death or serious illness is relatively rare in mature dogs in the CDBM colony: it is therefore somewhat early to speak of "common" causes of death. However, it is possible to distinguish those conditions occurring with greatest frequency, and to associate these conditions with specific age groups. Most puppies dying at 7 weeks or a little older were cachectic and anemic. In slightly older animals, bronchopneumonia or right-sided heart failure predominated. Small groups of mature dogs died of uremia subsequent to chronic glomerulonephritis or nephrosclerosis or of anemia of undetermined origin. A point of some interest is that chronic diffuse interstitial nephritis, so common in street dogs, has not yet been encountered in dogs retained in the CDBM colony and that the "common" lesion in the colony, glomerulonephritis, is said to be extremely rare in dogs.

The spontaneous mineral deposition observed to occur in the soft tissues of puppies in the CDBM colony has continued to be investigated. It is characterized by deposition of calcium salts around proximal convoluted tubules in the kidneys and in subepithelial tissues of the lungs and upper respiratory passages. In these locations a peak incidence of about 90% is reached between 12 and 30 days of age, i.e. when puppies are nursing. The condition appears to be transient and does not resemble previously reported forms of spontaneous soft tissue mineralization. It does not produce clinical signs or prevent rapid growth; neither is it related to season, sex, litter size, or general health. The circumstances of its occurrence suggest that it may be an exaggerated physiological process.

One process which may be related is reabsorption of phosphate by the renal tubules. There appears to be an increase in the filtered load of phosphate during the period when calcium deposits are observed. Tubular reabsorption is high and conditions exist which would result in high phosphate concentrations in the tubules.

Subcapsular scarring and mineralization of the liver has been observed in about 8% of fetuses and very young puppies examined routinely. The lesion has no functional significance and its pathogenesis is not known.

B. THE LONG-TERM EXPERIMENT: CURRENT STATUS AND FEASIBILITY STUDIES

The raison d'etre of the Collaborative Radiological Health Laboratory is the experiment designed to examine the long-term effects in the beagle of a single whole-body exposure at different periods of development. Six periods of development have been chosen for study; 8, 28, and 55 days post-coitus and 2 days, 10 weeks and 1 year. Exposure levels are 0, 20, or 100 R over a constant exposure time of 10 minutes. A total of approximately 1,700 animals will be involved. The first pups were entered into the experiment in December, 1967; the total committed is now 122. Commitment of animals will continue over the next 4 to 5 years.

This experiment is expected to last for upwards of 20 years. In order to obtain a preview of events to be expected in animals reaching the end of their life-span, a pilot study has been initiated which will involve the intensive study for periods of up to 4 years of animals which have survived an exposure in the LD_{50} range at 8, 28, or 55 days post-coitus (dpc) or 2 days post-partum. This work is still in its initial stages.

Acute lethality studies are continuing using the 5,000 Ci cobalt-60 source and the constant exposure time of 10 minutes currently employed in the long-term experiments. Ages under consideration are 8, 28, and 55 dpc., 2 days, 2, 5, 9, and 10 weeks post-partum and young adult (1-2 years). The $LD_{50/60}$ in the young adult under these conditions has been established as 315 R (mid-line air dose), a value close to that observed in studies at Davis, California of which the long-term studies are regarded as an extension. Tentative values for the $LD_{50/60}$ at 10 weeks and $LD_{50/30}$ 9, 5, and 2 weeks are 270 and 270, 300, and 400 R, respectively.

A detailed analysis has been made of the results obtained from a comparison of $LD_{50/60}$ in young adults using the original (400 Ci) and the new (5,000 Ci) cobalt sources. "Days to death" was found to be marginally significantly dependent upon body weight and exposure level but not upon body width or age. The BEGA (beta-gamma) function was used in establishing an exposure-response curve; this approach offers theoretical advantages over the conventional probit analysis for estimating LD_{50}'s.

As the long-term experiment proceeds, methods will continue to be developed and refined to make the greatest possible use of the material and data available. Dental eruption may be of potential value as an indicator of effects upon growth and development, particularly of dogs irradiated in utero. The mean eruption times of the permanent teeth have been estimated and the minimum frequency with which examinations must be made to obtain adequate data has been established.

Electron microscopy is a powerful tool but has the disadvantage that only a very small volume of tissue can be examined. Staining procedures

suitable for examination of plastic-embedded thin sections suitable for examination with the light microscope are currently being evaluated as an aid to fine-structure studies now proceeding on the kidney.

Restrictions imposed in relation to the degree of stress permissible in routine testing of long-term dogs have required the development of atraumatic procedures for assessing renal function. A simplified, rapid method of determining parameters of renal function (glomerular filtration rate, effective renal plasma flow, and maximum tubular secretory capacity) from analysis of plasma disappearance curves and bladder accumulation curves subsequent to a single intravenous injection of ^{125}I-labelled hippuran appears to have great potential. A disturbing feature, however, is the observation of glomerular and tubular lesions in dogs used for evaluating this technique against the traditional constant-infusion procedures. The origin of these lesions will need to be determined before the procedure can be adopted as standard practice.

A fruitful approach to the extraction of the maximum amount of information from physiological data appears to be the application of sophisticated methods of mathematical analysis. The electroencephalogram is particularly amenable to such treatment and the use of auto- and cross-correlation techniques is being investigated.

The maze is a common tool in psychological studies. Effort has been directed towards developing maze problems, initially using rats as experimental animals, which may be useful in assessing behavioral effects of biological insults. A linear, multiple-unit maze appears to be promising but both the apparatus and the testing procedure need to be simplified if they are to be developed for use on other than a very small sample of the long-term animals.

C. IRRADIATION OF THE EMBRYO, FETUS AND NEONATE

The phase of work in this laboratory which has taken second place only to the long-term experiment is definition of the acute injury following irradiation during early development. Prenatal canine development has been studied in unirradiated litters collected at daily intervals during the time of major organ formation and at weekly intervals before and after organogenesis to determine the extent of normal variations and to compare different methods of timing development. The short-term effects of a single exposure to 150 R cobalt 60 gamma radiation have been compared at five prenatal ages: 8, 15, 21, 28 and 35 days following breeding. Preliminary results indicate that 21 and 28 day concepti respond similarly in terms of lethal effects. However, animals exposed at 28 days lack the major malformations that characterize irradiation at 21 days.

An experiment has been initiated to investigate recovery in the embryo, fetus, and neonate following exposure at 8, 28, or 55 days post-coitus (dpc) or 2 days post-partum to 100 R cobalt-60 gamma radiation. A split-dose technique is being employed with determination of the $LD_{50/60}$ at 10 weeks after the conditioning exposure.

Development of renal function in the young beagle has been investigated during the first year of life. Parameters studied were ability to concentrate urine, urine pH, glomerular filtration rate (GFR), effective renal plasma flow, and maximum tubular secretory capacity for p-aminohippurate. The opportunity has also been taken to examine the effects of exposure to 290 R cobalt-60 gamma radiation at 8 or 28 dpc on these parameters. These pilot studies indicate possible early effects on urine osmolarity and GFR.

The developing mammalian eye appears to be peculiarly radiosensitive and considerable attention is thus being given to the visual system in both short- and long-term studies at this laboratory. A survey of survivors of LD_{50} studies in pre-, neo- and post-natally irradiated beagles in the CDBM colony has revealed an interesting variety of clinically observable eye lesions, particularly following exposure at 28 or 55 dpc or 2 days post-partum. The lowest exposure at which lesions which could be associated with irradiation were detected was 210 R (at 28 dpc). The results suggest that ocular lesions may well occur in some age groups receiving 100 R in the long-term experiment.

Another aspect of visual function currently being investigated is the average evoked visual potential (AVEP). Development of the AVEP in the beagle has been examined from birth to 6 months of age. It first appears at 5 days post-partum at which time it is the surface-negative immature type, but this is replaced by the surface-positive mature type by 30 days. Latency increases with age. Exposure to 300-500 R cobalt-60 gamma radiation at 57 dpc produces a significant change in initial peak latency and peak-to-peak amplitude of the primary response at 7-9

months of age. The irradiated animals had sustained extensive retinal damage; the results of this work indicate that cerebral damage was also present.

Exposure to 325 R at 2 days post-partum appears to have little effect upon visual discrimination learning in the dog as evaluated by tests of brightness discrimination, shape discrimination, and discrimination reversal; however, irradiated animals took longer to respond to the test problems than sham-irradiated dogs of the same age.

The effects have been examined of exposure to 150 R of the rat ovum, conceptus and neonate on post-natal activity of serine dehydratase in liver and glycerol phosphate dehydrogenase and non-specific esterase in liver and brain. Contrary to expectations, early irradiation may apparently have a stimulatory effect on post-natal enzyme activity.

D. DATA PROCESSING

Development of satisfactory systems for data acquisition, storage, and retrieval is an essential requirement in any study in which large volumes of data can be expected to accumulate over a number of years. The system currently in use at CRHL has been developed following the acquisition of a CDC-6400 computer by the Colorado State University Computing Center; it replaces the optical reader - IBM-1401 system previously described. The system is designed to facilitate daily updating and correcting of data files and to retrieve information in multiple output formats for generating listings and for performing data analyses.

The coding and retrieval of data collected from clinical examinations and autopsies poses a particular problem. The initial phase for the coding and retrieving of necropsy diagnoses by computer is nearly complete with the compilation and coding of a 4,700 word pathology dictionary. It is anticipated that the system can be readily extended to clinical data.

A new look has been taken at the analysis of life-death statistics. Some of the mathematical characteristics of the BEGA (beta-gamma) function, of promise in the analysis of LD_{50} studies, have been considered; a method for obtaining estimates of mathematical model parameters in terms of the type of data obtained in such studies has been developed.

APPENDIX A

PUBLICATIONS JANUARY - DECEMBER 1968

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APPENDIX B

PRESENTATIONS JANUARY - DECEMBER 1968

Abuelo, J.G. Ultrastructural aspects of radiation-induced chromosome damage. Washington Area Radiobiology Association, Bethesda, Maryland, February 29, 1968.

Cisar, C.F. The rat kangaroo - handling and husbandry practices in a research facility. 19th Annual Meeting, American Association of Laboratory Animal Science, Las Vegas, Nevada, October 21-25, 1968.

Fred, R.K. The effect of anticoagulant doses of heparin on the clearance of large doses of colloidal carbon in the mouse. 5th Annual National Meeting of the Reticuloendothelial Society, New York, December 1-4, 1968.

Gillespie, L.J. Karyotypic and phenotypic observations on a mongoloid child. Hudson High School, Hudson, North Carolina, April 22, 1968.

Harris, J.Y. Radioiodide clearance rates in lactating goats. 24th International Congress of Physiological Sciences, Washington, D. C., August 25-31, 1968.

Kahn, B., C.P. Straub, P.J. Robbins, H.N. Wellman, R.A. Seltzer, and N.C. Telles. Retention of radiostrontium by infants. Health Physics Society, Denver, Colorado, June 16-20, 1968.

Lambert, P.D., A.C. Lee, J.A. Modrick, R.D. Phemister, and W.J. Tietz. Evaluation of eye defects in beagles by means of visual evoked responses. 3rd Annual Joint Meeting of the Clinical Society and the Commissioned Officers Association, San Francisco, California, March 26-29, 1968.

Leach, W.M. and J.G. Abuelo. Electron microscopy of chromosomes. Zoology Department, George Washington University Seminar, Washington, D. C., April 3, 1968.

Mills, W.A. and H.D. Youmans, Jr. Population exposures from natural background radiation in Kerala, India. Health Physics Society, Denver, Colorado, June 16-20, 1968.

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Phemister, R.D., B.P. Stuart, and R.W. Thomassen. Spontaneous soft tissue mineralization in young puppies. Annual Meeting of the American College of Veterinary Pathologists, Chicago, Illinois, December 1, 1968.

Pollock, E.J., and G.J. Todaro. Enhancement by irradiation of *in vitro* transformation by SV40 virus. Health Physics Society, Denver, Colorado, June 10-13, 1968.

Shively, J.N., and G.P. Epling. Demonstration of radiation induced changes in the fine structure of the canine retina. Rocky Mountain Society of Electronmicroscopists, Denver, Colorado, May 11, 1968.

Stara, J.F. The role of radioisotopes in veterinary public health. 72nd Annual Meeting of the U. S. Livestock Sanitary Association, New Orleans, Louisiana, October 8-11, 1968.

Stara, J.F. Radiation and man. Meeting of the Allis-Chalmers Management Club, Cincinnati, Ohio, January 20, 1968.

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Telles, N.C. The program of the National Center for Radiological Health of the Public Health Service. The Medical Association of the Portuguese Language, Luanda, Angola, Africa, August 4-11, 1968.

Telles, N.C., and D.W. Coble. The nucleolus - a morphological and possible functional relationship to the nuclear membrane. Annual Meeting of the Federation of American Societies for Experimental Biology, Atlantic City, New Jersey, April 16-20, 1968.

Wagner, M.T., and R.J. Garner. The influence of prenatal gamma irradiation on postnatal enzyme patterns in the beagle. Radiation Research Society, Houston, Texas, April 21-25, 1968.

Ward, B.C., and W. Moore. Spontaneous lesions in Chinese hamsters. 19th Annual Meeting of the American Association of Laboratory Animal Science, Las Vegas, Nevada, October 21-25, 1968.

Ward, B.C., and N.C. Telles. Effects of radiation and ethionine on rat mammary tumor incidence. Washington Area Radiobiology Association, Bethesda, Maryland, February 29, 1968, and Armed Forces Radiobiology Research Institute, Washington, D. C., April 4, 1968, and 16th Annual Meeting of the Radiation Research Society, Houston, Texas, April 21-25, 1968.

Zaremba, T.G., and R.K. Fred. The isolation of Kupffer cells from rat liver and studies of cellular respiration during phagocytosis. 5th Annual National Meeting of the Reticuloendothelial Society, New York, December 1-4, 1968.

APPENDIX C
ADVISORY COMMITTEES

RADIATION BIO-EFFECTS AND EPIDEMIOLOGY ADVISORY COMMITTEE

Dr. Victor P. Bond, Chairman
Chairman, Medical Department
Brookhaven National Laboratory

Dr. Charles E. Dunlap
Professor and Head
Department of Pathology
Tulane University School of Medicine

Dr. Alan M. Gittelsohn
Department of Statistics
School of Hygiene and Public Health
Johns Hopkins University

Dr. Louis H. Hempelmann
Professor of Experimental Radiology
School of Medicine
University of Rochester

Dr. Edward B. Lewis
Professor of Biology
California Institute of Technology

Dr. Leonidas D. Marinelli
Director, Radiological Physics Division
Department of Radiological Physics
Argonne National Laboratory

Dr. Karl Z. Morgan
Director, Health Physics Division
Oak Ridge National Laboratory

Dr. Richard R. Overman
Associate Dean
College of Medicine
University of Tennessee

Dr. Leonard M. Schuman
Professor of Epidemiology
College of Medical Sciences
School of Public Health
University of Minnesota

Dr. M. Thomas Wagner, Jr., Executive Secretary
Assistant to the Chief
Radiation Bio-Effects Program
Bureau of Radiological Health

COLLABORATIVE RADIOLOGICAL HEALTH LABORATORY ADVISORY COMMITTEE

Dr. Edward Alpen
Head, Biology and Medical Sciences Division
U. S. Naval Radiation Defense Laboratory

Dr. Allen C. Anderson
Radiopathologist
Radiobiology Laboratory
School of Veterinary Medicine
University of California

Professor Ernest Furchtgott
Department of Psychology
University of Tennessee

Dr. Marvin A. Kastenbaum
Statistician
Oak Ridge National Laboratory

George A. Sacher, Jr., Chairman
Senior Biologist
Division of Biological and Medical Research
Argonne National Laboratory

Dr. Carl F. Tessmer
Chief, Experimental Pathology Section
M. D. Anderson Hospital and Tumor Institute
University of Texas

Dr. M. Thomas Wagner, Jr., Executive Secretary
Assistant to the Chief
Radiation Bio-Effects Program
Bureau of Radiological Health

Observers

Representing AEC:

Dr. William W. Burr
Chief, Medical Research Branch
Division of Biology and Medicine
Atomic Energy Commission

Representing AFWL:

Lt. Col. Milford D. Harris
Chief, Biophysics Division
Air Force Weapons Laboratory (AFSC)
Kirtland Air Force Base

Representing NIH:

Dr. Nathan W. Shock
Chief, Gerontology Branch
Baltimore City Hospitals

APPENDIX D

RADIATION BIO-EFFECTS PROGRAM STAFF

Office of the Chief
Dr. William A. Mills, Chief
Dr. Norman C. Telles, Deputy Chief
Jayne Blanton
Leo C. Cox
Darla D. Davis
Valeria Dempsey
Ruth G. DePrenda
Linda G. Funk
Irene A. Hardman
Donald M. Hodge
William O. Holcombe
Linda F. Hutchison
Loretta G. Ilgenfritz
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Dr. Gordon L. Jessup, Chief
Richard P. Chiacchierini
Louise A. French
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Animal Care Unit
Clayton F. Cisar, Chief
Flora S. Nicholson
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Radiation Cytology Laboratory
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Dr. Emanuel C. Beyer
Steven Brecher
Darilyn Dolimpio
Dinniemaud J. Ellingson
Lillie J. Gillespie
Mayme M. Jiles
Susan A. Knadle
Nina D. Morris
Tim L. Pay
Dr. Kenneth T. S. Yao

Physiology and Biophysics Laboratory
Dr. Moris L. Shore, Chief
Thomas P. Abbott, II
Roger A. Budd
Rachel H. Draley
Richard P. Felten
Dr. Richard K. Fred
Dr. Dewitt G. Hazzard
Mary K. Howes
David E. Janes
Dr. Gopal A. Kamat
Anthony Lamanna
John W. Laskey
Katherine M. Selby
Lawrence R. Simmons
Sarah Jane Smith
Terrye M. Zaremba

Radiation Oncology and Pathology Laboratory
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Stephen A. Carr
Joe R. Childress
Don W. Coble
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Dr. Carl D. Lytle
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Dr. James N. Shively
Judith O. Singley
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Dr. Billy C. Ward
Elliot A. Willensky

Radiation Physics Laboratory
Harry D. Youmans, Chief
George F. Anderson
Ulrich H. Behling
Lynda Kramer
Wah Lee
Anne Marie G. Pakenas
Franklin C. Pendleton
Richard A. Tell
Victoria Yancik

Collaborative Radiological Health Laboratory
Dr. R. John Garner, Director
Dr. Dennis F. Cloud
Dr. A. K. Davis
Dr. Paul D. Lambert
Dr. Robert D. Phemister
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Thomas J. Withrow

Radionuclide Toxicology Laboratory
Dr. Jerry F. Stara, Chief
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Arnold L. Cohen
Joan M. Cooper
Walden C. Crocker
Polly F. Geyer
Carol A. Haynes
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Dr. Neal S. Nelson
Eugene S. Pinkston
Mary J. Replogle
Lawrence S. Rosenstein
Dr. Robert G. Wolfangel
Dr. James F. Wright

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Mr. CARTER. Thank you, Mr. Chairman.

Mr. ROGERS. Thank you, Dr. Carter.

Mr. Preyer.

Mr. PREYER. Mr. Hansen, there have been some encouraging reports so far as color television is concerned recently. I wonder if you could tell us if they are accurate, or if you could briefly describe to us the situation in that segment of the problem area.

Mr. HANSEN. Our program has involved working extensively with the manufacturing concerns. And during the past 6 to 8 months we have visited, I believe, 19 of the manufacturers of color television sets to review their manufacturing processes, their checking systems. This study was made at the invitation of the manufacturers to visit their plants. And we feel we have a good start here in reaching an understanding on what will be required in producing television sets which do not create a hazard in their use from X-ray emission.

Dr. Elder, do you have any other specific areas that you would like to mention here?

Dr. ELDER. I think one of the things that we would like to point out is the development of the protocol for testing. This takes only one line in our testimony, but 10 man-years is a great amount of effort for us to put on one project, but these are very complex devices. Although we may be close to the point of establishing the radiation emission level, whenever we got in and tell the manufacturers how they are going to comply and how we are going to test them, we must have this protocol. We are quite pleased that our people have advanced far enough to be able to tell you that we have a protocol for testing. I think this is a very significant advancement in our laboratories.

Mr. HANSEN. Also, Mr. Preyer, we have purchased 20 color television sets and are running extensive tests on those from various manufacturers. In addition to this, we are planning to run tests on new sets manufactured after the passage of the law out in the field, after they have been shipped from the factory, to evaluate them from the standpoint of X-ray emission.

Mr. PREYER. You say you have visited 19 manufacturers. How many manufacturers are there of television sets? Does that pretty substantially cover the industry?

Dr. ELDER. The domestic suppliers, yes, sir.

Mr. PREYER. And the 20 sets you are testing would cover the primary types of television?

Dr. ELDER. We would also include some foreign imports in that class.

Mr. PREYER. Thank you, Mr. Chairman.

Mr. ROGERS. Mr. Hansen, I would like to receive from you an organizational chart showing us the organization before the change was made and the present organization, the number of people listed and their competency in accordance with Dr. Carter's suggestion.

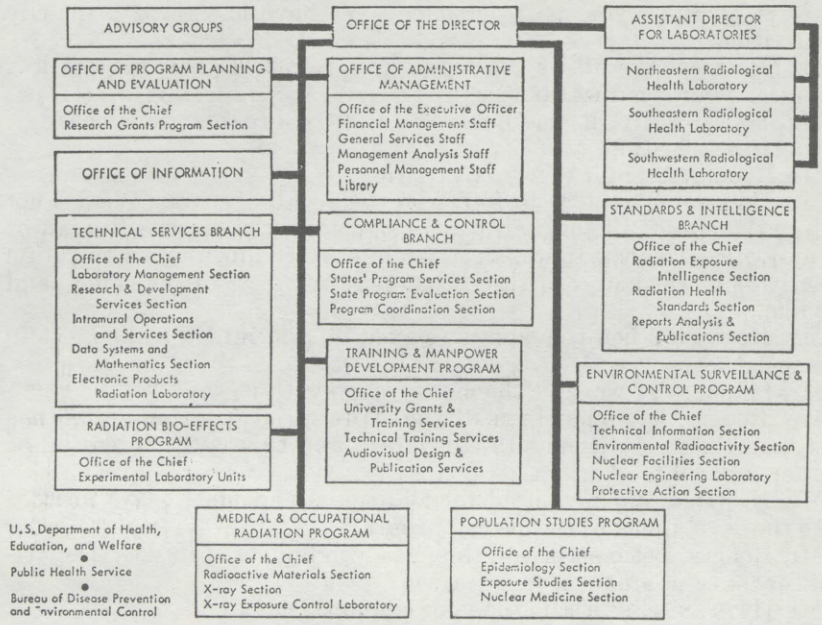
Let me ask you this. How many people do you have working in your radiological lab as compared to before the organization, more or less.

(The following charts were received by the committee. See also, Staff curriculum vitae on p. 47.)

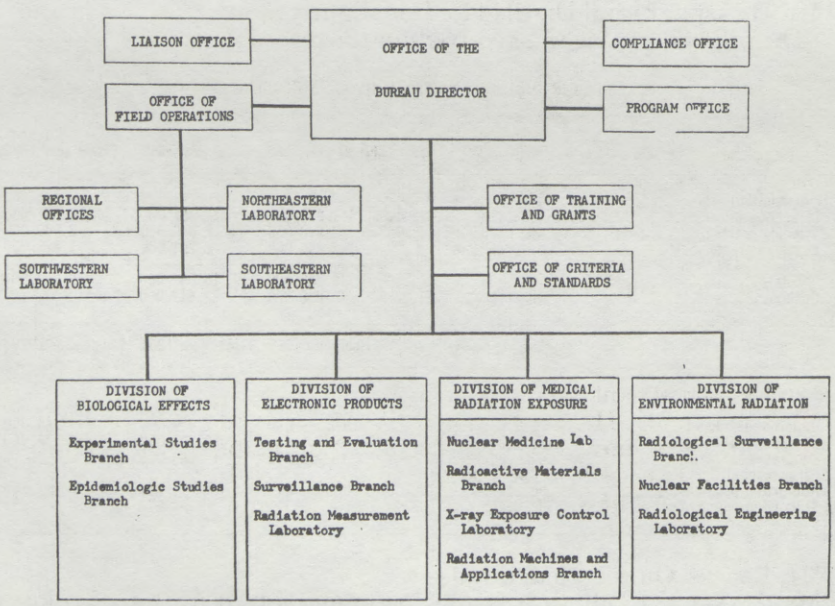
BEFORE REORGANIZATION

NCRH/OAM 1/1/68

NATIONAL CENTER FOR RADIOLOGICAL HEALTH



BUREAU OF RADIOLOGICAL HEALTH
FOLLOWING REORGINAZATION



BRH 3/21/69

Mr. HANSEN. Less, by about 100. We now have approximately in the total program 800. This reduction is brought about by the limitations we have on employment of personnel. We have lost these primarily by attrition.

Mr. ROGERS. Are all of the losses as a result of that, or was it a change in your organizational setup?

Mr. HANSEN. No, it was not as a result of organizational change. It was from attrition.

Mr. ROGERS. All of it was from attrition?

Mr. HANSEN. To the best of my knowledge, all of it was. We did not reduce the size of the organizational structure, that is, the Bureau of Radiological Health. It was brought in exactly into the organization exactly as it was before with no change in numbers of personnel, and the like.

Mr. ROGERS. When this ban is relaxed do you intend to bring it to strength?

Mr. HANSEN. If we have the money to go with it, yes.

Mr. ROGERS. The chairman of the Appropriations Committee has just made some statements to this effect, and this is the intention of the department?

Mr. HANSEN. We have need for additional personnel as we proceed with the developmet of the overall program.

Mr. ROGERS. Let me ask you this. Are you budgeted in your Departmet for the same amount, your Bureau?

Mr. HANSEN. Essentially the same amount.

Mr. ROGERS. Either more or less, or what?

Mr. HANSEN. I have the figures here, I believe.

Mr. ROGERS. You can submit those for the record and just tell us.

Mr. HANSEN. I would be glad to. It is slightly more.

(The following table was received for the record:)

BUREAU OF RADIOLOGICAL HEALTH BUDGET INFORMATION

	Fiscal year 1968	Fiscal year 1969	Request, Fiscal year 1970
A. Budget authority:			
Direct operations	$11,939,000	$11,767,000	$12,661,000
Training grants	2,500,000	2,000,000	2,000,000
Research grants	2,296,000	2,296,000	1,866,000
Total	16,735,000	16,063,000	16,527,000
Outlays	16,066,000	14,617,000	

	Fiscal year 1968	Fiscal year 1969	Fiscal year 1970
B. History of BRH submission:			
Agency budget	$20,580,000	$21,229,000	$18,594,000
Department budget	19,289,000	17,929,000	17,964,000
Congressional budget	16,735,000	16,297,000	16,527,000
Congressional action	16,735,000	16,063,000	
C. BRH personnel:			
Authorized positions	711	711	760
Authorized employment	711	674	631

Mr. ROGERS. On what magnitude?

Mr. HANSEN. I believe it is plus or minus $300,000. But of course this has to take into consideration the normal increases, salary increases that are required so that programwise it is not an increase.

Mr. DIXON. Is the Bureau getting more or less in terms of funds than the Center got.

Mr. HANSEN. I would say the same, when we take into consideration the increased costs, the escalation that occurs each year, 5 to 7 percent, the normal increases that are required, it would have about the same.

Mr. ROGERS. There was no increase before, as I recall it was there? Has there been any dramatic increase in personnel in the radiological field of HEW?

Mr. HANSEN. Not recently; no. Actually, Mr. Chairman, there has been a reduction of a hundred during the past year.

Mr. ROGERS. This concerns me, because I think this is a field that is very important, and the Congress felt so in passing this legislation. But, from the activities that we have seen and the emphasis placed, this would not appear to be the approach the Department has used so far. And this committee hopes this will be changed. And whatever action is necessary for the Congress to take I think the Congress would take it to put added emphasis on this field. Because we don't know enough about it yet. We need more research done, more work done. And I am concerned that the department is not placing the emphasis in this area that it should. The fact that the committee has not even, the advisory committee has not even been selected or announced some 7 months after the law was passed, as brought out by Mr. Kyros—and everything is dependent on that, really, isn't it, as far as the law is concerned?

Mr. HANSEN. The committee is vitally important to our operations.

Mr. ROGERS. It is all important right now, you can't move, can you, until that committee is established as far as setting standards?

Mr. HANSEN. As far as setting standards that is correct, Mr. Chairman.

Mr. ROGERS. And the industry doesn't have to respond to anything until you have set standards, does it.

Mr. HANSEN. That's correct.

Mr. ROGERS. Of course. So in effect by not appointing the committee as called for by the law 7 months ago your department is stymied as far as protecting the American people, isn't it, by law.

Mr. HANSEN. Mr. Chairman, we have a large number of dedicated, highly qualified engineers and scientists, and they have been working mightily during this past year.

Mr. ROGERS. I didn't say that. I am sure your people have been working. I am saying, as far as the law is concerned, since the committee, advisory committee, hasn't even been appointed, all of the work that you have done to get ready to formulate your standards—which I hope you have been doing, I want to find out a little more about that, I presume you have—you can't put forth any standards under the law, and industry doesn't have to respond until their standards are established under the law; they don't have to give you a notice of whether they are producing products that are not correct or not, do they?

Mr. HANSEN. That is correct, relative to meeting a yet-to-be-established standard. However, under the defect requirement notification by industry to the Secretary is in effect.

Mr. ROGERS. Of course.

Now, let me find out just where you are in getting your standards.

In all of this work, now, that has been going on for 7 months—and I know you have been doing it—have you drawn up the standards ready to present to the committee for their consideration?

Mr. HANSEN. They are not complete, but they are very near completion.

Mr. ROGERS. Your standards are not complete yet?

Mr. HANSEN. That is correct.

Mr. ROGERS. How far are they from completion? You mean even though the advisory committee was appointed you are not ready to proceed immediately.

Mr. HANSEN. We would proceed with the committee, because we feel that the committee should be a part—obviously not just for approval, but a vital part of reviewing the standards. We have information, we have action papers on the standards which we would present to the committee at a very early date.

Mr. ROGERS. Don't you have recommended standards now within your bureau ready to give to the committee?

Mr. HANSEN. We have recommendations, but we still want to review them with the committee.

Mr. ROGERS. I understand that. What I want to know is, have you in your department got recommended standards for radiation for color TV?

Mr. HANSEN. We have.

Dr. ELDER. Yes, sir.

Mr. ROGERS. I thought you would. I would hope you would. Or else we have been wasting 7 months.

Mr. HANSEN. We haven't wasted 7 months.

Mr. ROGERS. And there is no point in Congress passing a law—so I would hope you have, and I am glad to know that you do.

Dr. ELDER. Sir, we have an additional submittal on radiation safety recommendations for X-ray diffraction equipment. We will submit the radiation safety recommendations for X-ray diffraction and spectrographic equipment to the committee. We now have that available for industry, and we can submit that for the record today if you would like it.

Mr. ROGERS. I don't think we are ready to have that made public yet, and I don't think you should submit that for the record yet. But I would like for you to list for me those areas where you have standards ready to go to the committee, the advisory committee, for their review and thought and either their approval or disapproval.

Mr. HANSEN. We would be happy to supply that for the record.

(The following information was received for the record:)

LIST OF STANDARDS READY TO GO TO TECHNICAL ELECTRONIC PRODUCTS RADIATION SAFETY STANDARDS COMMITTEE

1. *X-radiation from television receivers and other cathode ray tube display devices.*—Standard ready.

2. *Radiation from X-ray diffraction and spectrographic equipment.*—Several radiation emission performance criteria and related safety criteria for these products ready for Committee review prior to development of complete standard(s).

3. *Radiation performance standard for microwave ovens.*—Standard now being drafted for integrity of oven door interlocks and oven door leakage.

4. *Radiation performance standards for fixed and mobile medical and dental diagnostic radiographic equipment.*—Codification completed on all recommenda-

tions or specifications for these equipment made by standards-setting organizations, including those of Canada and Great Britain and the General Services Administration. Extent of coverage of first standard under this heading is not yet determined. Codified materials are ready for review by Committee.

Mr. ROGERS. And can you generally give me those areas now? You say you have two.

Dr. ELDER. Standards are available for color television, for the X-ray diffraction, and for the spectrographic equipment. Now, on the microwave oven, our problem there essentially boils down to the test procedure. All the problems we went through with color TV, its radiation, and the detection are magnified even more in this area. Our problem is not only the biological effects and the level we are willing to accept, but the procedure for measuring electronic radiation from microwave ovens. We believe that this is one standard that we must push very hard. We want to specifically ask the advisory committee's opinion, because we may have to move in this area before all the details are worked out.

These are four that I can recall.

We also have a very extensive working document, in which we have collated all known standards applicable to X-ray equipment in the medical arts to see what recommendations other people have made. From this the committee can see how the various standards compare among the international and the national recommending societies. This will be available at a subsequent meeting. This has required a tremendous amount of staff time.

Mr. ROGERS. Do you have all the information from other nations, what other nations do on standards? Are you assembling that?

Dr. ELDER. Yes, we are assembling these standards very rapidly.

Mr. ROGERS. How many do you have working on this microwave oven standard.

Mr. HANSEN. We have about 10 people, do we not.

Dr. ELDER. Yes, sir.

Mr. ROGERS. Is that a sufficient number?

Mr. HANSEN. At this point in time we are making good progress with that number.

Mr. ROGERS. I presume these are 10 experts in this field.

Mr. HANSEN. Yes, indeed.

Mr. ROGERS. What does industry do on this? Do they have a set standard already?

Dr. ELDER. Yes, sir. They are following essentially the United States of America Standards Institute recommendations at the 10 milliwatt level. I have not seen this on a piece of paper, but this is my opinion, that they are including this in their design criteria.

Mr. ROGERS. What about other departments of government, have you made contacts with them on this microwave oven?

Mr. HANSEN. Very extensively, Mr. Chairman, with the Department of Defense particularly, but also with the Bureau of Standards and other departments. We feel, that in view of the extensive research that has been done in other areas, that we want to take advantage of that, and build it into our total resource of information on any of the equipment that we are involved in. We have had excellent cooperation in working with other agencies and obtaining their information.

Mr. ROGERS. When do you expect to complete your microwave oven standards.

Dr. ELDER. Sir, it may be that we will not be able to complete all of the work, but will just have to set a preliminary standard in order to have a set of criteria as a guideline. This may be one of the areas where there will be facts coming in over a period of years.

Mr. ROGERS. I presume all of these standards will be subject to change as we know more about the whole subject matter. And we provide that in the law. This is what we anticipated that you would do. But we would think that you would protect the American public quickly and immediately by setting standards very rapidly even though they may be an interim standard as such.

Dr. ELDER. The problem with the microwave oven is that we are in a specific area where the effect may be dependent on frequency. This is reflected in differences between one country from the other country. So if we come out with a standard relative to, say, microwave ovens, this would be specific for that frequency. Now, there are other frequencies that we are going to have to look at. This is going to take a lot of time. This is what I meant when I said an interim type for one frequency.

Mr. ROGERS. But you can go to the American products immediately, can't you?

Dr. ELDER. Yes.

Mr. ROGERS. Is there any reason not to?

Dr. ELDER. No, sir.

Mr. ROGERS. Of course not.

And I know you are working on this. But I am concerned that evidently we haven't gotten across to the department yet, the emphasis that the Congress is placing on this matter, and the desirability for some action. And we want to get that across.

I am also concerned that Mr. Johnson, the Administrator of Consumer Protection and Environmental Health Service, didn't consider this hearing important enough to be here. Isn't he the department head, in effect?

Mr. HANSEN. Mr. Johnson is deeply interested and concerned——

Mr. ROGERS. He hasn't demonstrated it, and neither has the department, by the lack of appointing this committee to allow you to proceed with standards. Right now the American people under this law have no standards. And there is no excuse for that. We know enough to set standards to at least give some protection to the American public, and it should be done.

Now, have you agreed on techniques of testing color television? Do you have your technique, your procedure of testing?

Dr. ELDER. Yes, sir.

Mr. ROGERS. There is no problem there now. This has been straightened out.

Dr. ELDER. To our satisfaction, yes.

Mr. ROGERS. How about industry, how do you feel about it?

Dr. ELDER. We are talking to them about it. As you know, we had the conference last year to round this out, and I think we are on very close agreement on this. There are also new equipment developments coming in this area.

Mr. ROGERS. And have you developed the instruments or instrument that you think is sufficient to do the testing?

Mr. HANSEN. Yes, we have. We are now using the instrument that was developed during the past year in testing equipment. Some of the manufacturers have adopted the instrument that we developed as their testing technique.

Mr. ROGERS. I would like to have that described and put in the record.

Mr. HANSEN. We would be happy to, Mr. Chairman.

(The following information was received for the record:)

A DESCRIPTION OF THE BUREAU OF RADIOLOGICAL HEALTH TV SURVEY INSTRUMENT AND MEASURING TECHNIQUES AND THE INDUSTRY'S REACTION TO THEM

(Division of Electronic Products, Bureau of Radiological Health)

A draft copy of a procedure for testing television receivers for ionizing radiation emission is enclosed (exhibit I). The Bureau of Radiological Health representatives are scheduled to meet with representatives of the Electronic Industries Association (EIA) to discuss radiation measurement procedures and instrumentation during the week of June 2, 1969.

The BRH large area TV survey meter was described in the Technical Services Branch report No. 1 of January 1968 (exhibit II). It was also described during the March 1968 government and industry Conference on the Detection and Measurement of X-radiation from Color Television Receivers. Copies of the Technical Services Branch report and the Technical Papers and Discussions of the Conference are also enclosed (the publications referred to have placed in committee files). Several television manufacturers have built their own versions of this instrument. William B. Joseph & Associates of Montville, New Jersey, has a commercial version in production.

The BRH recommends this type of an instrument for the rapid and sensitive detection and location of ionizing radiation sources in electronic products. Many industrial organizations have recognized its value for this purpose. The BRH instrument and other instruments suitable for making accurate measurements of X-ray emissions from television receivers will be matters for discussion at the above-mentioned BRH-EIA meeting.

EXHIBIT I

PROCEDURE FOR MAKING MEASUREMENTS OF X-RAYS FROM TV RECEIVERS RECEIVED BY DEP

I. IDENTIFY THE RECEIVER

Before any measurements are made, record the name under which the set was sold, the manufacturer and distributor if known, the type and body style (color console), the chassis, model, and serial numbers, and the Sams Photofact number if available. Next, list the primary potential X-ray emitting components that are in the set when it is received by DEP, i.e., picture tube, shunt regulator tube, rectifier tube. Identify the components by tube type, trade name,[1] and manufacturer. Use the same data recording format for each receiver which you test.

II. RECORD THE INSTRUMENTS TO BE USED

List, in detail, each instrument by type, manufacturer, model and serial numbers, and range. Also give the percentage accuracy of each instrument and refer to the use of calibration data by location in the DEP files, only attaching them if they are unusual.

III. PERFORM MEASUREMENTS AND GATHER DATA

To properly evaluate the X-ray emitting capabilities of a TV receiver, at least three tests have to be run, assuming the receiver has a shunt regulator tube. In this case tests will be made on the regulation and operating conditions of the receiver, X-ray emissions from the picture tube, and shielding of the shunt regulator tube.

[1] Trade name is the name of the company printed on the tube but is not necessarily the tube manufacturer.

Tests on the rectifier tube and its shielding are desirable, but at this time no valid method has been developed because of the unusual emitting characteristics of the rectifier tube. Incidental radiation from this source should be noted. During the tests mentioned above, it is assumed that the rectifier tube is adequately shielded so that no radiation can be detected outside the high voltage cage.

A. Typical operating conditions

To measure the typical operating conditions of a TV receiver, use all original components. Measure the picture tube current and the shunt regulator tube anode electron current with two milliammeters with a rated accuracy of ±2 percent of full scale or better. The sum of these two currents is usually the total current output of the high voltage power supply.

High voltage on the picture tube will be measured to ground with an electrostatic voltmeter with rated accuracy of 0.5 percent to 30 kV and 1 percent above 30 kV.

Line voltage (regulated) will be measured at the line cord plug with a taut band meter with an accuracy of 1 percent of full scale.

To make a set of measurements, set the rear panel high voltage control (0–10) at an arbitrary point. Then adjust the front brightness control to give various values of anode electron current in the shunt regulator tube, from minimum to maximum, while the picture tube current, picture tube voltage, and the line voltage are recorded. Use a dot-bar-color generator to maintain a standard pattern on the picture tube. Increase the line voltage progressively by autotransformer from 110 VAC to 135 VAC in steps of 5 Volts.

A series of quasi-linear relationships will be obtained for picture tube voltage and total current output with line voltage, showing the type of high voltage regulation circuit used in that particular receiver. The relationships also show the operating capabilities of the receiver in the range of the line voltage variation. (See Figure 1.)

B. Picture tube

Before any radiation measurements can be made from this picture tube, it is necessary to properly shield the shunt regulator tube by placing a sheet of lead between it and the picture tube. Use a Victoreen Model 440 RF survey meter, or equivalent, to measure the exposure rates from the picture tube.

To obtain a set of measurements, place the Victoreen 440 RF flush with the surface of the screen at its geometric center. Then adjust the front brightness control and the rear panel high voltage control to positions that will produce an exposure rate (measured by the Victoreen 440 RF) equal to the standard, or to the recommended standard (presently 0.5 mR/hr). Increase the line voltage to 135 VAC if necessary to achieve this exposure rate. Record the values of picture tube voltage and picture tube current which produce that exposure rate. If it is not possible to obtain 0.5 mR/hr from the CRT discontinue these tests and go on to the shunt regulator tube. An additional set of measurements should be made if some area of the picture tube (front or rear) emits radiation in excess of that measured from the center of the tube. Plot these data to produce a relationship that shows values of picture tube voltage and current which produce an exposure rate of 0.5 mR/hr. (See Figure 2.)

C. Shunt regulator tube

To test the shielding of the shunt regulator tube, first place a sheet of lead between the shunt regulator tube and the picture tube to isolate the radiation from the shunt regulator tube. A suitable large area survey meter (Stoms meter or equivalent) should be used to measure the exposure rates. This experiment consists of placing various shunt regulator tubes (good and bad) in the receiver, finding the point of maximum emission from the surface of the set for each tube, adjusting the brightness control and high voltage control for various values of line voltage to give an exposure rate equal to the standard (0.5 mR/hr), and recording the anode electron current in the shunt regulator tube and the high voltage on the shunt regulator tube (equal to picture tube voltage). If an exposure rate of 0.5 mR/hr cannot be obtained, discontinue the test on that tube. Plot these data to illustrate the relationship for the tube showing corresponding values of high voltage and shunt regulator tube current that produce a constant exposure rate. (See Figure 3.)

D. Rectifier tube

To observe radiation from the rectifier tube, set the line voltage and other conditions to produce the maximum voltage on the picture tube. Use the Stoms meter to survey for X-rays from the rectifier tube (shielded from other parts, if possible). Use the brightness control to change the current ratio I_p/I_s. If the shunt regulator tube is the X-ray source, the X-ray rates measured will increase linearly with I_s if the picture tube voltage is constant. If the radiation is from the picture tube, the rates will vary linearly with I_p. If the radiation is from the rectifier tube, there may be no predictable relationship. Then use a time-synchronized scintillation detector to see if the X-ray output pulses coincide with the rectifier tube duty cycle. If they do, this proves that the rectifier tube may be a source of the X-rays.

IV. INTERPRET THE RESULTS

Using a plot such as Figure 1, and knowing the manufacturer's recommended operating conditions (high voltage and line voltage), it is possible to see the maximum high voltage attainable for a given line voltage. Knowing this, general statements as to the X-ray emitting capabilities of the picture tube and shunt regulator tube can be made.

With Figure 2 and the maximum picture tube ratings, it is possible, by referring to Figure 1, to determine if the picture tube (used in that set) will emit radiation in excess of the standard.

Using Figure 3 and Figure 1 it can be seen whether radiation above the standard could be detected from a shunt regulator tube in the receiver. In that case, the shielding would be inadequate.

KEY FOR FIGURES

Abbreviation	Units	Description
I_p	Milliamperes, mA	Picture tube electron current.
I_s	Milliamperes, mA	Anode electron current of high voltage shunt regulator tube.
I_t	Milliamperes, mA	I_p+I_s, total electron current.
V_p	Kilovolts, kV	Picture tube high voltage.
R	Milliroentgens per hour	Radiation exposure rate.
V_L	Volts, VAC	Line voltage.

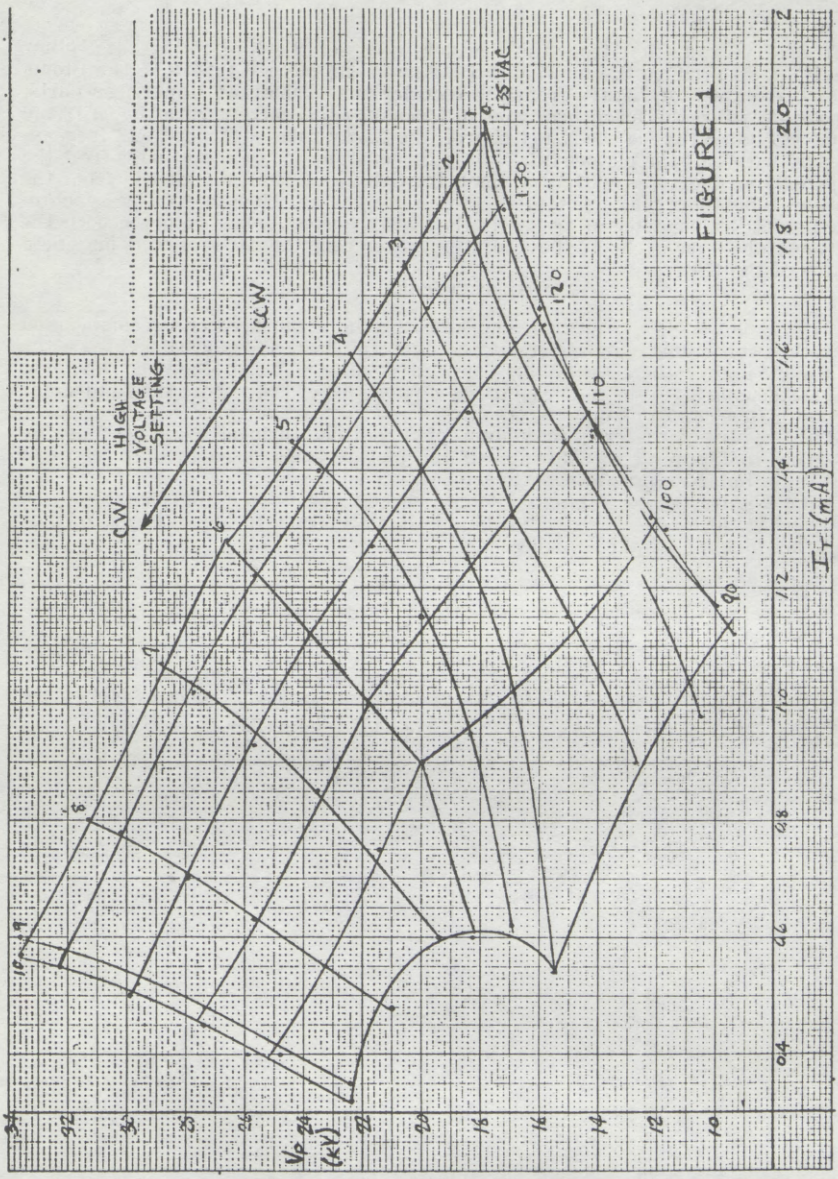

HIGH VOLTAGE SETTING
CW
CCW
135 VAC
130
120
110
100
90
V_{P-P} (kV)
I_T (mA)

FIGURE 1

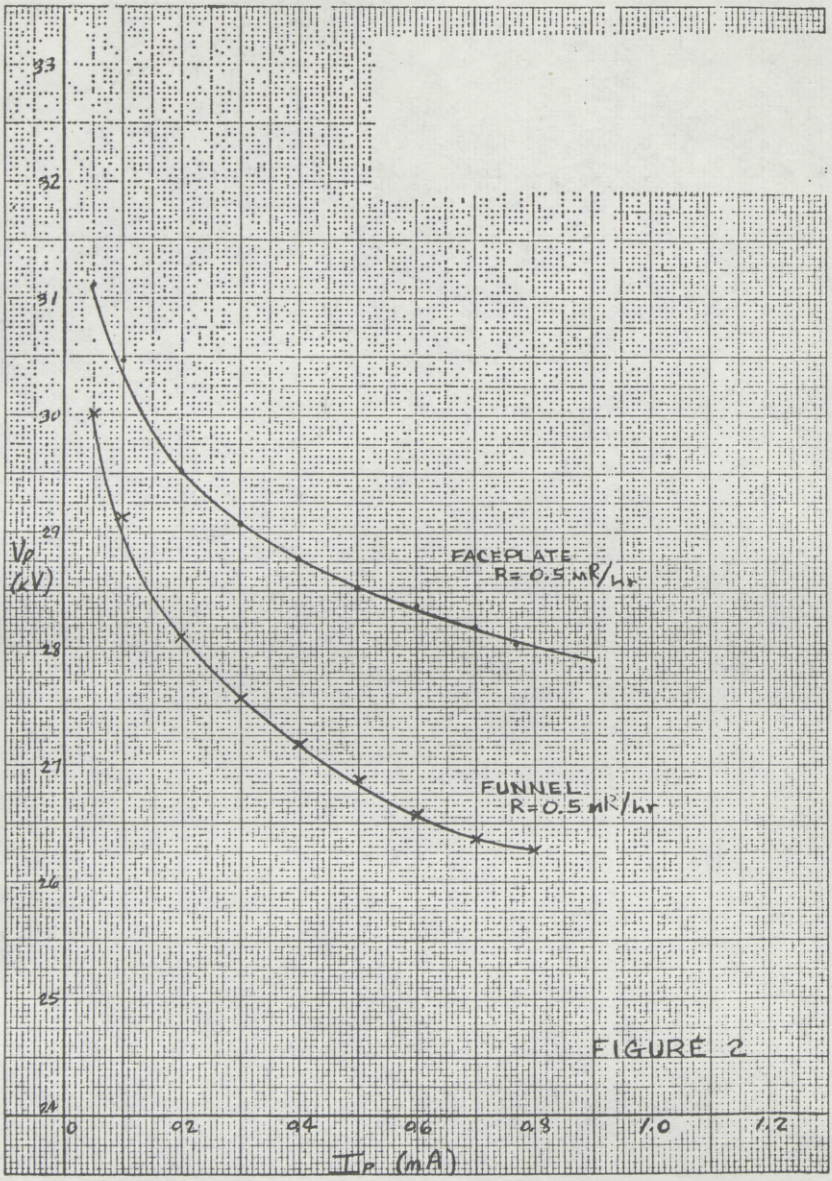

33
32
31
30
29
28
27
26
25
24
V_p (kV)
FACEPLATE
R = 0.5 mR/Hr
FUNNEL
R = 0.5 mR/hr
0
.2
.4
.6
.8
1.0
1.2
I_p (mA)

FIGURE 2

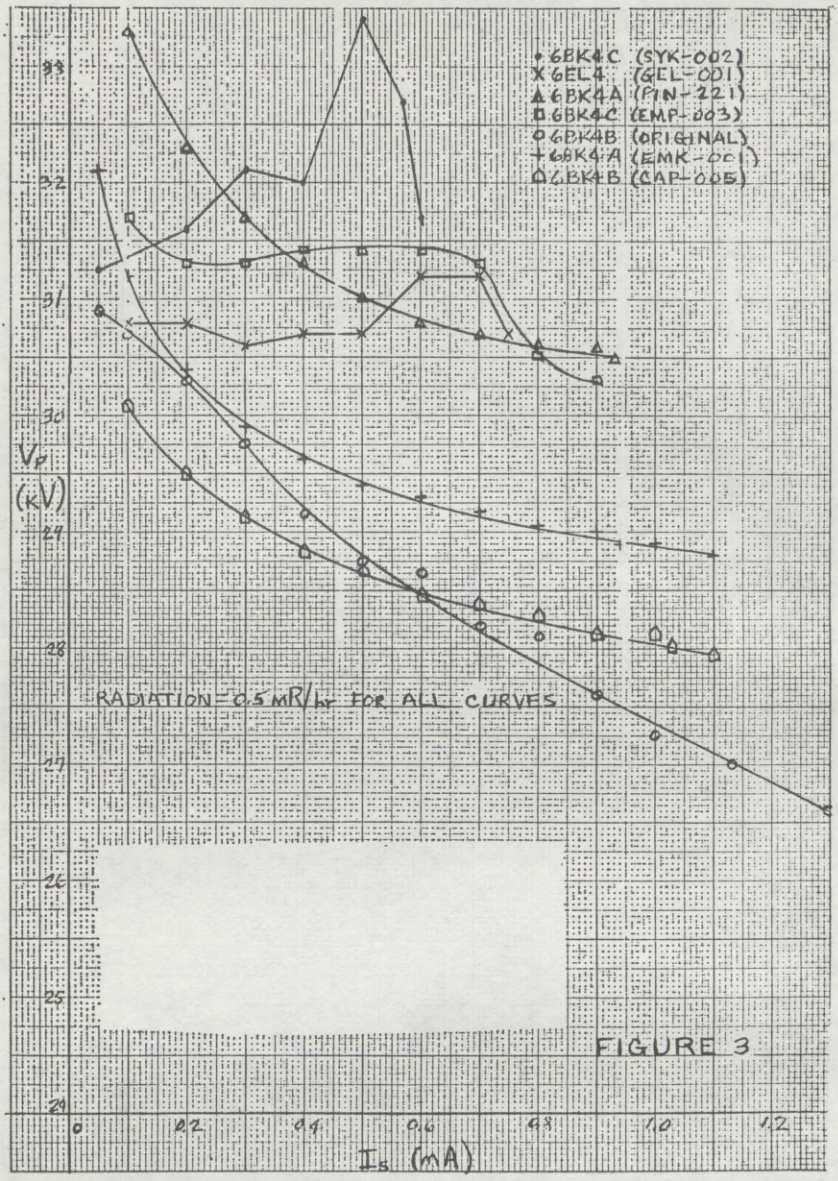

• 6BK4C (SYK-002)
X 6EL4 (GEL-001)
▲ 6BK4A (PIN-221)
□ 6BK4C (EMP-003)
○ 6BK4B (ORIGINAL)
+ 6BK4A (EMK-001)
△ 6BK4B (CAP-005)
RADIATION = 0.5 mR/hr FOR ALL CURVES
V_p (kV)
I_s (mA)
0
0.2
0.4
0.6
0.8
1.0
1.2
33
32
31
30
29
28
27
26
25
24

FIGURE 3

EXHIBIT II

TSB NO. 1

INSTRUMENT FOR MEASUREMENT OF X-RAY EMISSION FROM TELEVISION SETS

by
Richard K. Stoms & Edward Kuerze
Electronic Products Radiation Laboratory

January 1968

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Technical Services Branch
National Center for Radiological Health
Rockville, Maryland 20852

FOREWORD

The survey instrument used by the National Center for Radiological Health to measure X-radiation from approximately 1200 color television receivers surveyed in the Washington, D. C. area is described in this report. It has the same basic design as the measuring equipment that was field-tested for the first time by the Center during a pilot survey made in November 1967 in Pinellas County, Florida.

The report contains details on the instrument's design, circuitry, operating characteristics and instructions. The instrument was designed by the Center's Electronic Products Radiation Laboratory for measuring X-rays as rapidly and as accurately as possible under field conditions.

We hope that the report will be useful to the industry and other official agencies who are planning future activities and programs relating to the control of radiation emissions from electronic products.

Donald J. Nelson, Jr.
Acting Chief, Technical Services Branch
National Center for Radiological Health

January 5, 1968

Instrument for Measurement of X-Ray Emission from Television Sets

by:

Richard K. Stoms and Edward Kuerze

January 5, 1968

Introduction

An instrument to determine X-ray emission from television sets was required to conduct a survey of a number of sets in owners' homes and distributors' stock (see picture attached).

The instrument must be capable of measuring the exposure rate listed in the NCRP recommendation which states "the exposure dose rate at any readily accessible point 5 cm. from the surface of any home television receiver shall not exceed 0.5 mR per hour under normal operating conditions".

The instrument must be portable and designed to obtain measurements rapidly and accurately under field conditions by health agency personnel.

As a result of the foregoing requirements, an instrument having the following general characteristics was designed and several were built by the Cincinnati, Ohio facility of Electronic Products Radiation Laboratory, TSB, NCRH:

Dimensions: 26-1/4" long, 4-1/2" wide, 1-1/2" thick

Weight: 3-1/2 lbs.

Sensing element: Six 1B85 GM tubes aligned to provide an active probe length of 16-1/2".

32-418 O - 69 - 14

Readout: Linear meter and audio.

Power Supply: 12 volts at 22 mA (8 type AA penlight cells connected in series) and 9 volts at 0.7 mA (Eveready No. 222 or equivalent) stacked on top of the 12 volt supply.

Ranges: Full scale for 3000, 10,000, 30,000, and 100,000 for any one GM tube. (Circuitry automatically selects and gives reading for the GM tube with highest exposure rate.)

Time Constant: Operator selection of 1 and 5 seconds (approx.)

Note: [As a preliminary effort, a line voltage powered prototype instrument was designed and built. It consisted of six 1B85 tubes arranged so as to provide a probe with an active length of 16-1/2 inches. Circuitry was designed to automatically and continuously select and measure the pulse count rate of the GM tube with the highest exposure rate and display this count rate on a meter. In this circuit, the output pulses from the GM tube actuated a transistorized circuit that provided the conversion from count rate to a DC voltage or current that operated the meter movement.]

Description

Some redesign of the prototype was considered necessary to provide increased simplicity of calibration and construction. A battery type power supply was also considered to be of sufficient advantage as to warrant its inclusion.

The major change in the redesigned instrument from the prototype was the direct integration and measurement of the electrical current represented by the GM tube pulses rather than determining the

number of pulses per unit time by means of an electronic circuit. The instruments in the first group produced (including all instruments used in the Pinellas County, Florida study, November 1967) were given serial numbers "1" through "5". The instruments in the second group produced were given serial numbers "6" through "15". Some minor changes in the design of the electronic circuit were made in the second group. The differences between the two groups are discussed in Appendix I. All discussions and schematic diagrams of circuits given here refer to the second group, instruments "6" through "15".

Figures 1a, 1b, and 2 show the schematic diagrams of the main circuit, the high voltage circuit, and the audio circuit, respectively. In Figures 1a and 1b, Q8 is a constant current generator supplying a stable reference voltage for adjustment pots R14 and R20 which are used to equalize the steady state zero signal voltage at points b and c (about 3 volts). FET (field-effect transistor) Q4 and transistor Q5, and R26 make up what amounts to a source follower with the voltage at point b following the Q4 gate voltage. On all four ranges (3K, 10K, 30K and 100K full scale) the gate voltage is developed across the series combination of R12 and R13 shunted by capacitor C4 as a result of the electrical charge collected from the pulses in the 1B85 GM tube. The number of these pulses, and hence gate voltage, is related to the X-ray field incident on the 1B85. Originally, the prototype instrument was calibrated in thousands of counts per minute; for convenience, when the instrument was redesigned, the meter scales were kept the same, although readout is no longer in counts per minute.

Calibration resistor, R12 and R13, is a series combination of a 3.3 megohm resistor and 5 megohm potentiometer or a selected resistor between 3.3 and 6.8 megohm and a 1 megohm potentiometer, depending on availability of potentiometers. The pot is adjusted so that the base voltage range across the meter and its range resistor on the 3K range is 0.3 volts. Thus the 10K, 30K, and 100K ranges have a voltage range of 1.0, 3.0, and 10.0 volts full scale.

If voltages at b and c vary equal amounts in the same direction, there will be no meter deflection. If the gate of Q7 were made to follow the changes of point b, then point c would also follow these changes and the meter reading would not change. Time constant capacitor C5 is connected between point b and the Q7 gate and in conjunction with R17 determines the time constant. These capacitors allow relatively fast changes to couple to the Q7 base but not slow or DC voltages. It has been found convenient when using an instrument with an appreciable time constant to be able to occasionally revert to a fast response for a short time to allow the meter to assume its approximate reading and then return the instrument to its longer time constant. This is done by pressing the push button switch, SW 5, located on the front panel near the meter face. This shorts R17 reducing the time constant. Note that an additional "base" time constant is provided by R12 and R13 and C4.

Position 1 of range switch SW 3 is the "off" position. Position 2 causes the meter to read battery voltage under its normal load. Position 3 indicates operation of the high voltage supply. The meter current is a portion of the GV3A 900 volt shunt regulator current.

Any "on scale" reading indicates that there is shunt regulator current and that the high voltage supply is on and regulating. Note that in this position all circuits other than the HV are off (battery voltage being blocked by D4) thus there is no voltage at point c to obscure the meter reading. Position 4 is the zero check position. In this position the high voltage supply is disabled.

Positions 5 through 8 are the ranges previously described.

At this point, operation with only one GM tube has been considered. If in Figures 1a and 1b, six units identical to the sensor unit shown are paralleled and proper adjustments made, the meter will indicate only the current in the tube seeing the highest X-ray exposure rate. This comes about because the increase in voltage at point b due to an increase in gate voltage on one (or more) Q4 transistor will tend to cut off current through the remaining Q4, Q5 transistors. SW 1 is provided on each of the sensor units so that each unit may be zero set individually and also to facilitate trouble shooting.

GM tube No. 6 (tube farthest from meter) receives its high voltage directly from the HV supply while tubes 1 through 5 are supplied through push button switch, SW 2. Pushing SW 2 disconnects HV from 1 through 5 and discharges the stray capacity so that only tube No. 6 is operational. This is convenient in order to localize a beam or small area emitting X-rays. SW 2 must be kept depressed by the operator to deactivate tubes 1 through 5. When released, it is spring returned to normal.

The high voltage circuit shown in Figure 1b is fairly simple. A UJT (unijunction transistor), Q9, is operated as a relaxation

oscillator. The ramp voltage at the emitter of Q9 is capacitively coupled to the base of the normally off Q10. The result is a series of square wave current pulses through the primary of the UTC 0-2 transformer. The frequency is approximately 2 kc. Use of the UJT oscillator provides a very reliable means of self starting as compared to the usual methods of feed back oscillators using a transformer tap.

The secondary circuit uses a standard voltage doubler and a GV3A 900 volt "Corotron"(1) shunt regulator. R34 is placed in series with the shunt regulator so that when SW 3 is in position 3, the meter will indicate a part of GV3A current.

Figure 2 shows how an audible signal is produced for a preselected X-ray level. Potentiometer, R1, is connected to point b of Figure 1a so that the emitter voltage of UJT, Q1, is related to X-ray exposure. R3 has been selected so that maximum setting of R1 will just barely keep Q1 from oscillating when the zero signal voltage at point b, Figure 1a, is present. Any increase in voltage at point b will increase emitter voltage at Q1 and cause oscillation. The frequency of oscillation is a function of emitter supply voltage which results in an increasing audio tone as X-ray exposure is increased. Q2 and Q3 comprise a monostable multivibrator. In its normal state, both Q2 and Q3 are off. A positive pulse from Q1 coupled into the base of Q2 will turn Q2 and Q3 on. Feedback network R9 and C3 provide the positive feedback required for monostable multivibrator action and control the "on" time. The speaker receives a pulse of energy for every pulse produced by Q1.

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(1) Registered trademark of Victoreen Instrument Company.

Operating Instructions

The range switch positions and functions are described on pages 4 and 5. The battery check position should show a reading of 21 volts. The batteries should be changed if the reading is 18 volts or lower.

Any "on scale" reading in the HV position of the switch indicates that the high voltage supply is operational.

Zero is checked by placing the range switch on the "zero" position. Adjustment is made with the screwdriver adjust pot below the meter face.

Most readings will be made with the time constant switch in "F" position (fastest time constant). The longer time constant may be selected if desired. When depressed, the red push button switch next to the time constant selector switch reduces the time constant to its shortest value. This can substantially reduce the time required for a reading.

The red push button switch labeled 6 is used to disable all GM tubes except the end one in the probe. This facilitates locating or defining the area of a beam.

An audible signal is incorporated and may be used at the operator's discretion. The sound is turned off by turning the audio control completely clockwise. Other positions of the control will determine the level or amount of X-ray exposure that the audio circuit will respond to. A radioactive check source emitting X-rays or gamma rays can be used to obtain any desired meter reading. The control can

then be set so that an audible signal can just be obtained. A decrease in X-ray exposure below this value will produce no sound. Increasing exposure over this level will result in a sound of increasing frequency. The sound is not that obtained by producing a click or sound pulse for every geiger tube pulse.

The time constant selector does not affect the response time of the audio signal which always operates on the shortest time constant.

Field Tests and Maintenance

A radioactive source emitting X-rays or gamma-rays can be used to check the operation of the instrument.

When the source is successively placed adjacent to the GM tubes, fairly consistent readings should be obtained. Differences in readings between tubes or between readings taken on both sides of the same tube are due to the fact that small variations in the short "source to tube" distance become important. These differences are minimal when the source is more than a few inches away as when measuring the field external to a television set.

If improper operation is indicated by the source check or a large change in the zero setting, the trouble can be isolated by means of switches mounted on the GM tube boards. Remove the screen on top of the instrument. If the trouble is one in which a high reading is obtained, the switches should be opened and closed successively until the one producing the malfunction is located. Usually the trouble will be due to dirt or excessive moisture on the GM tube mounting. If the trouble is not located in this manner, and cleaning and drying the tube

and mount does not correct the condition, proceed as described below.

In the event that the malfunction is indicated by a down scale reading or the above procedure has not corrected the condition, turn off all but one switch on the GM mounting boards. Set range switch on "zero" position. Set zero with the control below meter face. Turn switch off and another one on. Set zero with the 100K potentiometer on the mounting board. Turn this switch off and proceed with the next board, setting zero with the 100K potentiometer. When all units have been set to zero, turn all 6 switches on and, if required, set meter zero with control below meter face.

During initial adjustments and calibration in the laboratory, the front panel zero control is adjusted to produce a potential of between 2.6 and 2.8 volts at point "c" with all sensors switched off.

It is possible that the instrument will respond to light (especially ultra-violet) or strong electromagnetic fields. Light sensitivity is almost invariably caused by a defective light seal at the base of a GM tube. Recoating the glass seal with a light-tight coat of insulating material, such as a black silicone rubber, will eliminate this type of sensitivity.

In the event that operation without the perforated aluminum cover is required, or if an abnormally strong electromagnetic field is expected, the integrating capacitor C4 should be connected between the base of Q4 and ground on each of the GM tube circuit boards, and a 0.1 microfarad capacitor connected between the gate of Q7 and ground. This does not affect calibration or time constant.

SENSOR UNIT

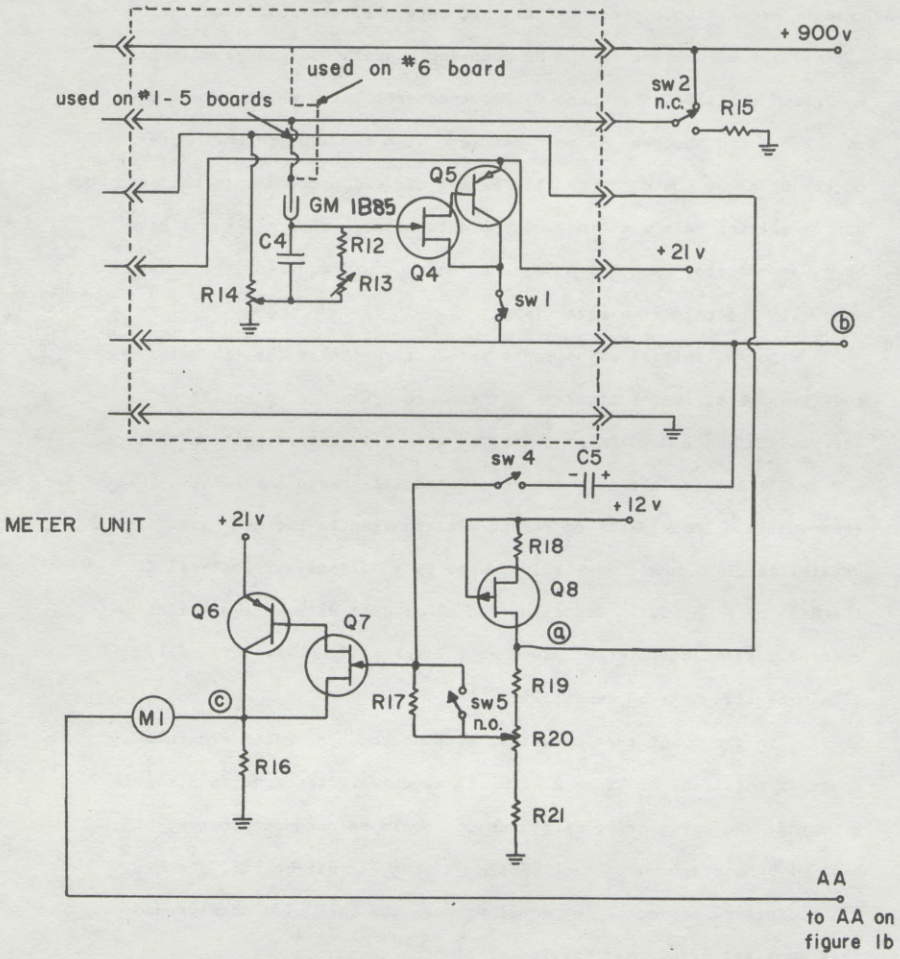


FIGURE 1a

Corrected 1/10/68

SELECTOR SWITCH & HIGH VOLTAGE CIRCUIT

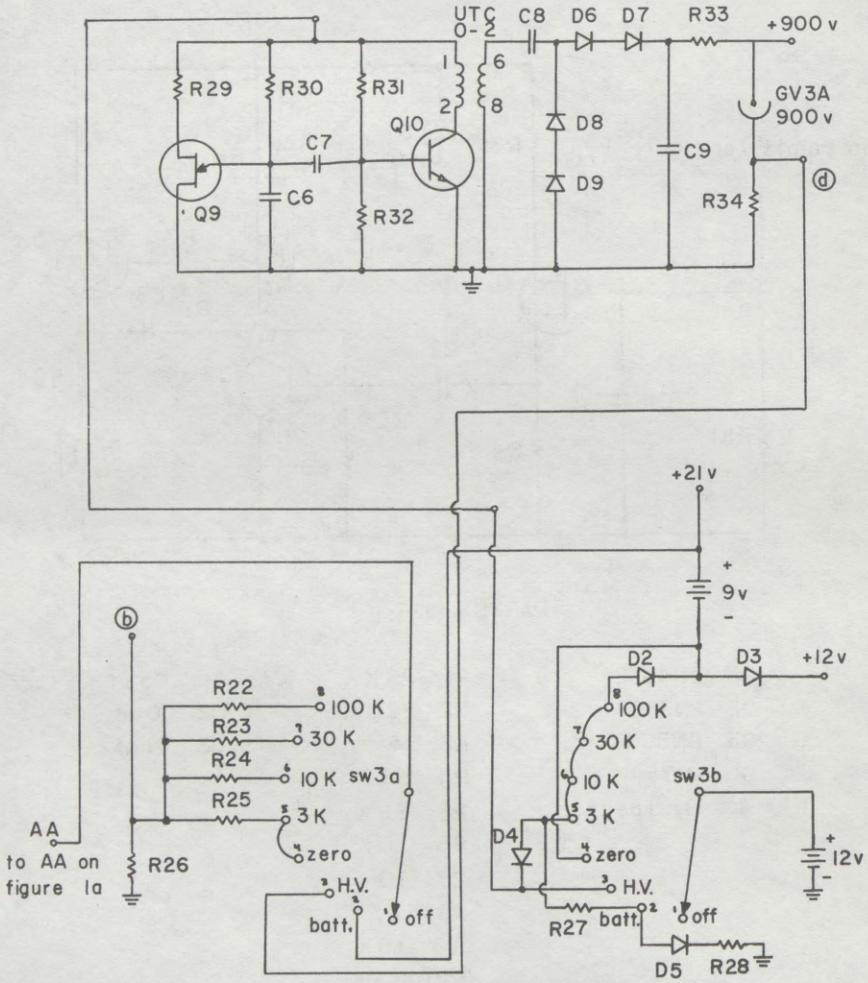
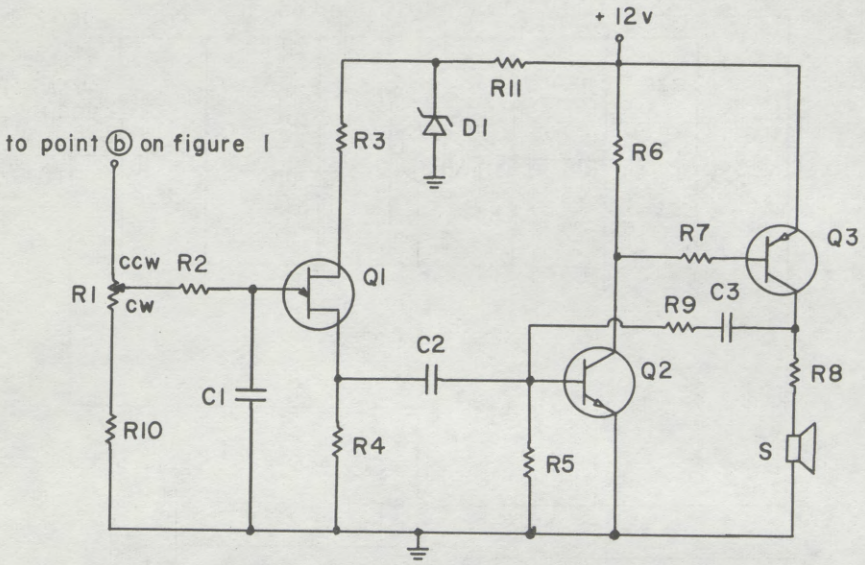


FIGURE 1b

AUDIO CIRCUIT



PARTS LIST

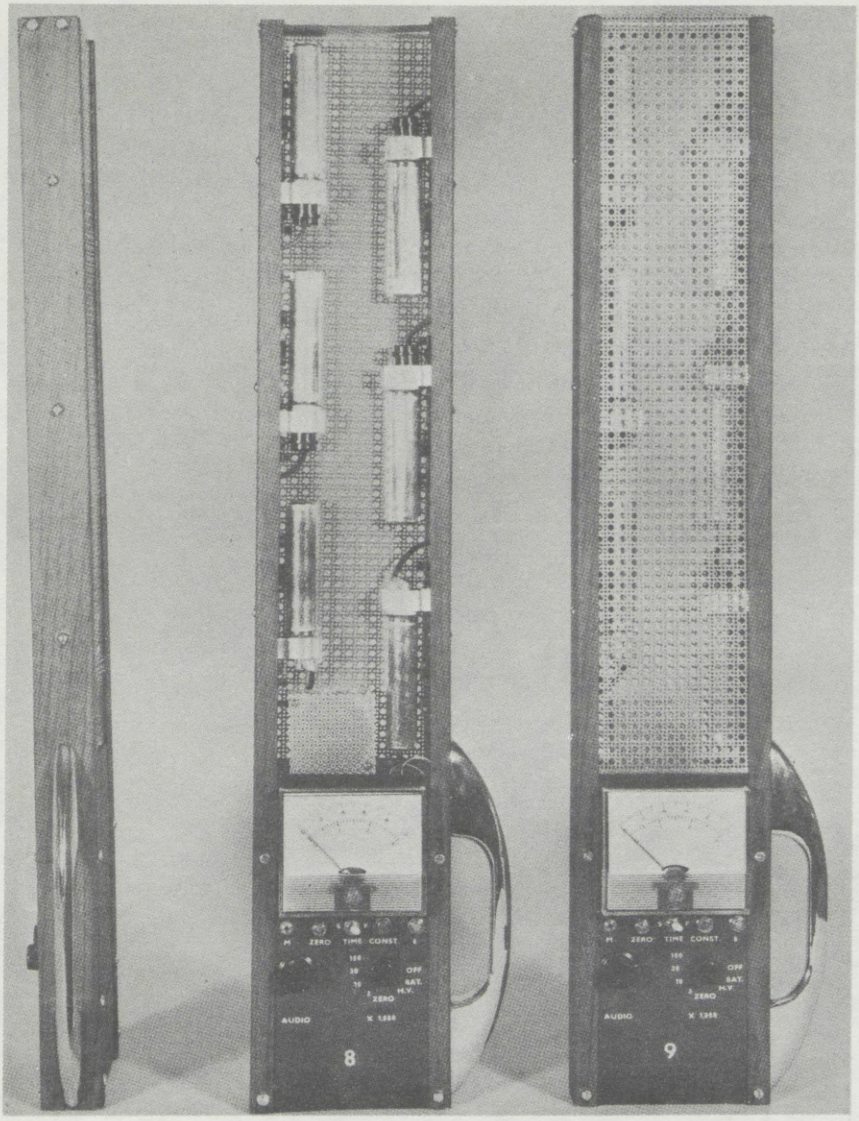
Q1	2N4852	R1	25 K	C1	.05 uf
Q2	2N3567	R2	220 K	C2	1.0 uf
Q3	2N3638	R3	*	C3	.01 uf
D1	IN754	R4	560		
S	8Ω speaker	R5	6.8 K		
		R6	1.0 K		
		R7	1.0 K		
		R8	47		
		R9	1.5 K		
		R10	3.3 K		
		R11	1.0 K		

* selected for sound threshold in zero x-ray field with R1 ccw

FIGURE 2

Parts List (cont'd.):

Q4	2N4221	R12	selected	C4	0.1 uf
Q5	2N3638	R13	selected	C5	3.0 uf
Q6	2N3638	R14	100 K	C6	0.1 uf
Q7	2N4221	R15	4.7 M	C7	1.0 uf
Q8	2N4360	R16	10K	C8	0.01 uf 2KV
Q9	2N1671B	R17	1.0 M	C9	0.01 uf 2KV
Q10	2N3567	R18	selected		
D2	F8	R19	22 K		
D3	F8	R20	25 K		
D4	F8	R21	22 K		
D5	F8	R22	selected		
		R23	selected		
		R24	selected		
		R25	selected		
		R26	10 K		
		R27	560 K		
		R28	560		
		R29	1.0K		
		R30	6.8 K		
		R31	47 K		
		R32	6.8 K		
		R33	10 M		
		R34	15 K		


ZERO
TIME CONST.
OFF
BAT.
H.V.
ZERO
AUDIO
8
9

Appendix I -- Circuit Differences in Instruments 1 through 5

The first group of instruments, serial numbers 1 through 5, had an 18 volt power supply with a drain of 22 mA consisting of two Burgess PM6 or equivalent 9 volt batteries in series. A correct reading in the battery check mode was 8 on the 10 scale.

These instruments had a 1 K full scale range. This required an extra transistor on the "Sensor Circuit" board and some slight changes in the range switch. The voltages at point b were 1, 3, and 10 volts above the fixed zero signal voltage of approximately 3 volts for 1 K, 3 K, and 10 K full scale, respectively. On the 30 K and 100 K full scale ranges two resistors were switched into a parallel combination with the calibration resistor (now the series combination of R 12 and R 13) by an FET providing a resistance reduction of 30:1. The 30 K and 100 K ranges then had full scale voltages of 1 and 3 volts, respectively, over the zero signal voltage.

Operation of these instruments was the same as for the second group with the exception of the absence of a separate position on the range switch for zero setting. The instruments are zeroed on the 30 K full scale range in a low radiation area.

These instruments had an additional switch selected time constant. The three were approximately 1, 3, and 10 seconds.

Mr. ROGERS. Your technique, and the instrument, and the reaction of industry to it.

Dr. Carter.

Mr. CARTER. We might ask just what type this is.

Mr. ROGERS. Could you just tell us briefly what type of instrument it is?

Dr. ELDER. The survey instrument that we designed is essentially a geiger-Mueller instrument. It has a bank of tubes in it so situated that you may use it to rapidly screen a large surface area, where the individual detector detecting the largest quantity of radiation will be the one that reads out and the others will blank out. So it enables us to use a device that covers large areas quite rapidly. This was one of the problems. The instrument also responds very quickly to the incident radiation.

Mr. ROGERS. Thank you.

Now, just a few more questions. Let me ask, about how many microwave ovens do you suppose there are in use in this country?

Dr. ELDER. Approximately 50,000.

Mr. HANSEN. Yes, about 40,000 estimated in the previous year, and 50,000 now.

Dr. ELDER. This is both domestic and commercial types.

Mr. ROGERS. Have you done any check on these at all?

Dr. ELDER. As we mentioned in the testimony, there have been surveys. We have bought some microwave ovens for testing.

Essentially, Mr. Chairman, there are two problems. No. 1 is the interlock. This is a specific problem, because if the interlock does not shut the microwave oven off whenever the door is open, a large amount of radiation can come out. This one we are addressing ourselves to very quickly.

Mr. ROGERS. How large an amount, do you know? Has it been determined?

Dr. ELDER. In excess of a hundred milliwatts, which is considered by all recognized experts to be hazardous.

Mr. ROGERS. It is my understanding—I think they brought out last year that Walter Reed Hospital tried to purchase 30 of them, and only six were correct.

Dr. ELDER. Yes, sir. That was relative to the second problem, which is leakage. This is leakage around the seals of the doors. We are actually addressing ourselves to two specific topics when we speak of microwave ovens, the leakage and the interlock. We are very seriously concerned about the interlock.

Mr. ROGERS. Where are they using these microwave ovens mainly, hospitals, snack shops, restaurants, and this sort of thing?

Dr. ELDER. Yes, sir.

Mr. ROGERS. How about airlines?

Mr. HANSEN. Some airlines I understand are using them.

Mr. ROGERS. Now, do you know which?

Mr. HANSEN. No, I do not. I would be happy to find out and give you that information.

Mr. ROGERS. I wish you would, because it is my understanding from FAA that airlines are not now using them, they advised us of that. And the only airplanes using these microwave ovens are Air Force

1 and Air Force 2. And I think this might go well for your department to check on it and see if those ovens are all right.

Mr. HANSEN. My information may be old. I know that they did have some planes with microwave ovens.

Mr. ROGERS. I think this would be worth checking out. And I would like to have you let the committee know what the condition of these microwave ovens are on Air Force 1 and 2.

(The following information was received for the record:)

CONDITION OF MICROWAVE OVENS ABOARD AIR FORCE 1 AND 2

With regard to the alleged hazard associated with microwave ovens aboard Presidential aircraft, the following comments are provided:

Air Force 1 was surveyed at McClellan Air Force Base, California on 1 June 1968 by personnel of the Ground Electronics Engineering-Installation Agency. The highest level measured was 0.15 milliwatt per square centimeter, which is well below established USAF standards. Follow-up surveys were accomplished in July 1968 and January 1969 by Bioenvironmental Engineering personnel at Andrews Air Force Base. At these times no detectable radiation was noted. Because of the question having been raised, the ovens aboard Air Force 1 were resurveyed on 26 May 1969. Again there was no detectable radiation.

Air Force 2 was surveyed during July 1968 and January 1969. No detectable radiation was measured. A follow-up survey will be accomplished following routine aircraft maintenance now being accomplished.

MAY 27, 1969.

The above information was presented to me this date. It was prepared in the Office of the Air Force Surgeon General by Col. Richard S. Malone and his staff. Further documentation or authenticity if needed can be confirmed by contacting the above named officer.

ANDREW C. WHEELER.

USE OF MICROWAVE OVENS IN COMMERCIAL AIRCRAFT

[NOTE.—A copy is included of Donald R. Smith's memorandum of May 28, 1969, documenting his conversation with Mr. James Beddow, Environmental Control Administration, regarding the use of microwave ovens in commercial airlines.]

MAY 28, 1969.

Memorandum for the record.

From: Donald R. Smith.

Subject: Conversation with Mr. James Beddow, Interstate Travel Sanitation Branch, Division of Food, Milk, and Interstate Travel Sanitation, Bureau of Community and Environmental Management, Environmental Control Administration, Alms and Doepke Building, Cincinnati, Ohio 45202 (telephone 513–684–2473).

On May 27, 1969, Mr. Beddow was requested by me to check on the use of microwave ovens in airplanes. He reported back on May 27, the following:

(1) Eastern Airlines and Trans World Airlines have used microwave ovens in the past. As far as they are able to determine there is no airline presently using microwave ovens in planes.

(2) Planes are now being designed with radar ranges (microwave ovens), however, no prototypes are now in service.

(3) There are a number of ships with radar ranges. Microwave ovens have been placed on ships since the Litton Industries have taken over the ship yards in Pascagoula, Mississippi, 50 to 60 ships have had microwave ovens installed in them. The ships with microwave ovens include the U.S.S. United States and the U.S.S. Savannah.

NOTE.—Mr. Beddow offered to assist in arranging surveys of some microwave ovens on ships either in New York or Newport News, Virginia. I suggested to Mr. Beddow that we wait until Mr. Haverland, the Acting Chief, Interstate Travel Sanitation Branch, provides us with the location of microwave ovens on interstate carriers.

Mr. ROGERS. I also understood that at the Army environmental hygiene agency that they can open one of these ovens a little bit and fry an egg 18 inches away. Are you aware of that?

Dr. ELDER. We have received results from them, yes, sir. I don't know this specific experiment, but that doesn't surprise me.

Mr. ROGERS. Have you contacted the manufacturers of microwave ovens yet.

Dr. ELDER. Yes, sir. We had a meeting as recent as last week where various topics were discussed, including interlock and leakage problems. This was with the American Home Manufacturers Association in Chicago. They have offered to help us visit the plants to see the quality control procedures and how they do it. We intend to follow through on that.

Mr. ROGERS. I think that would be essential, and I commend the industry for cooperating in that degree.

I would hope that you would do this very shortly and let this committee have a report on this. I think this can be very important.

Dr. ELDER. Yes, sir.

Mr. ROGERS. Are you checking with any local health units to see if they are making surveys? Is there any contact between your bureau and the States, or local health, county health.

Mr. HANSEN. There is extensive contact. We have a program that has been in operation for some time, consisting of an assignment of people to the States and the development of State interest in this. This has progressed very well, with some 30 States having technically qualified people on this program. We held the meeting in Montgomery, Ala., earlier this year to go over the Public Law 90–602 to solicit their cooperation.

And they are deeply concerned and ready to assist within the limits of their capability.

Mr. ROGERS. I think you might also want to contact the Pinellas County Health Department in Florida. It is my understanding that they are currently completing a recent survey of microwave ovens there, the commercial type and the home type. In commercial ovens the survey indicates that at present about 40 percent had leakage above the current standard of the 10 milliwatts, even with the door closed.

And I think there are over 300 microwave ovens in the St. Petersburg area, and 20 to 25 percent of those tested so far have been found to emit radiation above the 10 milliwatt level. This seems to be an excessive number. And I think action should be taken right away. We would like the names of all of the manufacturers, and the number they have supplied, and if you can find out, in what areas they have supplied the microwave ovens to. I think this can be important.

Dr. ELDER. We will do that.

(The following information was received for the record:)

MICROWAVE OVEN MANUFACTURERS, NUMBERS OF OVENS PRODUCED, AND GEOGRAPHICAL DISTRIBUTION

Request: The names of all microwave oven manufacturers, the numbers of ovens produced and, if possible, their geographical distribution.

A list of manufacturers and marketers of microwave ovens has been obtained from the Association of Home Appliance Manufacturers. A copy of this list is enclosed.

Microwave oven production data have been provided by the Association for the period through August 6, 1968. A copy of the data tabulation is also attached. The Division of Electronic Products has requested information from the Association on the geographical distribution of ovens that have been sold. Such information is presently unavailable. The test marketing areas, where the concentration of ovens in use is probably the greatest, are the New York City, Chicago, and Los Angeles Metropolitan Areas.

ASSOCIATION OF HOME APPLIANCE MANUFACTURERS,
Chicago, Ill., October 29, 1968.

Mr. JAMES G. TERRILL, Jr.,
Center Director, National Center for Radiological Health,
Rockville, Md.

DEAR MR. TERRILL: This is to acknowledge and thank you for your letter of October 17, 1968. I apologize for not having answered earlier but the AHAM staff was completely occupied with the Second Annual Home Appliance Conference in Denver this past week.

As soon as AHAM representatives at the October 3, 1968, meeting have had an opportunity to review the minutes submitted with your letter, we will forward our comments to you.

As agreed at our meeting on October 3, attached is a list of manufacturers and marketers of microwave ovens. A complete and accurate history on those that might have participated at one time and even on those presently involved is difficult to develop. This list is the best we have been able to collect to date.

It is our understanding that AHAM is to receive a copy of the amended protocol which will reflect the results of discussion between Mr. Smith of NCRH and Mr. Prucha, AHAM's Standards Subcommittee Chairman. We will react on this protocol as soon as we have an opportunity to study it.

We are looking forward to further and continued cooperation between NCRH and AHAM.

Sincerely yours,

HERBERT PHILLIPS,
Technical Director.

MICROWAVE OVEN MANUFACTURERS

Name	Address	Microwave products
Amana Refrigeration, Inc	Amana, Iowa	Domestic oven.
American Microwave, Inc	Salt Lake City, Utah	Commercial oven, working on domestic oven.
Cryodry		Industrial and commercial equipment.
Eden, Fishe & Hirst, Ltd		
Eimac Division (Varian Associates)	301–T Industrial Way, San Carlos, Calif.	Industrial equipment and tubes.
General Electric	Commercial Equipment Department, 14th and Arnold Sts., Chicago Heights, Ill.	Manufacturers of commercial ovens.
	Appliance Park, Louisville, Ky	Domestic ovens.
Genesys		Industrial equipment.
Hayakawa		Japanese manufacturers represented in the United States by Sharp Electronics Corp., Los Angeles, Calif.
Heathkit		Proposing a "do it yourself" kit for domestic ovens.
Hotpoint (Division of General Electric)	Appliance Park, Louisville, Ky	Domestic oven (no longer in production).
Husqvarna		Swedish manufacturers of domestic and commercial ovens.
International Crystal Laboratories	122 Coit St., Irvington, N.J	Manufacture and market domestic and commercial ovens (presently producing nothing).
Litton Industries, Atherton Division	974 Commercial St., Palo Alto, Calif	Commercial ovens.
Montgomery Ward		Markets ovens similar to Tappan.
Omnivent		Commercial ovens.
Radio Corporation of America	Electric Components and Devices, 415 South 5th St., Harrison, N.J.	Manufactures tubes.
Raytheon Co	Foundry Ave., Waltham, Mass	Manufactures tubes and commercial ovens.
Reeves Electric		
George D. Roper Corp	Newark, Ohio	Manufactures domestic ovens (do not market as Roper).
Sears		Markets ovens—Roper.
Siemens	Munich, Germany	German manufacturer of ovens operating at 440 MHz.
Tappan Co	180 Park Avenue West, Mansfield, Ohio	Domestic ovens.
Varian Associates Vacuum Division	611–T Hansen Way, Palo Alto, Calif	Commercial equipment.
Voltator		
Welbilt Corp	57–18 Flushing Ave., Maspeth, NY	
Westinghouse Eelectric Corp	Electronic Tube Division, Dept. TR–500, Elmira, N.Y.	Domestic ovens (no longer in production or selling).
Micromatic Electronic Ranges, Inc	3250 West National Ave., Milwaukee, Wis.	Markets ovens produced by Tappan.
Thermoware Electric Corp	1250 Rockaway Ave., New York, N.Y	Manufactures commercial ovens.
Microwave Energy, Inc	West Peabody, Mass	Manufactures magnetron tubes.
Whirlpool Corp	Benton Harbor, Mich	

Microwave oven total production figures.—Provided by the Association of Home Appliance Manufacturers (for all manufacturers), Aug. 6, 1968

Year:	*Production (estimated total units)*
1968 to Aug. 6	2,000
1967	3,500
1966–65	6,000
1964 and prior	10,000
Total	21,500

This listing does not include production figures for Amana which are estimated as being 20,000 total to August 6, 1968.

(NOTE.—Data confirmed by telephone on May 28, 1969, by Donald R. Smith of the Division of Electronic Products in conversations with William S. Comstock of AHAM and William Hullsiek of Amana.)

Mr. ROGERS. I understand you are in the process of making a study of 200 schools in nine States with devices using electronic equipment.

Mr. HANSEN. Yes.

Mr. ROGERS. How far have you progressed with these studies?

Mr. HANSEN. They are well along. We do not have the detailed information in, but our preliminary indications are that there is consider-

able electronic equipment being used in the schools, and there is a need for guidance to them in the effective use of the equipment to avoid exposure of the students. And we are working on that now to provide such guidance.

Mr. ROGERS. I think Florida is one of the States, is it not?

Dr. ELDER. Yes, sir.

Mr. ROGERS. What have you found there, anything to date?

Dr. ELDER. The specific results are actually coming in this week from all over. I could check to see on what actually the condition was in Florida.

Our regional representatives have already contacted State health departments to inform them that there are devices that do produce radiation in schools, and that they should look into these. Some of these X-ray tubes should be, according to some State laws, registered. And we recommend this.

We also recommend that the Handbook 32 as put out by the National Council on Radiation Protection be more widely distributed, because it is a very excellent series of recommendations which has not been widely disseminated.

Mr. ROGERS. What about used X-ray equipment? Is there much resale of X-ray equipment.

Mr. HANSEN. We have a study in process on the extent of that. There is a significant amount that is resold. The boundaries of the problem haven't been completely defined yet. But we consider this a rather important part of the radiation problem.

Mr. ROGERS. Will the law give you sufficient authority to meet this problem.

Dr. ELDER. I think that is why Congress wanted us to study this. It would be an example of equipment, and we use X-ray as only one example, produced before October 18, 1968. So the law would not be applicable as we understand it to this equipment. We are studying this problem to determine the need for further authority under the law.

Mr. ROGERS. I think we had better consider that very seriously, if this is much of a problem. And I think this committee would be receptive to it.

What about the grandfathering in of the television sets? Do you need additional authority there, if we find excessive radiation in sets produced before the date of the law.

Mr. HANSEN. We of course are concentrating on preventing the introduction of new equipment into the environment here that has a radiation hazard associated with it. There are still some uncertainties associated with the problem in the used sets. We know that the studies that have been made, there have been sets with various levels of leakage.

We feel that there is a problem, but within our resources we are concentrating primarily on the new sets. And one of the major problems in the old sets is components. We want to work with the manufacturers to be sure that the replacement components are ones that are essentially radiation free, so that in the repair of these sets we will end up with a product that gives maximum protection to the users.

Mr. ROGERS. I would like for you to furnish for the record too, please, the progress we are making on discussions with manufacturers to get the component parts free of radiation, if you could give us a rundown on this for the record.

Mr. HANSEN. We would be happy to do that, Mr. Chairman.

(See "X-radiation Control Programs in the Color Television Industry," on p. 23.)

Mr. ROGERS. I want to know too about this used X-ray equipment. Who buys this used X-ray equipment? And how is it used, and so forth? Will you let us have a rundown on that?

Dr. ELDER. Sir, we would be most pleased to do it. But our people are now in the field. We are getting cooperation from the States.

Mr. ROGERS. Well, as soon as you have it.

Dr. ELDER. As soon as we have it we would be most pleased to do it.

(The information requested was not available to the committee at the time of printing.)

Mr. ROGERS. And how many States have adopted a model code, and in what areas are they competent now within this law to operate in this whole radiation field?

And I would also like any suggestions you have as to what additional legislation you think this committee should consider.

You have a very large problem. And I know you are working on this. We were pleased with the work that the radiological center had been doing. We hope it has not been downgraded. We intend to follow this very thoroughly. And I hope you will take back to the administration and HEW the facts that we don't think they are putting enough emphasis on it yet. We hope the advisory committee will be appointed immediately and its standard will be issued immediately. Otherwise we can't hope to protect the American people, unless the law that the Congress has passed is going to be effectively administered.

We look forward to cooperating with you and protecting the public.

Mr. HANSEN. Mr. Chairman, we sincerely appreciate your interest and support on this.

Mr. ROGERS. Counsel brings to my attention here that the Russian, Polish, Czech exposure standards, as contrasted with ours, and England, France, and Western Germany, are approximately 1,000 times lower than those that we recommend for use. I would like to have you comment on that and furnish for the record the rationale.

Mr. HANSEN. That is correct. We are concerned and are studying this in great depth, searching for all the information we can find, because there is a significant difference of opinion on this between the United States and Europe and Russia.

I would like to ask Dr. Elder to comment further on that.

Dr. ELDER. Essentially there is a difference between those countries and our country on what effects are measured. In this country the standard that I mentioned previously is based upon a thermal effect. In fact, the whole basis throughout the countries that you mentioned that have the higher standard is a thermal effect. In Russia they do stress Parlovian types of studies and central nermous system studies. They are basing their standards on these types of effects.

There has been considerable disagreement in this literature interpretation. And in fact it is very difficult to interpret some of the data due to different technical terminology. But in all fairness we have no data really to say they are wrong. This is our very uncomfortable position.

Mr. ROGERS. Do we have studies going on in this area?

Dr. ELDER. We are supporting one study specifically in this type of response at the University of Arkansas. This is a parallel study to what was done in Russia, where they have reported an effect at low levels. These effects are generally called psychological effects. The study specifically is on the response of rats in a maze during exposure to microwaves. The American investigator is reporting effects energy levels lower than the Russian investigator.

Now, these are very difficult to document. And we would be most pleased to submit a review on the other standards if you would like to have it.

Mr. ROGERS. The committee would be very interested in receiving those reports and the difference in our approaches.

(The following material was received for the record:)

COMPILATION OF DOMESTIC AND FOREIGN MICROWAVE EXPOSURE STANDARDS

Country	Organization	Reference Documents (See attached list)	Frequency Range	Exposure Limits in Power Density
U.S.A.	Army/Air Force	1	300 to 300,000 MH_z	Occupancy: Unlimited — Average Power Density: Less than 10 mW/cm^2 Limited[a] — 10 to 100 mW/cm^2 Denied — Greater than 100 mW/cm^2 [a]Exposure Time (Minutes) Per Hour = $\frac{6000}{X^2}$ where X = Power density in mW/cm^2
U.S.A.	United States of America Standards Institute	2	10 to 100,000 MH_z	10 mW/cm^2 Averaged over any possible 0.1 hr period
U.S.A.	Proposal by W. W. Mumford	3	10 to 100,000 MH_z	The radiation protection guides (RPG) vary from 1 mW/cm^2 to 10 mW/cm^2 according to the temperature-humidity index (THI). When the THI is 70 or less, RPG = 10 mW/cm^2 When the THI is between 70 and 79, RPG = (80-THI) mW/cm^2 When the THI is 79 or greater, RPG = 1 mW/cm^2
United Kingdom	British Post Office	4	30 to 30,000 MH_z	10 mW/cm^2 - for continuous daily exposure In the case of pulsed systems, the radiation is to be averaged over complete trains of pulses, including any intervals between pulse trains
Poland	Council of Ministries	5	300 to 300,000 MH_z	0.01 mW/cm^2 - No limitation for time of work or sojourn 0.01 to 0.1 mW/cm^2 - Cumulative time of work or sojourn not to exceed 2 hours in every 24 hours 0.1 to 1.0 mW/cm^2 - Cumulative time of work or sojourn not to exceed 20 minutes in 24 hours
U.S.S.R.	Institute of Occupational Health and Hygiene	6	300 to 30,000 MH_z	0.01 mW/cm^2 - For a working day 0.1 mW/cm^2 - For 2 hours daily 1.0 mW/cm^2 - For 15 minutes daily

Country	Organization	Reference Documents (See attached list)	Frequency Range	Exposure Limits in Power Density
Czechoslovakia		7	300 to 300,000 MH_z	Occupational Exposure For continuous generation $N(mW/cm^2) \times T(hours) < 0.2$ Where N is the Permissible exposure and T is the Time of exposure Eight hours working time, therefore, corresponds to an average power density of 0.025 mW/cm^2 For pulsed generation $N(mW/cm^2) \times T(hours) < 0.08$ Where N and T are the same as above, therefore, eight hours working time corresponds to an average pulse power density of 0.01 mW/cm^2 General Population Exposure For continuous generation $N(mW/cm^2) \times T(hours) < .060$ Where N and T are the same as above therefore, 24 hours exposure time corresponds to an average power density of 0.0025 mW/cm^2
		7	300 to 300,000 MH_z	For pulsed generation $N(mW/cm^2) \times T(hr) < .024$ Where N and T are the same as above Therefore, 24 hours exposure time corresponds to an average pulsed energy flow of 0.001 mW/cm^2
West Germany	German Assn. for Radar (Direction Finding) and Navigation	8		10 mW/cm^2
Canada	Canadian Standards Institute	9	10 to 100,000 MH_z	10 mW/cm^2 - Averaged over any possible 0.1 hr period
Netherlands	N.V. Phillips Company	10	30 to 300,000 MH_z	Radiation intensities higher than 10 mW/cm^2 should be considered dangerous. Safety precautions should, however, be based on a permissible level of 1 mW/cm^2

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TSB 4

BIOLOGICAL ASPECTS OF MICROWAVE RADIATION
A Review of Hazards

by

Wellington Moore, Jr., D. V. M., Ph. D.

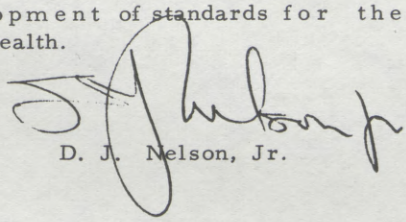
July 1968

U. S. Department of Health, Education, and Welfare
Public Health Service
National Center for Radiological Health

FOREWORD

In addition to the widespread use for military and communications purposes, microwaves are finding increasing applications in industry, commerce, and most recently, in the home. This report briefly describes the principal uses of microwaves and presents information from a literature review pertaining to the nature of biological effects.

The report is intended as a guide for those concerned with the potential hazards of microwaves. The conclusions of a relatively large number of experiments and observations concerning biological effects are discussed. We hope that the information presented will be helpful in the development of standards for the protection of the public health.



D. J. Nelson, Jr.

BIOLOGICAL ASPECTS OF MICROWAVE RADIATION

Introduction

The widespread use of microwave generators for military, radio-navigation, tracking, communications, food ovens, and other industrial purposes poses a potential hazard to the health of personnel concerned with their operation and to those who might be exposed in some manner to the energized beam. Microwave generators produce not only microwaves but also X-rays and small amounts of ultraviolet radiation which may constitute a local hazard. Modern high powered radars are capable of producing high power densities at appreciable distances from the sources. The potential hazards of these devices were recognized early in their development and concern for health hazards dates back to the early days of World War II, when Daily conducted his original studies on the U.S. Navy personnel engaged in the operation and testing of relatively low powered radar.[1] Although this study revealed no evidence of radar-induced pathology in human beings, somewhat later studies utilizing experimental animals revealed that cataracts, corneal opacities, testicular degeneration and hemorrhagic phenomena could be produced by exposure to microwaves.[2-4] During this period (1951), cataracts were first observed in a technician operating a microwave generator.[5] Several symposia have been held in recent years to discuss the various aspects of the potential hazards.[6-10] Evaluation of the experimental data led to the recommendation of

a maximum safe exposure limit for whole body microwave radiation. The limit of $10mW/cm^2$ for the average power density for continuous exposure was adopted generally, although it is not a universally accepted standard. Sufficient data were not available to determine the safe exposure level for each frequency throughout the microwave range; therefore, one level was set for all frequencies. The following remarks are concerned with the nature of the biological effects and the regulations established for the maximum safe levels of exposure.

Nature of Microwaves

Microwaves are electromagnetic radiations, intermediate in frequency and wave length between conventional radio waves and far infrared waves. The approximate physical characteristics of this type of radiation are: (1) frequency, 30-300,000 megahertz; (2) wavelength, 1000-0.06 centimeters; (3) energy content, 10^{-7}-10^{-3} electron volts per photon. The exact differentiation as to frequency and wavelength is a matter of definition and common usage. Existing radar systems utilize frequencies ranging from approximately 100 through 100,000 megahertz. Included also in the microwave range are frequencies used in television signal relay, long distance telephony, microwave ovens and electrotherapy. Frequenices of interest with respect to biological hazards are those lying between approximately 100 and 30,000 megahertz. Possible hazards at frequencies less than 100 MHZ have not been adequately investigated.

The energy value per quantum is characteristic for each type of electromagnetic radiation, and is inversely related to the wave length. Microwaves have comparatively low quantum energy; for example, one quantum of ultraviolet radiation of 2536A° wavelength has 400,000 times as much energy as one quantum of 10cm microwave radiation. The number of quanta for a given wavelength may be increased by increasing the flux density; however, the energy per quantum remains unchanged. Changes in molecular state depend upon the quantum energy of the radiation rather than on the number of those particular quanta. The energy values for microwaves are much too low to produce ionization as seen following X-ray and gamma radiation. The only transitions between energy levels in the molecular state that can be effected by microwaves are the extremely small transitions associated with heating and magnetic orientation.

Microwave radiation may be either the continuous wave type found in communication systems or the pulsed type utilized for radar installations, industrial and medical equipment. From a hazard standpoint, the pulsed energy may be considered of greater significance because of factors such as duty cycle, higher power density and energy distribution. On striking an object, microwaves may be transmitted, refracted, absorbed or any combination of these depending on the nature of the material interposed in

the path of the radiation. When the target is a human being, determination of the portion of the incident energy that is absorbed is complicated by the inhomogeneity of the target, differences in sensitivity of organs and tissues, body mass in relation to the exposed area, and frequency of the microwaves.

Mode of Action on Biological Tissues

Although the exact nature of the biologic effects of microwave radiation is not completely understood most of the experimental data support the concept that the effects are primarily due to local or general hyperthermia.[11-12] The heating effect of electromagentic radiation on humans was first demonstrated in 1890 by D'Arsonval. Since that time, microwaves have been used in diathermy for heating tissues for therapeutic purposes. Most of the biological effects are probably the result of the conversion of electromagnetic energy into heat energy within the tissue itself. Since temperature is related directly to the rate and extent of molecular vibrations, a large part of this increase in temperature is due to increased vibration of polar molecules.[13] Even though the overall electrical effect of a polar molecule is neutral, as in the case of water, the distribution of charge within the molecule is asymmetrical.[14] In an applied electrical field, the polar molecules tend to line up and vibrate. They oscillate (vibrate) with greater amplitude than normal thermal

vibrations only if the field oscillates such as is the case with microwave radiation. It has been pointed out that heat generation (and microwave absorption) is greatest in those tissues with a high content of water and is also enhanced locally in the areas adjacent to bone or tough fascial planes which act as reflecting surfaces.[16-17]

The separation of thermal and non-thermal effects of the absorption of microwaves in biological systems is very difficult. Several investigators have pointed out the possibility that microwaves may interact with biological material without the production of a significant amount of heat. According to Russian workers, exposure of animals to microwaves of low intensity, which do not produce any appreciable thermal effect, lead to functional changes mainly in the nervous and cardiovascular systems (changes in excitation and inhibition relationships in cerebral cortex, change in rhythm of cardiac activity, nature of electrocardiagram, etc.).[18] Other reported non-thermal interactions include pearl chain formations,[19] mutations in exposed garlic root tips,[20] changes in paper electrophoretic pattern of human gamma globulin,[21] sounds heard by several people which correspond to the frequency of modulation of an incident microwave beam[22] and occasionally epigastric distress in humans.[23] Thus, there is evidence of biological interaction with electromagnetic

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fields in the absence of appreciable tissue heating (although it is still questionable whether some of these are unrelated to heating effects), but their clinical significance to man, if any, is not known.

Physical Factors Influencing Tissue Damage

The type of body tissues and the degree of damage affected by microwaves depend in general on the frequency of the radiation, the intensity of the beam, length of exposures, the dielectric constant, and thermal conductivity of the tissues. The percentage of absorbed energy and distribution of energy in the skin, fat and deep tissues are determined by the tissue dielectric properties which vary with the frequency.[24] The depth of penetration decreases with an increase in frequency (or decrease in wavelength). It has been postulated that the depth of penetration of microwaves in human tissues is of the order of 1/10 of the wave length.[25] At frequencies less tha 150 MHZ, the body is transparent to the radiation with no appreciable absorption occurring. Between 150 and 1000 MHZ, the energy is absorbed by the deeper tissues due to the penetration. From theoretical considerations and experiments on phantoms, it has been shown that the proportion of energy absorbed is approximately 40% of the incident energy arriving at the body surface for frequencies in this range. This

energy range is potentially the most hazardous with respect to whole body heating because there is little or no heating of the skin where thermal receptors would be stimulated. Radiation at frequencies between 1000 and 3000 MHZ is subject to varying degrees of penetration and is absorbed in both superficial and deeper tissues depending upon tissue characteristics. The percentage of incident energy absorbed varies from approximately 20 to 100% because of tissue factors governing impedance values.[25] Absorption coefficients for body tissues depend on the water content. For example, skin, muscle and internal organs all have a high water content and high absorption coefficients; whereas, bone, fat, and yellow marrow have a low water content and low absorption coefficients. The eyes are most susceptible to frequencies around 3000 MHZ where production of cataracts is an important consideration. For higher frequencies only superficial penetration occurs with heating of the tissues in much the same manner as for infrared radiation or direct sunlight. Except for the eyes, the sensation of warmth provides a warning mechanism for the individual exposed. The percentage of energy absorbed may approach 40% with the remaining portion being largely reflected.

In addition to frequency, the hazards potential of microwave radiation is dependent upon the intensity of the radiation and the length of exposure. The thermal response to microwave radiation is a function of the energy input or flux density. The fact

that the amount of heating in tissues can be controlled by regulating the intensity and length of exposure forms the basis for the clinical use of microwave diathermy and the development of microwave ovens. The design of the antenna or reflector used in transmission affects the concentration of the energy and the potential hazard. The designs used in radar and diathermy concentrate the energy into a relatively small, narrow beam whereas those used in communications tend to disperse the beam so that the energy per unit of cross sectional area is exceedingly small. Also, in regard to radar exposure, the length of exposure is somewhat complicated because of the pulsed nature of the transmission. The importance of the length of time between exposures of pulsed microwaves has been demonstrated in animals. Deichmann[26] found that at 24,000 MHZ and a power density of 300 mW/cm^2, a rat could be killed by receiving 16 minutes of actual exposure on a schedule of one minute of exposure and one minute of nonexposure in alternation. However, if an animal was given one minute of exposure followed by five minutes of nonexposure in alternation, it would take approximately 34 minutes of actual exposure to produce a lethal effect. The longer interval of time between exposures allowed for some adjustment by the heat regulatory mechanisms in the animal body and some dissipation of heat.

Whole Body Exposure

When the whole body is subjected to microwave irradiation, the heat results from energy absorption must be dissipated by various

means at the disposal of the body including radiation, conduction and evaporation of perspiration. If the body cannot dissipate the heat energy as fast as it is produced, the temperature of the body will rise. The amount of heat the human body can transfer is, under normal circumstances, about 10 mW/cm^2.[11] This may be raised about ten fold under very favorable circumstances. From the standpoint of whole body heating, the frequencies between 150 and 1200 MHZ are most important since most of the energy received is absorbed by and heats the deeper tissues.[27]

The problem of heat dissipation is complicated by the fact that for each degree of temperature rise above normal the basal metabolic rate increases by as much as 14 percent. This increase in basal metabolic rate demands an increase in the blood circulation and respiration, as well as a 50 to 100 percent increase in the supply of oxygen to the tissues to maintain cellular activity. The condition is aggravated by the reduced capability of hemoglobin to combine with oxygen and by the increased blood circulation rate, which reduces the time available for oxygen transfer in the lungs. During the rise in temperature, reactions indicative of a non-specific pituitary-adrenal response to stress occur, including a sharp decrease in eosinophils and lymphocytes, and a rise in leukocytes.[28-30] Since the whole body will tolerate only a limited increase above normal temperature, an excessive rise in temperature

due to microwave irradiation will produce tissue damage indistinguishable from that due to fever of any origin.[4,17,31,32] Pathological changes found at autopsy following death due to severe hyperpyrexia include diffuse degenerative changes throughout the body, myocardial degeneration and necrosis, hemorrhagic lesions in the gut, respiratory tract, liver and brain. Fatally exposed animals develop acidosis, hyperpnea, tetany, and finally die of respiratory arrest.

It is difficult to define safe exposure limit with respect to the production of hyperthermia resulting from whole body microwave irradiation. From the accumulated experimental data it becomes clear that each species differs in terms of relative sensitivity to whole body radiation. Thus it would be inaccurate to extrapolate to man from data obtained from animals; however, this information does provide guidelines. The great variability is due to many factors such as thickness and texture of the animals' hair coat and skin, the ratio of surface area to body mass, body size in relation to wavelength employed, etc. Also the mechanisms of thermo-regulation and their efficiency vary in different species and in this respect man is perhaps the best protected of all animals. Human beings, for example, exposed to a flux of 0.22 W/cm^2 for 48 minutes showed a slight fall in rectal temperature due to the efficiencyof the sweating mechanism in the dissipation of heat.[33]

In contrast, rabbits can tolerate an indefinite exposure to a flux of 0.01 W/cm^2 with no rise in body temperature,[34] but show a $1^{\circ}C$ rise with a flux of only 0.02 W/cm^2 and some deaths from hyperthermia occur in two hours at a power density of 0.03 W/cm^2.[4,33,35] Ely and Goldman using 10-cm microwave radiation with a flux of 0.1 W/cm^2 produced lethal fevers in rats, rabbits, and dogs.[33] Ely and Goldman postulated that the human could tolerate a higher flux than fur-bearing animals. They estimated that 100 mW/cm^2 would be required to maintain a human body temperature rise of $2^{\circ}C$.[36]

Critical Organs

Experimental evidence has established that certain organs (eyes, testicles, gall bladder, urinary bladder, and portions of the gastrointestinal tract) of the body are more susceptible than others to microwave radiation. This increased susceptibility is due to difference in the magnitude of blood flow which effects the rate of heat removal from these tissues during exposure. Experimental evidence indicates that the eyes and testicles are the most vulnerable to microwave radiation. Similarly in the case of localized irradiation of a single organ or tissue, the dissipation of heat is dependent chiefly upon the magnitude of blood flow through the part. A temperature rise resulting from moderate irradation of the normal human arm or leg is self-limited. in that the temperature rise which reaches a maximum of 10 to 20

minutes is then reversed by a marked local increase in blood flow.[17] In relatively ischaemic tissues, such as the eye and testes, continued irradiation can result in local temperature rises of as much as 10 to 20°C for a longer duration.[33,37-38]

A. Eye

Within the critical wavelengths, the potential hazard to the eye is one of the most serious aspects of microwave exposure. In addition to the relatively poor blood supply, the cavities near the eye and high electrical conductivity of the intraocular fluids and the consequent short penetration of electromagnetic radiation in the eyeball (depth of penetration is approximately inversely proportional to the electrical conductivity within frequency and conductivity limitations) affect the eye's ability to conduct excessive heat to other parts of the body. The lens, being avascular and enclosed in a capsule, is at a disadvantage by not having a cooling system (vascular system) as other tissues. Not having available macrophages to remove dead cells or replacement cells, it cannot repair itself as occurs in reparative processes elsewhere in the body. Thus, damage to the lens is generally irreversible. Depending upon the dose, the damaged cells slowly lose their transparency and the opacity may not occur until sometime after exposure. Microwave irradiation may also produce damage to other ocular structures such as the conjunctiva, cornea, and iris.[39-40]

Microwaves have been shown to produce cataracts in a variety of experimental animals [2,3,37,38,39,41], and have also been implicated in the induction of cataracts in man following accidental exposure.[45-48] In 1952, Hersch [42] reported the first case of cataract formation in a technician operating a microwave generator in the 1500 to 3000 MHZ range, whose eyes were exposed in his daily work for approximately one year to a power density of 0.1 W/cm^2. The amounts of energy delivered to this man's eyes were in the order of hundreds of joules per square centimeter. Zaret[45] reported three cases of cataracts in individuals who had histories of repeated exposures to microwave radiation. All of the cases were discovered after a time lapse and the power densities were retrospectively estimated to have ranges from 350 mW/cm^2 to several $Watts/cm^2$. A crude relation between the power density of microwave radiation delivered to the eye and the time of occurrence of cataract formation was established. Where the lens was believed to be exposed repeatedly to 5 W/cm^2, the cataract was fully formed in two months. Where the lens was believed to be exposed repeatedly to 500 mW/cm^2, many months passed before early opacifications appeared and many years passed before the cataract was fully formed. In addition to these three cases, Zaret has reported several other cases which are discussed in another section of this paper.

There is some disagreement as to the lowest effective intensity required to produce cataracts in experimental animals. It

has been established that a power density of 0.1 W/cm^2 applied directly to the eye can be tolerated for hours at a time with no production of cataracts.[33,35,37,46] Carpenter[46-47] stated that a ten-minute exposure at 0.28 W/cm^2 will cause opacities while Ely et al. indicated that an indefinite exposure at a density of 0.2 W/cm^2 does not cause any damage. Williams et al.[37] demonstrated cataract formation with a single exposure of five minutes at 0.59 W/cm^2, 20 minutes at 0.40 W/cm^2, 40 minutes at 0.32 W/cm^2, and 90 minutes at 0.29 W/cm^2. Vitreous temperatures between 53° and 49°C, respectively, were characteristic of threshold exposures between 5 to 25 minutes duration. The level represents a 10° to 14°C eleviation of vitreous temperature above normal and agrees well with the range of 51° to 55°C which was found significant in opacity production by Richardson.[48] Damage to the eye is especially pronounced at wave lengths around 12 cm.[49] Temperature graphs give the location of the temperature maximum for this wavelength (12 cm) near the center of the eye.

Carpenter[46-47] has presented evidence that pulsed radar waves with a high peak power are more effective in producing cataracts in the rabbits' eye than continuous output of the same average power. A single 20 minute exposure to radar (frequency, 2500 MHZ) on a 50% duty cycle, with a peak power of 0.28 W/cm^2 (equivalent to continuous power of 0.14 W/cm^2) produces opacities in eight out of twelve rabbits, while a 20 minute exposure to continous power of 0.14 W/cm^2 did not produce opacities.

An important practical question, on which there are conflicting opinions, concerns the possibility of cumulative damage to the lens from repeated subthreshold irradiation. Most investigators agree that there is a critical intraocular temperature which must be reached before opacities develop. This temperature, as reported by various authors, ranges from 45 to 55°C. Obviously no cumulative rise in temperature can occur if the intervals between exposure exceed the time required for the tissue to return to normal temperature. The cumulative effect to be anticipated, therefore, is the accumulation of damage resulting from repeated exposures each of which is individually capable of producing some degree of damage. However, Carpenter[47] states that if the eye is subjected to repeated subthreshold exposures cataracts may develop with the time interval between successive exposures being the most important factor in the production of a cumulative effect. Cleary et al.[50-51] found that although repeated subthreshold exposures may produce minimal types of lens changes it did not appear to increase the incidence of cataracts in Army and Air Force personnel following occupational exposure.

B. Testicles

The testicles are extremely sensitive to elevations in temperature. It has been found, as in cases of undescended testes, that spermatogenesis can take place only at temperatures below

that of the body core. Normal human testicular temperatures below that of the body core. Normal human testicular temperatures average 2°C (3.6°F) below body temperature although this varies from individual to individual and varies in the same individual from time to time depending upon age and environment.[12] Of the various organs studied, the testes appear to be the most sensitive in terms of the minimum exposure required to produce a minimal change (reduction in spermatocytes and damage to cells lining the seminiferous tubules). In a study utilizing dogs, rabbits, and rats, Ely et. al.[33,36] tried to determine the threshold value in terms of the lowest power density required to produce a minimal change in the most sensitive animal in the group. For this criteria, an exposure rate of 0.01 W/cm^2 was considered the threshold for testicular damage, on an indefinite exposure. It should be noted that the threshold for testicular damage in this study, 0.01 W/cm^2, in the same power density as the generally accepted exposure guideline. However, the authors stressed that the damage observed at such low levels of power is slight, almost certainly fully recoverable, and in no way different from that due to other common forms of heat that might be applied to the testes. Others have found evidence of testicular damage in rabbits when the testicular temperature was raised to 35°C.[52]

The pathological changes found in the testes include a degeneration of the epithelium lining the seminiferous tubules, and a sharp reduction in the numbers of maturing spermatocytes in the lumen.[33,36,52,53] The distribution of damage is irregular with adjacent tubules often showing markedly different degrees of degeneration. The reduction in testicular function due to heating appears to be temporary and probably reversible except in severe cases. Because of the paucity of information, any statement concerning the genetic implications of microwave radiation would be premature.

A general resume of the biological effects of microwaves is given in Table 1.

Cumulative Effects

An important consideration in the control of microwave hazards is the possibility of cumulative damage resulting from repeated exposure. Experimental data in this area of whole body radiation is limited and the observations are influenced by the exposure characteristics and by species differences. Prausnitz and Susskind[54] studied the pathological and longevity effects of chronic whole body exposure on two hundred male mice. These animals were exposed daily for 59 weeks to 0.10 W/cm^2 (9270 MHZ) for 4.5 minutes. The treatment produced an average body temperature rise of 3.3°C. No significant differences were found in body

Table 1

Resume' of Biological Effects of Microwaves

Frequency MHz	Wavelength (cm)	Site of Major Tissue Effects	Major Biological Effects
Less than 150	Above 200		Body is transparent to waves above 200 cm.
150 - 1,200	200 - 25	Internal body organs	Damage to internal organs from overheating
1,000 - 3,300	30 - 10	Lens of the eye	Lens of the eye particularly susceptible and tissue heating
3,300 - 10,000	10 - 3	Top layers of the skin, lens of the eye	Skin heating with the sensation of warmth
Above 10,000	Less than 3	Skin	Skin surface acts as reflector or absorber with heating effects

weight, hemogram or longevity. Increased incidence of testicular degeneration and neoplasms of the white blood cells were observed. In another study two femal beagle dogs were exposed to microwave radiation of 24,000 megahertz at a power density of 20 mW/cm^2.[55] Over a period of 20 months, one dog was exposed for a total of 2631 hours (6.7 hours per day on five days of the week) and the other dog was exposed for a total of 3970 hours (16.5 hours per day on four days of the week). No significant changes were found in the parameters (hemogram, blood chemistry, eyes) studies with the exception of subnormal body wieght. Both animals reproduced normally although there was one or more "still borns" in each litter. The data obtained on man is based on microwave exposure situations where the amount of the body exposed, field intensities, and duration of exposure cannot be accurately determined. Daily[1] conducted the first studies on United State Navy personnel who were exposed over a period of time in the operation and testing of relatively low powered radar. No evidence of radar-induced pathology was found. Lidman and Cohn[56] examined the blood of 124 men who had been exposed to microwaves for periods from two to 36 months. They concluded there was no evidence of stimulation or depression of the erythropoietic or leucocytic systems of these men. In another study of a large group of radar exposed employees along with a control group were put under a four-year surveillance program.[57] During this period they underwent repeated physical, eye, hematological and other laboratory examinations. These

examinations failed to detect any significant changes. Fertility studies revealed essentially the same findings for both groups. Zaret[46,48] conducted an extensive study of the frequency of occurrence of lenticular imperfections in the eyes of a sample of 736 microwave workers and a control sample of 559 individuals engaged in installation, operation and development of microwave equipment. The exposure ranged from a few days to almost 18 years with a wide range of frequenices and power outputs varying from less than a watt to several kilowatts. No late lens defects were found to be peculiar to microwaves. Significant increases in the occurrence of lens defects were found in the exposed groups as compared to the control group. This study further concluded that the extent of minor lenticular imperfections does not serve as a clinically useful indicator of cumulative exposure to microwave radiation. As of May 1967, Zaret has reported 26 new cases of lenticular damage from microwaves.[59] In contrast to the experimental data available in the United States, the Russians[60] have reported a large number of general effects in humans due to chronic exposure to microwaves. The general effects of chronic exposure include bradycardia, hypotension, hyperthyroidism, central nervous system exhaustion decrease in the sense of smell, increase histamine level in the blood, lenticular changes and changes in intraocular pressure. The effects tended to vary with the intensity of the radiation. The significance of this discrepancy between experimental results remains to be determined. Also a major drawback

of the human studies which especially illustrates the need for further research is the limited sample size on which the findings are based. The numbers of people observed are miniscule so far as epidemiologic surveys go. The only human epidemiologic evidence to date, for possible genetic damage as a result of microwave exposure is in the study of Sigler et al.[61] There was an increased incidence of Mongolism in children of fathers having prior exposure to radar.

Maximum Permissible Exposure Levels

In the development and use of microwave equipment a major concern of both military and civilian authorities was the establishment of safe limits of exposure for personnel engaged in their operation. In 1953, Schwan recommended that microwave radiation of 10 mW/cm^2 be accepted as a tolerance dose. Subsequently after a review of all the experimental data on animal exposures available at that time, it became apparent that an exposure to a power density of approximately 0.1 W/cm^2 was necessary in order to produce any effect of biological significance. Whole body or localized exposure at this power density had been shown to produce either hyperthemia or damage to organs such as the eye or testes. Because of the uncertainties concerning the possible effects of certain variables, it was decided to include a safety factor of ten in the proposed safe level. On this basis a maximum safe exposure level of 10 W/cm^2 was promulgated. This level was to be interpreted in terms of

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TABLE 2

Maximum Permissible Intensities

Institution or Country	Frequency MHz	Maximum Permissible Intensity in mW/cm^2	Remarks
U.S.S.R. (1958)[60]	300 - 30,000	0.01 0.1 1	Whole working day 2 - 3 hours daily 15 - 20 minutes daily
Poland (1961)[61]	Over 300	0.01 0.1 1	Whole working day 2 - 3 hours daily 15 - 20 minutes daily
Post Office of Great Britian (1960)[62]	30 - 30,000	10	Continuous daily exposure in case of pulsed waves, an average over the complete train of pulses
U.S. Army and Air Force (1965)[24]	-	10	Maximum permissible level for continuous exposure
	-	10 - 100	limited occupancy exposure time (minutes = $\frac{6000}{(XmW/cm^2)^2}$
	-	Over 100	Denied occupancy
U.S. Standards Institute[63] C95.1 - 1966	-	10 $1mW\ hr/cm^2$	For periods of 0.1 hours or more during any 0.1 hour period

the ambient energy level without reference to frequency or duration of exposure. The value was accepted generally and formed the basis for working levels in industry and the armed services. Table 2 presents the maximum permissible intensities reported for several countries. Attention is called to the very stringent exposure levels for certain countries. These values range from 100 to 1000 fold less than those used in the United States.

Recently the United States Army and Air Force and the C-95 Committee of the United States of America Standards Institute have adopted new standards which equates the power density to the length of exposure. This new standard permits exposure to levels greater than 10 mW/cm^2 for a given interval of time. This revision of the standard to allow exposure to higher power density levels became necessary because of the increased power output of newer microwave systems. The Standards Institute regulations allows exposures up to 1 mW hr/cm^2 for any 0.1 hour period. For example, if a worker is exposed for 0.1 hour (six minutes) during a one hour period, he may receive 10 mW/cm^2; if he is exposed to 0.01 hour (36 seconds) during a one hour period, he may receive 100 mW/cm^2. For periods of 0.1 hour or more the level is 10 mW/cm^2. The Army-Air Force regulations permit exposures exceeding 10 mW/cm^2 based on the following equation:

$$T_P = \frac{6000}{W^2}$$

Where:

T_P = permissible exposure time in minutes during any one-hour period.

W = power density in the area to be occupied (mW/cm^2)

The Standards Institute specified no upper limit for the power density whereas the military standards prohibit any exposure over 100 mW/cm^2. Figure 1 shows exposure in minutes versus power density for the standard of 10 mW/cm^2, the Standards Institute 1 mW hr/cm^2 and the military $\frac{6000}{W^2}$. For a single discrete exposure, the Standards Institute would be more conservative for levels below 100 mW/cm^2 and less conservative for levels above 100 mW/cm^2 where the military permit no exposure. The two are in agreement at 100 mW/cm^2 and have their greatest divergence at six minutes where the exposure the Standards Institute would allow 10 mW/cm^2 and the military, 32 mW/cm^2.

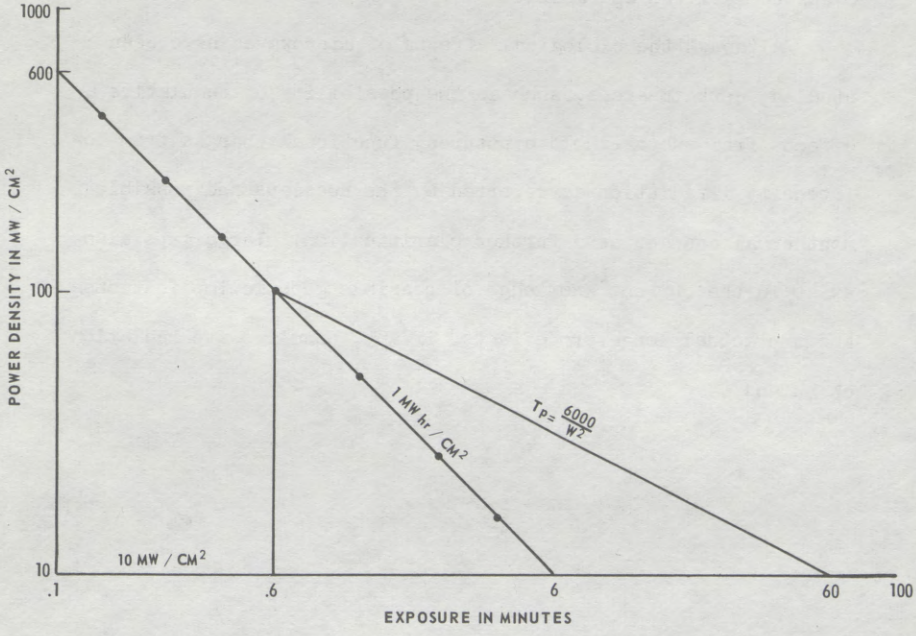
Discussion and Conclusion

Microwave systems have become a part of our way of life and exposure is not limited to military personnel, nor persons engaged in the fabrication of this equipment. Besides communications and navigational uses, microwaves have been utilized in a variety of commercial processes that require heating and drying, such as drying of photograhic film, potato chips, and glue binders in plywood. Probably the greatest area of advancement is in the use of microwave heating in food preparation. Microwave ovens are popular in

commercial restaurants, self-service, food vending establishments, and now are available for home use. Some estimates put the microwave oven purchases as 25% of all ovens bought in the United States by 1976, or approximately 1.8 million ovens.[64] Although the magnitude of the potential hazard of microwave ovens is less, many operators of these units are not aware of the potential health hazards and precautionary labels are not displayed on the ovens to warn the operators.[65]

Although the biological effects of microwaves have been studied, certain areas, such as the possibility of cumulative effects from subthreshold exposures, functional changes from low intensity irradiation as reported by the Russians and possible nonthermal changes need further clarification. Large gaps also exist in the current knowledge of possible genetic implications and the actual long-term effects, if any, of microwave radiation on humans.

EXPOSURE vs POWER DENSITY[12]



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Dr. ELDER. Thank you, sir.

Mr. ROGERS. Thank you.

Mr. Kyros, do you have additional questions?

Mr. KYROS. Thank you, Mr. Chairman.

Mr. Hansen, in this testimony you gave this morning, this statement, I notice you paralleled the sections of the act all the way through section 360E. But one section, 360D, you didn't tell us anything about. That section states that the Secretary shall prepare for the President an annual report by April 1 of the year that he will submit to the Congress detailing the list of electronic products where standards have been made up, and giving us an evaluation of the act, and naming some of the problems, and the extent of cooperation between the Government and industry. I wonder, has that report been filed?

Mr. HANSEN. Dr. Elder.

Dr. ELDER. Yes, sir. The report for the year October 18 through December 31 was prepared. It is going through the proper channels. And we had hoped it might be here today. But it is on its way to Congress.

Mr. KYROS. You mean you didn't prepare it and file it before April 1 of this year.

Dr. ELDER. Sir, I believe that we have until April 1—excuse me, I would have to check the law.

Mr. KYROS. It is May now.

Dr. ELDER. We prepared it and sent it through the proper channels for transmittal, it must go through the Secretary to the President for transmittal.

Mr. KYROS. You prepared it but it hasn't been transmitted to Congress. It is supposed to be transmitted to Congress on or before April 1. And you say it hasn't been. I don't remember it coming out.

Dr. ELDER. We sent it through channels. If you haven't received it we would be most pleased to check and find out where it is.

Mr. KYROS. Has the President transmitted it to the Congress by April 1, do you know, yes or no?

Dr. ELDER. He couldn't have, sir.

Mr. KYROS. What?

Dr. ELDER. As a bureau we were unable to get it out ourselves, due to a very heavy workload, until the latter part of March. So we were remiss in this, due to the amount of time and workload. So we are to blame as much as anyone else in not getting this through channels in time.

Mr. KYROS. Well, it is a lesson to me, really. I remember how quickly we put this thing together and got the money together. I thought there was enormous emphasis on this whole program. But from the testimony today it seems to me either you are lax or there is not this kind of emphasis needed on this consumer protection that we thought was so vital last year.

Mr. HANSEN. Mr. Kyros, we agree with you. It is important, it is vital. We are pushing the program as effectively and as rapidly as we can with our scientists and engineers working very long hours. The process of implementing the law is one that takes a lot of time. And I think that the output that we have been able to accomplish is a result of real dedication on the part of our whole staff. I hope that as the year proceeds that we can be even more productive. But we are

certainly making maximum effort. And we are deeply interested and concerned. We consider this one of our most vital programs.

Mr. KYROS. No one is questioning you and your staff about your abilities and dedication. There is no question about that in my mind. But the real question is that last year, in formulating the kind of legislation that the Congress wanted, in making sure that we didn't go too far in terms of giving you too little power, or too much power, one of the things was that you would report to the Congress, so we would know what is going on. There are a lot of us on this committee that feel that in an area that is brandnew, like this, the Government shouldn't be in a position where it can be destructive of the American electronics industry.

One of the reasons for the requirement for the report which was finally put in, if you follow the course of the legislation chronologically, was so that the Congress could then know what your problems were. And all I am saying is that despite your dedication and everything you have just failed to report to the Congress.

Mr. HANSEN. We were a little late, yes, sir.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. Personally I regret that you were not able to report.

There are many things, though, that are difficult to find answers to in the short period of time in which you have been at work. For instance, biological results would be very difficult, because even with rats, which multiply rapidly, it takes time.

I believe you said Mr. Johnson was the head of your group.

Mr. HANSEN. That is correct.

Mr. CARTER. How long has he been the head of it.

Mr. HANSEN. Since July 1.

Mr. CARTER. Certainly this is a subject that could very well be vital, because it could affect so many millions of people in our country adversely. I am interested that some of our microwave ovens leak as much as a hundred milliwatts per hour, it that correct?

Dr. ELDER. That would happen if the door interlock failed. I don't believe that there has been leakage around a closed door that high. But if that interlock failed this is a concern.

Mr. CARTER. Of course, you have been checking on color television, have you not, and also on our microwave ovens? What other appliances have you checked.

Dr. ELDER. We have checked dental X-ray timers, we have a review on this particular product.

We mentioned the X-ray diffraction equipment.

We are working very seriously and very hard on this automatic collimator. As we have testified before, we believe that this is one of the major accomplishments that we can make in reducing exposure.

So on the equipment side, sir; one is a development and research type and the other one is an enforcement type.

Mr. CARTER. Of course, dental X-rays are quite a problem. But are you checking anything else that is commonly used as the microwave over or as a color TV, other appliances?

Dr. ELDER. Within our resources we have said that the color TV and the microwave oven would be the No. 1 and No. 2 priorities for us. I believe this in in line with what the Surgeon General testified.

Mr. CARTER. You are checking no other appliances at the present time?

Dr. ELDER. No, sir; not to my specific knowledge.

There are members in the audience who might be able to better respond if you would like a response on this.

Mr. CARTER. That is quite all right.

Thank you, Mr. Chairman.

Mr. HANSEN. Mr. Chairman, I would like to come back for a moment to Mr. Johnson's presence or absence here.

Mr. ROGERS. Yes.

Mr. HANSEN. Mr. Wilson, our legislative officer, I believe, is in the audience here—or Dr. Meyer—and could comment on that.

STATEMENT OF DR. ALVIN MEYER

Mr. MEYER. Mr. Chairman, I am Dr. Alvin Meyer, the special assistant to Mr. Johnson, and also the director of his office of legislative affairs. And for the record, I will qualify myself professionally.

I am board certified in health physics by the American Board of Health Physics, and industrial hygiene by the American Academy of Industrial Hygiene and the American Board of Environmental Engineers. I am a fellow of the American Public Health Association. And I have been in public health work for 27 years.

I recently was assigned to the Department of Defense Environmental Pollution Central Committee, and as such was responsible for management of the Department of Defense pollution control activities, including those relating to the subjects at hand.

I have recently taken on the job of being Mr. Johnson's special assistant, and the manager of his legislative affairs program.

I would not like for the record to indicate that the Department of Health, Education, and Welfare is not putting proper emphasis on this subject. It is faced with a lot of problems resulting from a reorganization of the entire Department, which as you know occurred before the first of the year. It also is faced with a number of problems associated with the accomplishment of many varied and diverse tasks.

The selection of witnesses to appear before a congressional committee is a very important element of the Department's interest. We are determined to provide to you the most responsive situation that we possibly can. And when the invitation from your committee arrived last week for this hearing, we recognized your deep personal interest in this matter and we thought that it was best to provide the people in the organization who were the most knowledgeable.

Mr. Johnson, of course, is responsible for supervision of the Food and Drug Administration, and this Administration, and the National Air Pollution Control Administration. If there is anybody responsible for Mr. Hansen being here, it is me.

I discussed this with Mr. Johnson, and it was on my recommendation that Mr. Hansen be here. It was not an affront to the committee, or a lack of emphasis.

Mr. ROGERS. I think it is well to put this on the record because I am concerned that the man who really is in charge of the program, the overall responsibility to the Secretary, I presume, is not present. Of

course, we would have wanted Mr. Hansen and Dr. Elder too, because they have greater knowledge.

But I would hope that we can have Mr. Johnson come before the committee and let him know and get from the committee perhaps directly the importance which we attach to this part of his responsibility. And this what I want to get across. And I am sure you will discuss this with Mr. Johnson. I would hope so.

And we are glad to have you here with us.

Mr. KYROS. Mr. Chairman, may I make a comment?

Mr. ROGERS. Yes.

Mr. KYROS. You just said you were responsible for the Defense Department's environmental and pollution activity. Is that what you just said?

Mr. MEYER. Prior to my retiring to the first of May, sir, and coming with the Department of Health, Education, and Welfare.

Mr. KYROS. I hope you do a better job here for our consumers than you have done in the past in releasing nerve gas and killing hundreds of sheep. I hope you do a lot better job here. My feeling is that we are not so confident in the branch you have just set up. Again, I say, it is not due to the lack of dedication of any of you. I hope you won't take this in an inquisatorial spirit. I just remember the press that was on to set up this legislation and to get this bill passed. In fact, there was sharp criticism of some members of this committee in not going much further in the legislation. Yet it seems to me in the execution of the legislation you haven't even half caught up to what we already gave you.

The reason I bring this out is, well, last year was my first term. I listened to a lot of members on the committee. I think for the first time I learned that you can only do so much. Yet I remember the sharp criticism and the sharp importance that we felt at the time for giving you all the power that you needed.

So I hope that this coming year we will be able to do something where the Congress will just give you sufficient power to do only what you can do.

Mr. ROGERS. Thank you, Mr. Congressman.

I think in conclusion you have gotten the feeling of the committee.

Dr. Carter, do you have a question?

Mr. CARTER. I want to say, Mr. Chairman, that I am sure the distinguished gentleman didn't intend that the sheep be killed at all, and perhaps he had no knowledge of it whatever.

Mr. MEYER. Thank you, Mr. Carter.

Mr. ROGERS. What I want to say in summary here is that we are very much concerned about the color TV program. From that I understand you feel you are ready as soon as the committee is appointed to move. Let's get the advisory committee appointed.

Do you consider the microwave oven problem a serious one.

Dr. ELDER. Yes, sir.

Mr. ROGERS. Then let's see what we can do on that.

I think these are the two immediate ones. The X-ray problem you are studying, X-ray equipment. The laser beams I presume you are studying too. And if you will keep this committee advised we will try to cooperate with you and try to be helpful.

Mr. HANSEN. We appreciate that very much.

Mr. ROGERS. Thank you, and we appreciate your presence here today.

The next witness we are pleased to have is Mr. Hanson Blatz, who has done a great deal of work in this field. He is director of the New York City Office of Radiation Control.

Mr. Blatz, if you will present your testimony the committee will be pleased to receive it.

We appreciate your being here today.

STATEMENT OF HANSON BLATZ, DIRECTOR, NEW YORK CITY OFFICE OF RADIATION CONTROL AND ASSOCIATE PROFESSOR OF ENVIRONMENTAL MEDICINE AT NEW YORK UNIVERSITY

Mr. BLATZ. Thank you, Mr. Chairman, and members of the committee.

I was asked only a day or so ago to testify today, so I haven't been able to prepare a statement.

Mr. ROGERS. I understand that. And you may just give us your thoughts.

Mr. BLATZ. Since some of my remarks are in the nature of personal opinions, I should like to state my qualifications to give a personal opinion on radiation.

For over 35 years I have been spending my full working time in the field of radiation, including its medical use for diagnosis and therapy, its industrial use and in atomic energy.

For the past 14 years I have been teaching a graduate course at New York University on "Radiological Health" for which I have written a textbook that is used in several colleges.

I have served as editor-in-chief of McGraw-Hill's "Radiation Hygiene Handbook" for 11 years.

For over 10 years I was Chief of the Radiation Branch of the Atomic Energy Commission Health and Safety Laboratory.

Mr. ROGERS. I think that qualifies you.

Mr. BLATZ. My present position as director of the Office of Radiation Control in New York City has been held for over 10 years.

I consider that the most important problem in human radiation exposure is in the medical and dental use of x-ray equipment. We have about 17,000 x-ray sources in New York City, for which I am responsible as far as their safety, and we have learned a great deal about the problem. One of my concerns is that the provisions of Public Law 90–602 seem to be directed only at new equipment manufactured after a certain date.

I did a quick survey in New York City and estimate that less than 5 percent of the x-ray equipment in use is replaced each year. That would mean that most equipment not meeting established safety standards would require a generation or more to be eliminated.

Mr. ROGERS. What would be the average lifetime span, would you say, of an X-ray machine? Do you have any idea?

Mr. BLATZ. I would say 15 or 20 years.

Mr. ROGERS. About 15 or 20 years?

Mr. BLATZ. Yes. There are many machines 30 and 40 years old in use in New York City, and I think some effort should be made to

update the old equipment. Certainly at the local level we have been attempting it.

Mr. ROGERS. Is this possible to do.

Mr. BLATZ. Yes, in many respects it is possible. I think the most important faults can be corrected.

Mr. ROGERS. Do you have the authority under your local ordinances or statutes to require corrective action on equipment that was in being at the time this statue was passed?

Mr. BLATZ. Yes, we have done his, but in many cases we do not have enough power. I am asking for more next year to cover other items. So far, we have been limiting our updating to those recommendations that have been made by the National Council on Radiation Protection and Measurements, but there are many other respects in which I think equipment should be updated.

Mr. ROGERS. We would appreciate it if you would furnish for the committee the ordinances that apply in this regard that give you such authority so that the committee may consider them.

Mr. BLATZ. I would be glad to. It is very simple. One of the provisions of our Health Code says that we shall follow the recommendations of the National Comimttee on Radiation Protection and Measurements that are written with the word "shall". There are two types of recommendations, "shall" recommendations which are considered mandatory and "should" recommendations which are considered advisory. We are required to enforce the "shall" recommendations of the NCRP.

(See sec. 175.11(j) of the New York City Health Code, as follows:)

175.11(j) Except as otherwise specified by the Department, the pertinent "shall" recommendations of the National Committee on Radiation Protections and Measurements contained in the National Bureau of Standards Handbook 73, published on July 27, 1960, or equivalent safeguards, shall be followed by a person in charge of a sealed source in carrying out the requirements of this Article; and the pertinent "shall" recommendations set forth in Handbook 76, published on February 9, 1961 by said Bureau or equivalent safeguards, shall be followed by a person in charge of X-ray equipment. The Commissioner may, by publishing notice thereof in the City Record, require that such persons follow the recommendations contained in any publication of said Committee supplementing or superseding the above mentioned Handbooks.

Mr. ROGERS. What is the extent of used equipment? Have you gone into that at all, or made a study?

Mr. BLATZ. You mean the resale of used equipment?

Mr. ROGERS. The resale of used equipment.

Mr. BLATZ. Yes, there is considerable sale of used equipment in New York City. I would expect that about 50 percent of the equipment sold in New York City is used equipment. The reason is that when a hospital uses equipment for several years and a new model becomes available, the old equipment will be turned in. Dealers acquire it and resell it, generally to a physician.

Mr. ROGERS. I see. Are these sold by the regular dealers?

Mr. BLATZ. A few of the large X-ray manufacturers do sell used equipment. But there are many dealers who deal only in secondhand equipment. They are generally secondhand medical equipment dealers that include X-ray equipment sales.

Mr. ROGERS. Does your office check these before they are resold?

Mr. BLATZ. Yes, we check them but only after they have been sold.

A very effective part of our code requires each dealer to report every sale to us. We visit the dealers regularly to make sure that they are reporting to us.

Mr. ROGERS. Thank you.

Mr. BLATZ. I would like to say a few words about microwave ovens. We have just completed a small survey. Our Department of Hospitals placed an order for microwave ovens to be used in special diet kitchens, snack bars and for uses like that. In 11 tests of microwave ovens, only four met the usually accepted standard limit of 10 milliwatts per square centimeter of leakage.

Mr. ROGERS. How many?

Mr. BLATZ. Four out of 11. Seven did not meet this standard. Some of them had interlock switches that just didn't operate, but the most common fault was leakage around the door. In some cases just by resting a hand on the handle of the door there was enough movement of the door to result in considerably increased leakage. Many of them had interlock switches that didn't operate until the door was opened an inch or so, so that anyone standing there opening the door would get quite a bit of microwave exposure.

Mr. ROGERS. Would this be indicated by a burn on the hand if you had exposure from a microwave, or not.

Mr. BLATZ. I really don't know, but I don't think so.

Mr. ROGERS. All right.

Mr. BLATZ. We also had some experience with laser beam devices. We have had about seven art exhibits in New York City employing laser beams.

Mr. ROGERS. Art exhibits?

Mr. BLATZ. Yes. There is an effort to interrelate, science technology, and art. There is an organization in New York City called Experiments in Art and Technology, Inc., that sponsors and supports this effort. As a result of its efforts several exhibits were arranged. One was brought from Tokyo in which an artistic effect was derived from having a laser beam rotating in the center of an area where people walked and their bodies intercepted the laser beam. Of course, when this was put in New York we stopped it immediately until we had an opportunity to investigate. The health commissioner under his broad powers issued an order to discontinue operating the laser source. They modified it and put up screens, and eventually it was doctored up so that it could be exhibited safely.

Mr. ROGERS. Do I understand that in an art exhibit they had a laser beam?

Mr. BLATZ. Yes.

Mr. ROGERS. Just going around the room to make spots of light, is that it?

Mr. BLATZ. That is right. As a matter of fact, this was reported in, I believe, Newsweek magazine where a photograph showed the artist standing with the laser beam passing across his face. We had his eyes examined by an ophthalmologist, who found no evidence of damage, but the beam may not have hit the eyes. This exhibit was open to the public, who could walk in.

Mr. ROGERS. Where was this in New York City did you say?

Mr. BLATZ. There were seven such exhibits of different types.

Mr. ROGERS. Seven art exhibits?

Mr. BLATZ. Yes, at several galleries, the Pace Gallery, the Brooklyn Museum, the Jewish Museum, and the Museum of Contemporary Crafts. There were one or two others.

Mr. ROGERS. Now, do we know yet what exposure to a laser beam would affect the eyes?

Mr. BLATZ. No, I believe there is less known about acute laser beams effects than anything else. I haven't been able to find out a good way of measuring laser beam exposure in the field. We secured the services of a person whom I think is probably an expert in the health aspects of laser beams as any one. He had also worked with the Atomic Energy Commission for many years. His method was merely to determine the energy involved and the divergence of the beam and then estimate what the exposure would be. We weren't able to measure it.

Mr. ROGERS. Have you talked to the radiological health people here about this problem yet?

Mr. BLATZ. I have talked to them informally about it. Our practice is to report all of these experiences to the local Bureau of Radiological Health representative in New York, Mr. Saul Harris.

To go back to the microwave oven business, you expressed interest in the number being sold. We are doing a survey now. They are being offered for sale for home use by five large stores in New York City to my knowledge. It is often difficult to obtain sales figures. One organization said it had sold 400 in the last year, and this is one out of five, but probably the one with the greatest sales.

Mr. ROGERS. Is this for home use?

Mr. BLATZ. For home use. The Wall Street Journal just about a year ago carried a statement from the Amana organization that they had reached a production rate of 2,000 per month for domestic use, and it was going up. I was greatly surprised at the figure of 50,000 that Mr. Hansen gave. I would have guessed that there were more in use, just from this sort of evidence.

Mr. ROGERS. If they are selling 2,000 a month now, you say.

Mr. BLATZ. Amana, one manufacturer, said that it was making 2,000 a month about a year ago, and their production was increasing. The New York City Department of Hospitals has ordered about 20 for its hospitals. We know that there are cafeteria-type food establishments in the city that offer microwave facilities so that the patrons can warm up certain food products.

Mr. ROGERS. We will check into this. And I think the facts that you have brought out would indicate that many more than 50,000 would be in existence. I would agree.

Mr. BLATZ. I think that about finishes all the data that I could assemble quickly. If you have any questions I would be glad to try to answer them.

Mr. ROGERS. Thank you.

Mr. Kyros.

Mr. KYROS. Mr. Blatz, are you looking forward to the establishment of performance standards by the Environmental Control Administration?

Mr. BLATZ. Yes, I certainly am. And I should mention, I am president-elect of the Conference of Radiation Control Program Directors. We are having a meeting next week in Atlanta, Ga., with ECA representatives and with the X-ray manufacturers in an attempt to recom-

mend certain performance standards for new medical X-ray equipment. I am looking forward to this very much.

Mr. KYROS. Do you think that performance standards are necessary and absolute to any kind of program, beginning with consumer protection for electronic radiation hazards?

Mr. BLATZ. Yes, the need is imperative. As I said, I am not too optimistic about their effects on medical X-ray equipment, because I think there is much old equipment in use, which must be updated. I believe that we have been effective in updating many old fluoroscopes.

That is one area in which we had some pretty firm standards, and we estimate that about a thousand old fluoroscopes in New York City have been dismantled and taken out of use because they couldn't be updated. I think this is a very good thing.

Mr. KYROS. We certainly appreciate your coming to this committee. Thank you, Mr. Chairman.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. I am sorry that I had to be out when you first testified. Will you identify yourself, please, sir.

Mr. BLATZ. I am Hanson Blatz. I am director of the New York City Office of Radiation Control. And I am also Associate Professor of Environmental Medicine at New York University.

Mr. CARTER. On the microwave equipment, I believe you said that more than 50,000 ovens are in existence at the present time.

Mr. BLATZ. I would estimate that that figure is low.

Mr. CARTER. It is such a popular item that I thought about getting one for my wife. I think many people think of these things. And it could present a great hazard to thousands of people throughout the country.

Of course, standards, we want to develop them as quickly as possible. But it does take time, doesn't it, to develop the standards for these different items?

Mr. BLATZ. Yes; I believe it does if they are to be good standards.

Mr. CARTER. To know the biological effects—which we don't know at the present time. And we don't know the amounts which cause them, they may even be more minute than what we think of at the present time.

Certainly I want to agree with your statement concerning fluoroscopes. This is a great hazard in many cases, in the hands of inexperienced people they can cause serious damage?

Having had X-ray equipment in my office years ago I know the hazard is great. And exposure can be much longer at times than one thinks, even though you have it at 3 or 4 milliamperes as usual.

I hope that all companies which make microwave ovens and color television apparatus will be examined, and not just one. That mistake was made, I believe, by HEW a few years ago, in which they stated that one major manufacturer had all the television equipment which was causing trouble. And we just simply didn't do that company right. I believe that was General Electric. And I certainly have no reason for stating this, other than that it is true. I have no stock in General Electric.

Mr. BLATZ. May I comment on that. That was quite a different problem. Those General Electric sets were emitting thousands of milliroent gens per hour.

Mr. CARTER. As much as 40,000?

Mr. BLATZ. Yes; where as the present problem I think is much less important.

Mr. CARTER. We found that all of the television equipment emitted X-rays, not just that company, but others.

Mr. BLATZ. But in the Washington study, which the National Center of Radiological Health conducted, they found that though radiation was coming from the fronts of many of the 1,100 sets that they surveyed, only about 1 percent exceeded the manufacturing standard of a half milliroentgen per hour. Even the highest one of that group was only a matter of 10 or 15 milliroentgens per hour.

Mr. CARTER. That may well be true. But at the same time, the first was stated that only one company had these defective television sets, and then lo and behold, in 1 year's time they came up and all of them were emitting X-rays. And I think this is a bad policy, to use one company as a whipping boy.

Mr. BLATZ. That is one reason I avoided giving the names of the microwave ovens that we have surveyed, because we don't have any real sample yet.

Mr. CARTER. Thank you very much, Doctor.

Mr. ROGERS. Mr. Preyer.

Mr. PREYER. Doctor, you mentioned that you thought the most important problem was in the medical and dental use of X-ray equipment. Could you tell us just a little bit about the nature of the problem and the extent or the degree of it? For example, if I go to a dentist and an X-ray is made, what sort of risk do I run?

Mr. BLATZ. This can rarely be expressed in terms of a risk to the individual. I think the primary concern today is for the genetic effects of radiation. That is why our levels are set so low for the populaton. So, in terms of the risk to the population rather than to you, I would like to give a few examples.

We did a survey last year and found that by far most dentists—and when I say "by far," it is because I don't remember the exact figures, perhaps 60 or 70 percent—but most dentists in New York City were still using slow X-ray films. The American Dental Association and health authorities have been recommending for many years that dentists use fast films, except in certain special cases where they have to examine the films with a magnifying glass. Use of a fast film results in a reduced exposure to the patient by a factor of 4. A patient exposed when using a fast film receives 75 percent less radiation as a patient exposed with a slow film.

Another example is the fact that we have been talking about permissible levels of TV sets of a half milliroentgen per hour at a 2-inch distance. We found that there were many machines for taking routine mass chest X-rays that were delivering thousands of milliroentgens per exposure in New York City. We have just condemned six of them, and they are to be replaced with new machines where the exposure is only about 50 to 75 milliroentgens, which is more reasonable.

Similarly, many fluoroscopes are exposing patients to very great amounts of radiation in excess of what is necessary, because they have viewing screens that are 20 or more years old, whereas a new screen put in at the cost of about a hundred dollars or so would reduce this

exposure by about 80 percent. This is one of the items of updating for which I believe standards should be set.

Mr. PREYER. Thank you, Doctor.

Mr. ROGERS. Dr. Carter.

Dr. CARTER. There is an increase in leukemia among X-ray technicians and radiologists, is there not?

Mr. BLATZ. I don't really consider myself an expert in this field.

Mr. CARTER. Radiologists do show an increased incidence?

Mr. BLATZ. Radiologists, yes. I believe this applies only to the older radiologists. I think this problem has been solved by better protection for radiologists and technicians.

Mr. CARTER. That applies at the present time. And in the past few years it has been—most physicians X-ray youngsters particularly just as little as they can, is that not true?

Mr. BLATZ. That is true. The American Academy of Pediatrics has urged pediatricians not to use X-rays routinely.

Mr. CARTER. And pregnant women the same way. And just young people generally, unless it is really necessary. We don't X-ray as much as we formerly did. And certainly feel that it is necessary that we do not.

As it has been stated before, we don't know the level at which these rays can cause the damage they do, genetic or physical, do we?

Mr. BLATZ. No, I don't think this has been pinpointed.

I would like to make one comment, though. The use of X-rays by physicians certainly has decreased to some extent. But on the other hand, many, many more people have medical services available today who didn't have them before. So we think that the overall exposure of the population is increasing.

Mr. CARTER. Probaly so.

Mr. ROGERS. Have you had brought to your attention any product called a portable electronic welder?

Mr. BLATZ. Yes, sir.

Mr. ROGERS. Could you just tell us briefly what it is.

Mr. BLATZ. I really don't know much about it, except that I received a letter from a high school teacher, I believe from Minnesota. I had written a popular article on the subject of microwave ovens, that he had read. He wrote to me and sent me an advertisement for an electronic welder for welding wood and plastic sheets in a few minutes that his school was planning to buy. It looked to me as if it might be a microwave device, although it did not say in the advertisement.

It says that this device complies with the U.S. safety code and FCC regulations, which presumably is for radio interference. That is the only regulation the FCC would have for such a devise. From the picture, it looks as though it might be a microwave device, and there is apparently no shielding on it. I think if it were microwave device it might be dangerous, particularly for schoolchildren to use.

Mr. ROGERS. Any other questions.

If not, Mr. Blatz, we are very grateful to you for coming and letting the committee have the benefit of your experience and your testimony.

Thank you very much.

Our next witness is Mr. David Krantz, manager, of the Certified Calibration Laboratories, Inc., and also president of the Pennsylvania Federation of TV Service Associations.

Is Mr. Krantz here?

He is not here.

Mr. Seymour Becker, Suffolk County Department of Health.

Mr. Becker, the committee is delighted to welcome you here today, and appreciates your being present. Would you identify yourself for the record. And then give us your testimony.

STATEMENT OF SEYMOUR BECKER, CHIEF, RADIATION CONTROL UNIT, SUFFOLK COUNTY (N.Y.) DEPARTMENT OF HEALTH

Mr. BECKER. I am Seymour Becker. I am the chief of the radiation control unit for the Suffolk County Health Department. On behalf of Dr. George E. Leoni, commissioner of the Suffolk County Health Department in New York, I would like to thank the committee for giving me this opportunity to discuss the survey that I conducted in Suffolk County to determine the levels of radiation emitting from color television sets.

Any questions the committee might have I would be glad to answer.

Mr. ROGERS. Could you give us just generally your findings? If you could condense those findings for us it would be helpful.

Mr. BECKER. The survey started about 2 years ago. Within that 2-year period we had about 5,000 requests from residents of Suffolk County to have their color television sets measured by the county health department. Within that 2-year period we found 20 percent of the 5,000 sets surveyed were emitting X-radiation well above the recommended level.

Mr. ROGERS. Twenty percent?

Mr. BECKER. Yes, sir.

Mr. ROGERS. Out of 5,000 sets?

Mr. BECKER. Yes, sir.

Mr. ROGERS. Could you tell us how many were old sets and how many were new, as of what date, and so forth?

Mr. BECKER. In the beginning we kept records of the different makes and sizes. But as the study went along we found the age of the set or whether it was a metal cabinet or wood cabinet made no difference. So we discarded that particular information; if the set was emitting radiation it didn't matter what type of set it was.

Mr. ROGERS. I was just asking, for the record, so that the committee might know, but you don't have those records, then, as to exactly the year the set was made?

Mr. BECKER. No, I don't.

Mr. ROGERS. Did you have any contact with the National Radiological Center in conducting your survey or study?

Mr. BECKER. Yes. Prior to this study I contacted Federal Bureau of Radiological Health Representatives, and they were very much interested in what we started to do. Representatives came up and spot checked some sets in the field to make sure that our instrumentation was in compliance with their standards, and it was. With their encouragement and assistance we continued with the study.

Mr. ROGERS. What seemed to be the main problem? Where did most of the radiation emit from?

Mr. BECKER. One main problem of the sets that we surveyed was the malfunction of the high voltage shunt regulator tube. Another major problem was the high voltage of the set, which was primarily due, at least in Suffolk County, to the fact that TV servicemen, in repairing increased the voltage.

Mr. ROGERS. You felt these were the two main problems?

Mr. BECKER. Yes.

Mr. ROGERS. How about the rectifier.

Mr. BECKER. That, too, was a problem, but not as prevalent as the others.

Mr. ROGERS. Mr. Kyros.

Mr. KYROS. Do I assume that you have a list of those sets then, and the names of the manufacturers of the sets?

Mr. BECKER. Yes. And that information was sent to the Federal Bureau of Radiological Health for their interpretation.

Mr. KYROS. What corrective action was taken, if you know, in regard to these sets?

Mr. BECKER. In Suffolk County if we did find a set that needed correction, we notified the manufacturer of that particular make. They sent a representative out and corrected the set. We reinspected it, and the set was in compliance after the inspection.

Mr. KYROS. In all cases, to your knowledge—did you use a Geiger-Muether——

Mr. BECKER. The same instrument that the Bureau used.

Mr. KYROS. Did the test that they made correlate with the tests that you made, that is, in regard to the level of radiation measurement?

Mr. BECKER. Will you rephrase that. I didn't understand you.

Mr. KYROS. Let's assume you went to a set in someone's house and you tested it and it exceeded—what?

Mr. BECKER. 0.5 milliroentgens per hour.

Mr. KYROS. You then called the company in. And did they find the same amount of milliroentgens that you did?

Mr. BECKER. Those who brought a radiation detection unit found the same amount.

Mr. KYROS. Did they just make the correction on the high voltage regulator tube, or what?

Mr. BECKER. In many cases when the serviceman was dispatched, he had no voltmeter. We would be there with the serviceman, if it were possible. We would show him with our radiation survey meter what the problem was. In most cases he would immediately lower the voltage. We could see the radiation levels decrease dramatically. Under that type of observation we were able to correct the set.

Mr. KYROS. No further questions.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. What do you consider a safe level to be in milliroentgens of radiation?

Mr. BECKER. Our study was just in accordance with the NCRP recommendations that have been passed on to us.

Mr. CARTER. 0.5 MR?

Mr. BECKER. 0.5 MR per hour. But I would like to add, when correcting the thousand sets, of that 5,000 that we surveyed, we were able to

bring the levels of radiation down to natural background radiation. In other words, we didn't bring it down to 0.5 MR/RH; we brought it down even further.

Mr. CARTER. Good. What was the highest amount of *x* radiation you changed?

Mr. BECKER. The level ranges from 0.5 up to 150 MR per hour.

Mr. CARTER. 150 milliroentgens per hour. What was your mechanism for detecting and calculating the amount of *x* radiation?

Mr. BECKER. It was an instrument similar to what the Public Health Service uses.

Mr. CARTER. Certainly I want to compliment you and the people of Suffolk County who are responsible for this survey.

Mr. BECKER. Thank you.

Mr. CARTER. I think it is extremely good.

Thank you, Mr. Chairman.

Mr. ROGERS. Mr. Preyer.

Mr. PREYER. No questions, thank you, Mr. Chairman.

Mr. ROGERS. Was there any one company that was responsible for the sets?

Mr. BECKER. We found 37 different makes or brands.

Mr. ROGERS. Thirty-seven different makes or brands?

Mr. BECKER. Yes, that were emitting X-ray radiation at 0.5 MR/HR.

Mr. ROGERS. Or more. Do you have a continual program there?

Mr. BECKER. Yes. The program has been and still is part of our regular X-ray inspection program. Primarily my job is to check the dental and medical X-ray units. When we are inspecting that particular equipment, if there is a request from a set owner in that locality, we go and check it. So it is a part of the regular program in the county.

Mr. ROGERS. I think it is an excellent service to have.

What has been your experience with X-ray equipment?

Mr. BECKER. Very similar to what Professor Blatz has mentioned. We found in Suffolk County about—I have been with the program for about 8 years, from its inception, and in that period of time about 75 percent of the dental and medical units that we inspected were not in compliance with the New York State Ionizing Radiation Code.

Mr. ROGERS. But they have been brought to standard after your inspection?

Mr. BECKER. Yes.

Mr. ROGERS. What about microwave ovens, have you had any experience yet with those?

Mr. BECKER. Not yet, because we have a limited staff.

Mr. ROGERS. And you haven't had an opportunity to do it?

Mr. BECKER. Right.

Mr. ROGERS. Anything with laser beams.

Mr. BECKER. Not yet, sir.

Mr. ROGERS. We commend you, and thank you for being present. Your testimony has been most helpful.

I see the time now is 12:15. We have one or possibly two witnesses. And if it is agreeable to the witness, Mr. Day, you and your associates, and Mr. Krantz, if he comes in, we would like to adjourn until 1:30.

So the committee will stand in recess until 1:30.

(Whereupon, at 12:15 p.m., the committee recessed, to reconvene at 1:30 p.m. of the same day.)

AFTER RECESS

(The committee reconvened at 1:30 p.m., Hon. Paul G. Rogers presiding.)

Mr. ROGERS. The subcommittee will come to order, please.

We will continue our hearing on Review of Electronic Products Radiation Hazards, as well as other radiation hazards.

Has Mr. David Krantz come in?

Our next witness then will be Mr. J. Edward Day, special counsel of the Electronic Industries Association, and I understand you have a panel of three.

Mr. DAY. Yes, sir, Mr. Chairman.

Mr. ROGERS. You may invite them to come up, if you like, and, if you will, identify them for the record.

It is a pleasure to see you again.

STATEMENT OF J. EDWARD DAY, SPECIAL COUNSEL, ELECTRONIC INDUSTRIES ASSOCIATION; ACCOMPANIED BY C. W. THIERFELDER, H. H. HARRIS, AND N. W. ARAM, MEMBERS OF THE EIA/INDUSTRY AD HOC ADVISORY COMMITTEE ON X-RADIATION

Mr. DAY. Mr. Chairman, we appreciate the opportunity to be heard before the subcommittee.

I understood from my conversations with the staff and the members of the subcommittee in recent weeks that you wished to be brought up to date as to what is happening both from the standpoint of the Government and the industry, and we are here in response to that wish. I don't want you to feel that our appearance is gratuitous. I understand you wished us to appear.

Mr. ROGERS. We appreciate your doing it, and we appreciate the cooperation of the industry throughout this matter, I might state for the record. I have been impressed with the cooperation this industry has extended to this committee and the Congress. I think that was demonstrated particularly in the GE situation, where that company, without force of law, but on its own, when public notice was given, went in and corrected all of the sets.

So I think your industry has exhibited a cooperative spirit, and I understand from HEW people today, as well as my conversations before, that there has been no problem of their coming and talking to you, going over your programs, seeing what is being done.

Nobody has been denied the admission to a plant or anything like this, that we heard some people say might happen.

So I think the industry should be commended for this, and I do it for the record.

Mr. DAY. Thank you.

The gentlemen with me, Mr. Chairman, are three engineering experts in this field. On my right is—the first one on my right is Mr. C. W. Thierfelder, the next one is Mr. H. H. Harris, and on my left is N. W. Aram. They are members of the EIA/Industry Ad Hoc Advisory Committee on X-Radiation.

I am J. Edward Day, a partner in the law firm of Sidley and Austin, here in Washington. We are special counsel for the Electronic Industries Association which, on radiation matters, represents substantially

all of the U.S. manufacturers of television receivers, including representing some manufacturers that are not members of the EIA.

The total group represented by the EIA is made up of 20 companies which are manufacturers of finished sets, plus most of the major makers of the principal components of sets.

We realize that the purpose of this hearing is to enable this subcommittee, which has played such a key role in working out Federal legislation in regard to radiation emissions from electronic products, to keep itself up-to-date as to developments on this subject. Therefore, we will not undertake to make a lengthy presentation. There are five points which I want to touch on in my statement:

1. The television manufacturers have for an extended period of time been producing sets which are well within the recommended standard of permissible radiation.

2. The television industry has not opposed, and does not oppose, Federal regulation in regard to radiation emissions from electronic products, and the industry is cooperating in efforts for reasonable regulation.

3. The manufacturers have continued and expanded their efforts to perfect technical improvements which will further minimize any possibility of significant radiation.

4. Numerous independent experts have recently confirmed again that no hazard situation exists as to radiation from color television.

5. Some of the recent statements and studies which have caused a new flurry of publicity about the problem are of doubtful scientific validity.

On the first point, the television manufacturers have for an extended period of time been producing sets which are well within the recommended standard of permissible radiation.

A little over a year ago, the EIA collected from the television manufacturers the results of quality control checks and audit performance tests on X-radiation, as taken by the companies in their factories in the period of 9 months between July 1, 1967, and March 3, 1968. This quality control audit summary covered 19,225 sets of all makes and of various picture tube sizes. Out of this total number of sets, there were only four which exceeded the 0.5 mr. per hour recommended level and these four receivers never left the manufacturers' plants, but were corrected before they were shipped.

A similar quality control audit summary is now underway for the period from March 1968 to April 30, 1969. To date, the data received covers 138,003 sets. Of these sets, only eight were found to exceed 0.5 mr. per hour. Corrective action was taken in all cases. Of the total sets, 137,976 were measured at below 0.3 mr. per hour, including a large number of sets emitting no detectable radiation above background. It should be noted that most sets included in the qaulity control audit summary were tested while operating at high line voltage and at the most unfavorable adjustment of user controls which would produce a usable picture.

These audits reflect the results of effective quality control procedures involving accepted random sampling techniques and use of specialized personnel, adequate instrumentation, and sufficient time to test every surface of the set.

The Bureau of Radiological Health of the Department of Health, Education, and Welfare has, within the last 9 to 10 months, been making visits to the factories of television set manufacturers to check on radiation testing procedures. A representative of the Bureau of Radiological Health was quoted in the trade press early last month as saying that these visits "make us reasonably certain that sets coming off the line are meeting minimum standards for radiation protection."

The design and manufacturing cycle in the television industry is 2 years. Radiation came to urgent attention just about 2 years ago. The manufacturers did not wait for Federal legislation and regulation before making all changes which the state of the art and technical knowledge permitted at that time to reduce radiation to a minimum. The survey of over 157,000 sets which I have referred to shows that the situation was already excellent. However, with the 2-year cycle now bringing off the assembly line sets containing later improvements, there can be even further assurance that the sets being manufactured are well within the recommended standard.

The second point: The television industry has not opposed, and does not oppose, Federal regulation in regard to radiation emission from electronic products, and the industry is cooperating in efforts for reasonable regulation.

Before this subcommittee in 1967, and before the Senate Commerce Committee a year ago, the EIA has stated that it does not oppose Federal regulation and legislation on this subject. The television industry has attempted to work in close cooperation with regulatory authorities and to make its technical experts and facilities available to assist in perfecting workable regulation. We do not oppose appropriate regulation now. Since the manufacturers have, for an extended period of time, been in compliance with the conservative limit recommended by NCRP, we see no need to be concerned about the fact that the Government standards have not been formally proposed as yet.

Third point: The manufacturers have continued and expanded their efforts to perfect technical improvements which will further minimize any possibility of significant radiation.

Television manufacturers are and have been alert to the need for proper control of the voltage adjustment of television sets during repair and servicing in the field. Improper adjustments can in some situations increase radiation in sets that were well within the standard when they left the factory. There has been a continuation of the extensive program of manufacturers to alert and educate repairmen to avoid adjustment of voltage above the level recommended by the manufacturer.

Various ones of the manufacturers have taken one or more of the following steps to deter improper adjustments in the high voltage system:

1. Restricting access to the voltage control adjustment.
2. Restricting the range within which the high voltage may be adjusted.
3. Designing the adjustment control so that a special tool—rather than merely a screwdriver—is required to make adjustments.
4. Designing of circuits to eliminate adjustments.

There have also been advances in other areas of technology, and in manufacturing process, which likewise function to minimize or eliminate X-radiation. These continuing developments have been in the following general categories: High-voltage limiting circuits which provide added protection against increases in voltage due to component failure; more and better shielding; design changes which do away with radiation sources such as shunt regulators; improved instrumentation and methodology in quality control, supplemented by additional inspections of components prior to assembly; and improvements in components, including those produced as replacement parts. Some such design and manufacturing changes are in general use; others are in the process of development by one or more manufacturers. They are to a great extent cumulative in providing limitation of radiation.

There is a variety of satisfactory methods by which to meet performance standards respecting radiation.

These efforts are being pursued, not because there is is any feeling on the part of the television manufacturers that a hazard situation exists or that there is any justifiable cause for public alarm, but in an effort to eliminate the issue entirely and to bring an end once and for all to the flurries of public excitement over television radiation.

Fourth point: Numerous independent experts have recently confirmed again that no hazard situation exists as to radiation from color television.

Because of the fact that one of the subjects on the agenda today is the survey of color television sets conducted for the Department of Health in Suffolk County, N.Y. and because the announcement of results of that survey caused widespread publicity and a certain amount of public concern, it is appropriate to mention some other recent public announcements by officials having a responsibility in this field.

For example, shortly after release of the Suffolk County Survey, the Home Furnishings Daily on April 21, 1969, carried the following article:

> Dr. Hanson Blatt, Director of Radiological Control, New York City Health Department, told [a] Congressman at the weekend that X-radiation is "trivial" from color TV sets compared with the much more serious control problems involving medical and dental X-ray machines. * * *
>
> Blatt told the Congressman that field testing of color TV sets for X-radiation would make about as much sense as pulling the Beligian stone blocks out of certain roads in the Bronx. These blocks, he said, emit 25 millirontgens (of radiation) per year.

On April 17, 1969, the Los Angeles Times carried on article which included the following quotation from Dr. Gerald A. Heidbreder, Health Officer, Los Angeles County, Calif.:

> I know of no radiation problem that would cause adverse effects on any [television] viewer in Los Angeles County.

Even more recently, on May 7, 1969, the Illinois Department of Public Health issued a press release which included the following:

> A radiation detection survey of 100 new color television sets by engineers of the Bureau of Radiological Health, Illinois Department of Public Health, found only two that were emitting X-radiation to the exterior of the set and the radiation from these was insignificant. * * *
>
> Verdun Randolph, chief of the Bureau of Radiological Health, said * * * engineers from the Bureau of Radiological Health had checked many older sets in

the past and had found none which could be considered a radiation hazard. * * *
In 1959, the National Council on Radiation Protection and Measurements recommended that the exposure rate of 5 cm (approximately 2 inches) from any outer surface of a home television receiver should not exceed 0.5 mr per hour. At this rate, at the 2 inch distance, it would require 1,000 hours of exposure to receive the 500 mr yearly radiation exposure considered acceptable for the general public.

On April 19, 1969, the Benton Harbor, Michigan News-Palladium carried the following statement from the radiation section of the Michigan State Public Health Department:

The (Radiation) Section said the National Committee on Radiation Protection set the recommended exposure rate for radiation by home television receivers. This was set at 0.5 milliroentgens per hour two inches from the surface of the set. "The limit is not a danger level," the public was advised. "It is simply a guideline which is far below any level which could be expected to affect the general public in any way."

Publicity on this issue has even extended to Canada. On April 25, 1969, the Toronto Daily Star quoted Mr. Gordon Tebo, general manager of the Canadian Standards Association testing laboratories, as saying at a press conference that domestic and foreign made color television sets in Canada have been tested to Canadian federal specifications since last year and "no sets tested have exceeded the radiation limitations."

Fifth point: Some of the recent statements and studies which have caused a new flurry of publicity about the problem are of doubtful validity.

We will not attempt here to make a comprehensive analysis of the Suffolk County survey, but will only mention a few points which cause concern about that survey.

In terms of scientific credibility, the Suffolk County survey suffers from serious defects of instrumentation and methodology.

1. The measurements in Suffolk County were made with an energy-dependent instrument, the readings of which therefore varied with both voltage and source of radiation (i.e., shunt regulator, high voltage rectifier, or picture tube). Because the Suffolk County personnel did not measure voltage and did not identify the point in the set at which radiation was detected, their instrument calibration could not have been accurately applied to the readings, and their data are necessarily suspect.

2. In general, the Suffolk County personnel disclaim personal responsibility for instrument calibration and claim no qualification in that respect.

3. The statistics in the Suffolk County report do not actually represent numbers of sets, but rather numbers of measurements. Some sets were measured two or three times, and such duplications distort the statistics.

4. Sets emitting radiation at 0.5 mr per hour comply with the NCRP recommended standard; yet the Suffolk County report includes such sets—as well as sets measured at levels only slightly above 0.5 mr per hour—in the general conclusion that "approximately 19.9 percent of those TV receivers checked were found to be emitting X-radiation well above the NCRP recommendations."

There is a serious discrepancy between this conclusion and the result of the Washington survey conducted by the U.S. Public Health Serv-

ice at the end of December 1967 which, in contrast, showed 6 percent of sets to be emitting radiation above the recommended standard.

An article appearing in the Television Digest for April 28, 1969, attributed to an unnamed official of the Bureau of Radiological Health, raised questions about the methodology used in the Suffolk County survey and expressed dissatisfaction with the adequacy of the records made in conducting the survey.

That is our statement, Mr. Chairman. We appreciate the opportunity to present it.

Mr. ROGERS. Thank you very much, Mr. Day, for your statement.

Mr. Preyer.

Mr. PREYER. Like the Chairman, Mr. Day, I commend your industry for your cooperative attitude. I think the encouraging thing, as I understand it, is this: that you were saying that there will be no technical problems in meeting any standards that might be set.

Mr. DAY. There will be none in meeting what we hope the standard will be, because the 0.5 mr per hour is a long accepted standard of the NCRP, and is in effect an international standard. The NCRP reaffirmed that as their recommended standard only a year ago in light of all modern knowledge of this subject so that we expect there to be no difficulty with complying with that as a standard.

Mr. PREYER. On page 3 you mentioned statistics which showed that of the present sets being manufactured there are very few, indeed, which do not comply. But the Suffolk County survey, which you attack on a number of grounds showed the contrary. Does the fact that that survey may have dealt with older sets have any bearing on it, or if you applied the Suffolk County methodology to the 138,000 sets which you tested, would you come out with the same Suffolk County result?

Mr. DAY. Well, there are several answers to that, Mr. Preyer. First, the fact that the sets are already in the homes and some of them may have been there for a number of years indicates that they will undoubtedly have been worked on one or two or more times by repairmen and servicing personnel. That can, as we mentioned in our statement, result in voltage settings which will change the radiation emission.

However, we feel that the percentages as shown in the Washington survey, which we think is a much more scientific test of sets in the field, does not show a hazard situation because of the fact that it does not indicate a serious exposure of the population.

On another aspect of the difference between the tests in the manufacturers' plants and almost any survey made in homes, I referred to certain things that make the quality control in the factories quite reliable. There is time, there are controlled conditions, there is highly trained personnel. An instrument used to test radiation can be affected by changes in humidity, by changes in temperature, by bringing it in and out from a car into a home, by different humidity conditions in the home, by the fact that there may not be sufficient personnel with sufficient experience in this exact thing to see that the calibration is correctly handled.

The concept on that is that you cannot adequately measure radiation with an instrument without calibrating it for the sources of that radiation. You have to know the voltage from the source and which source you are dealing with, and in a proper measurement of radiation you have to make adjustments as to whether you are examining the picture tube, the shunt regulator, the rectifier——

Mr. PREYER. Simply because a set was manufactured before a certain year—in other words, simply because it was an early model, doesn't necessarily mean that it would be more likely to exceed the limitation, is tha right?

Mr. DAY. That is correct. Of course, as you know, on the black and white sets there has never been thought to be an issue particulary on this subject because of the fact that the black and white sets operate at a lower voltage level.

But the fact that a set is older, if it has been properly serviced, should not be an automatic factor in making it different.

Mr. PREYER. Let me ask one final naive technical question.

Why do repairmen turn up voltage? Does it make the picture clearer or stronger?

Mr. DAY. It makes it brighter; yes, sir. The brightness is a result of the voltage setting, and Mr. Becker mentioned this this morning, and he mentioned in his report that possibly one of the reasons repairmen set up voltage in Suffolk County is that many of those homes are out at the end of Long Island and they are setting up voltage to try to get a clear picture from New York City stations.

Mr. PREYER. Thank you, Mr. Day.

Mr. ROGERS. I have received a report from the Pinellas Health Department that they are still checking home color television sets only upon request. This is not going out and making any survey. They are still finding, they advised me today, 16 to 20 percent emitting radiation above 0.5 milliroentgens. However, they say in the 1969 models that they have checked there has been little or no excessive radiation, which would indicate to me that the new sets are coming out with a safety factor that we would hope for, at least in that area.

So that some progress, I think, is being made. Now, I would like to find out what the companies have done and are doing in some areas. For instance, we discussed with you and members of the industry in the committee before the possibility of doing away with part of the set which allows service people to increase voltage.

I understand at least one company has done this, and if we could have some comment on what is being done in this area——

Mr. DAY. Well, there are a couple of approaches toward that goal, Mr. Chairman, and that is a goal. We do not feel that it is ever going to be possible to have an absolute 100-percent fail-safe system, because if a repairman is determined to set up the voltage he can bypass or defeat the precautions that are taken.

But the type of thing that I listed at bottom of page 5 and the top of page 6 are a variety of approaches to that very problem, and we certainly agree that that is a matter that is of great urgency. One of those is the one you referred to, point 3, which is designing the adjustment control so that a special tool rather than merely a screwdriver is required to make adjustments.

There are other efforts to make that adjustment difficult to get at, and there are efforts to restrict the range within which the voltage can be adjusted. There are various approaches that can be taken to achieving this end result, and various companies are embarking on their own approaches, rather than nationally in a highly competitive industry, and rather than just one uniform approach.

Mr. ROGERS. I would like to get specific. I have read reports that RCA has actually had the high voltage eliminator. Would any of you experts know about this?

Mr. DAY. Well, we can describe that. Mr. Thierfelder can tell about that.

Mr. ROGERS. Could we have a quick—just a quick background of each of these gentlemen, where they are from and their competency in the area?

Mr. DAY. Why don't you start, Chuck?

Mr. THIERFELDER. My name is C. W. Thierfelder. I am associated with RCA. I am responsible for engineering of picture tubes, color and black and white, and I am located in Harrison, N.J.

Mr. HARRIS. I am H. H. Harris, Philco-Ford Corp., Philadelphia, Pa. I am responsible for the technical planning within the engineering of consumer products—electronics.

Mr. ROGERS. Thank you.

Mr. ARAM. I am N. W. Aram. I am the vice president and chief engineer of Zenith Radio Corp. in Chicago.

Mr. DAY. If I could just interrupt one second, Mr. Chairman. The fact that these particular gentlemen are here is not to pick and choose particular manufacturers. They are all active on this front that you are interested in. We knew you didn't want a whole army up here, and we have tried to make this an industry effort.

Mr. ROGERS. Yes, I understand that, and I appreciate it.

Now, getting to this activity of RCA, could you describe as to whether or not you have eliminated a control for voltage regulation by servicemen?

Mr. THIERFELDER. I would prefer, sir, not to respond to your inquiry from RCA, since I am here representing EIA and not RCA. I am sure that RCA will be happy to respond to your question, but I would prefer not to make that response at the table.

Mr. ROGERS. Well, maybe you could just do it as an individual, not speaking for RCA, if you have any personal knowledge of what is being done.

Mr. THIERFELDER. As a member of the EIA advisory group, I can give you my impressions of what RCA has done.

Mr. ROGERS. I don't care where you get it from, and we will categorize it in any capacity you wish to give it to us, as an individual or as EIA, or as a citizen or just a good American.

Mr. THIERFELDER. Thank you. We hope we are all of those.

Mr. ROGERS. I am sure we are.

Mr. THIERFELDER. RCA has attempted to control the high voltage adjustment in several ways and has implemented modified designs, depending upon particular models of the television sets involved. In one class of television sets, they have used precision divider resistors to eliminate high voltage adjustment control.

This has been implemented on all tube deflection chassis.

Mr. ROGERS. Let me stop you there, if I may. On that particular classification, then, you have no voltage regulator; is that correct?

Mr. THIERFELDER. The regulator may or may not be used in the receiver, but the adjustment that is available of the high voltage has been eliminated by replacing a variable resistor with precision fixed resistors so that——

Mr. ROGERS. Tell me that in layman language. Is there an instrument on your set that the television repairman can change?

Mr. THIERFELDER. No, sir.

Mr. ROGERS. Or increase?

Mr. THIERFELDER. No, sir.

Mr. ROGERS. Well then, you have done away with the voltage regulator on that particular set as far as adjustment, as far as the TV repairman is concerned?

Mr. THIERFELDER. Yes, sir; however, a determined serviceman could change it.

Mr. ROGERS. I understand. He could probably rebuild a set?

Mr. THIERFELDER. Yes.

Mr. ROGERS. But what I am trying to get at is what you have done—what I was hoping you would do, and I don't know why you are hesitant to admit this, because I think it would be a goal that everyone would want to reach, since we had testimony that one of the main reasons for the radiation problem in color TV sets is the fact that when they go in to repair people they up the voltage in order to get better viewing.

Mr. THIERFELDER. Yes.

Mr. ROGERS. So if you eliminate that, that may help some. That may not solve it, I will agree. But you have done this in one category?

Mr. THIERFELDER. Yes, sir.

Mr. ROGERS. Is it on color TV sets?

Mr. THIERFELDER. Yes, sir. Just to clarify a point, I am sure that RCA feels that this is an advancement. Mr. Sarnoff made an announcement to the stockholders covering this point.

My remarks earlier did not at all take away from this advancement, but rather to attempt to point out——

Mr. ROGERS. I understand, you are with the industry. I appreciate your whole approach. I realize you may not want to go into individual refinements, but I would like to see what stage we are in, in the art, because certainly it would be helpful for the commitee to know if certain things are possible of accomplishment.

Are you putting greater voltage in your black and white sets?

Mr. THIERFELDER. No, sir.

Mr. ROGERS. Is any company?

Mr. THIERFELDER. Greater than when? The high voltage of black and white receivers has not been increased in the last half a dozen years.

Mr. ROGERS. Is this true throughout the industry? I keep hearing reports that we are now beginning to increase voltage some in black and white sets. Is this in error?

Mr. DAY. I believe so, Mr. Chairman. We aren't familiar with any such report.

Mr. ROGERS. This is reassuring. I just wondered.

If you do find out, I would appreciate it if you would let us know.

Now, what does Philco-Ford have?

I read—this is not secret information I am sure—I have read activities that you have done, but you approach the problem differently, as I recall.

Mr. HARRIS. That is correct.

Mr. ROGERS. What do you do, speaking as an industry man?

Mr. HARRIS. For a number of years we have employed essentially a feedback mechanism which has the properties of regulating the limit to which the high voltage can rise. We limit the high voltage under more than what would be considered the normal operating conditions. That is, we have the system so regulated in its design criteria, that at high line voltage conditions, the user controls can be set to the maximum possible situation that would still give a usable picture.

Our sets are so designed that by the inherent regulation characteristics of this mechanism, the voltage cannot rise to any levels beyond what we consider could create any hazardous condition.

Mr. ROGERS. What happens to the set? Does it go off or——

Mr. HARRIS. No, it operates.

Mr. ROGERS. I mean, if something—what triggers the refusal of an increase in voltage?

Mr. HARRIS. There is a special component which has the property of very, very finely and acutely being sensive to the response that if the voltage wants to rise, this feedback mechanism in turn—it is a cybernetic problem—it says "No." We can, by virtue——

Mr. ROGERS. It is self-regulated?

Mr. HARRIS. It is self-regulated, yes, sir.

Mr. ROGERS. Do you feel it has proved out so that there is no question?

Mr. HARRIS. For the past 4 years we have been using the system, and we think very highly of it.

Mr. ROGERS. What is your upper limit for voltage that you allow?

Mr. HARRIS. We believe that our sets, under conditions that I have mentioned, can be held to not exceed about 30 to 31 kilovolts, that is under the conditions, not just normal conditions, but the ones I outlined.

Mr. ROGERS. Now, what do you mean, the ones you outlined?

Mr. HARRIS. That is the high line voltage and——

Mr. ROGERS. This is an extreme condition?

Mr. HARRIS. These are extreme operating conditions. It might still present a usable picture so that the customer might not turn the set off.

Mr. ROGERS. Now, with this 31,000 voltage your set will——

Mr. HARRIS. Still be within the recommended limit.

Mr. ROGERS. Still within the 0.5 milliroentgens?

Mr. HARRIS. That is correct. This is a design criteria that we have established.

Mr. ROGERS. May I ask, in RCA, what is your upper limit that you have which cannot be tampered with?

Mr. THIERFELDER. This varies with individual receivers.

Mr. ROGERS. Well, the highest amount on any of your sets?

Mr. THIERFELDER. RCA adjusts the high voltage on each and every set as it passes down the manufacturing line, and this is adjusted in accordance with the particular type and size of sets. The maximum voltage under the extreme conditions that Mr. Harris has defined is of the order of 32, or thereabouts, thousand volts.

Mr. ROGERS. 32-plus or 32-minus, would you think?

Mr. THIERFELDER. Thereabout. The current volume is of the order of 32,000 to 33,000 volts.

Mr. ROGERS. Thirty-two to 33. Thirty-three would be the top?

Mr. THIERFELDER. Yes.

Mr. ROGERS. Now, could you let us know what Zenith has been doing?

Mr. ARAM. I, too, would prefer to give an answer which is not a company answer.

Mr. ROGERS. I understand.

Mr. ARAM. What I would like to say is, I think, representative of more than one of the companies in the industry.

May I mention first, in case there is any misunderstanding about this, that most color television receivers have a voltage regulator which is an automatic device for controlling the voltage at the design level. It is this control level which is set by the high voltage adjustment which we speak of.

Mr. ROGERS. Can that be changed by the serviceman? Would that be what he would change?

Mr. ARAM. This is the control that has been spoken of here that has sometimes been misadjusted upward, yes, sir.

Now, as to that particular control, in some current products the control has been made, first, relatively inaccessible by putting it inside the set without an access hole from the outside, and in some instances it is of a type which cannot be adjusted in the normal manner by turning with the fingers or by using a screwdriver, which is the usual control for making service adjustments.

I wanted to go beyond that in the matter of extra precaution.

Mr. ROGERS. You make it a little more difficult for them to change?

Mr. ARAM. Distinctly, yes.

Now, in respect to the type of circuit that Mr. Harris mentioned, there is a growing practice to use, in addition to the normal voltage regulator circuit, which is an automatic one, an extra—what might be called holddown circuit or safety circuit, which only comes into operation if the manual control is misadjusted or if there is a component failure, either of which would otherwise cause the voltage to rise.

The extra holddown circuit then comes into play and limits the voltage at a small margin above the normal operating point.

Mr. ROGERS. I see. Now, what is the top limit that you would permit in your sets?

Mr. ARAM. This is, of course, a statistical thing that varies from set to set.

Mr. ROGERS. The top limit.

Mr. ARAM. I can't tell you precisely because I don't have the statistics, but it is in the range of 30,000 to 32,000 volts.

Mr. ROGERS. Now, this can be changed by a repairman if he goes to the trouble of——

Mr. ARAM. No, I am sorry, the holddown or safety circuit is not adjustable for the repairman or anyone else. It is a built-in thing.

Mr. ROGERS. So no matter what the repairman tries to do in order to up it, he could not?

Mr. ARAM. He could advance it to where the holddown circuit takes control and prevents him from doing anything further.

Mr. ROGERS. So, in the range of 30,000 to 32,000 volts?

Mr. ARAM. Yes.

Mr. ROGERS. Now, what about the quality control now? I notice you gave very impressive statistics on your checking, your audit of

quality control procedures and checking rather large numbers of sets. How is this done?

Mr. DAY. Well, this is done by random sampling, Mr. Chairman, by established scientific methods which are used in manufacturing of complicated products generally, whereby what has been determined to be a proper and adequate sample is withdrawn at the end of the manufacturing process and is checked very thoroughly and with deliberation, by people that are doing nothing else, with controlled conditions of temperature, humidity, instrumentation, so that they are sure to get the best possible check, and that is the quality control procedure.

There are efforts within the industry as there are elsewhere to try and further perfect the instrumentation to see that it is not affected by any other factors. So the quality control procedures, like the manufacturing procedures, are moving ahead.

Mr. ROGERS. Now, let me ask you this: do the major companies make their own component parts as a rule?

Mr. DAY. Some do and some don't, and some of the manufacturers of the sets make components for other manufacturers.

Mr. ROGERS. As well. What progress are we making on perfecting the various component parts as to the radiation from those parts?

In other words, a shunt regulator tube, are we shielding it? Is anything being done in this area?

Mr. DAY. We are confident, Mr. Chairman, that the components are also being further perfected from the standpoint of avoiding radiation, and that is a pertinent factor not only for new sets but for replacement parts.

Mr. ROGERS. Have we any examples of that, any particular component parts which any industry would know of? Any of the gentlemen at the table, would you know of any progress that is being made?

Mr. DAY. We had examples of better shielding. That would be a component. That would be an example.

Can you think of one, Mr. Aram?

Mr. ARAM. Yes. It has been the practice to provide shielding around those components which are potential sources of radiation, and those components are known to be a shunt regulator tube where it is used in the particular set—and they don't all use one—a high voltage rectifier tube, where it is used—and there are some instances where it is not used—and thirdly, the picture tube.

Now, the face of the picture tube, of course, cannot very well be shielded with metal or one cannot see the picture. But I think it should be said that during the period since the concern was first expressed by the Congress that very substantial steps forward have been made, for example, in the picture tube during this interval. Improved glass has become available which by itself is more X-ray absorbing, and this has improved any absorption of X-roentgens in the tube by a factor of two times to 10 times.

Mr. ROGERS. We would be interested to receive some detailed information on a period; I think that is very encouraging, and I think the committee would like to have, if you could, furnish for the record——

Mr. DAY. We will be glad to furnish further information.

Mr. ROGERS. Improvements made on the shielding of the tube itself. There has been concern expressed, as I am sure you recall, in previous hearings by some experts, at least one I recall from New York who has dealt with this field, that the eyes would be greatly affected from simply watching the picture tube, and particularly at very close range.

In fact, he was recommending a change from the standard from 0.5 to around 0.1 or less, and this would go to that problem, I think. I would like to have that information.

Mr. ARAM. Perhaps I could also say that the other two potentially radiating components have been similarly improved in their self-shielding properties.

Mr. ROGERS. I think it would be very beneficial if you could give us a rundown on these specific improvements that have been made, for the record. I realize you may not have them now, but if each of the companies could let us have something on this—you don't have to give us any secrets. We are not asking for your company secrets, but the progress that has been made.

I think it would be very reassuring to the public to know that great progress is being made, as you indicate. (See letter dated June 20, 1969, on page 297.)

What are you doing for training of repair people, not only your own people, but independent repair people? Is there any program? Is anything being done to try to bring their capability to a high degree of understanding the problem, and particularly this business of not increasing the danger by upping the voltage, by other——

Mr. DAY. Yes; various steps are being taken on that, Mr. Chairman. There is a program that the EIA has been engaged in for some time of distributing training materials to servicing personnel, regardless of whether they may be connected with some particular company, with warning information and educational information on the radiation aspect.

A specific example is in connection with the warranty on the picture tube. It has been worked out by some in the industry whereby the repairman, before he gets reimbursed for replacing the tube, has to file a form that shows that he checked the voltage and where it was when he checked it.

Mr. ROGERS. Now, this would be the authorized dealer repairman?

Mr. DAY. No; this would be anybody, because for a company that doesn't have its own repair personnel the picture tube warranty could be carried out by any repairman that had to replace the tube, and he would then file the form for reimbursement.

Mr. ROGERS. Thank you.

I have a few more questions, but I wanted Mr. Kyros to have an opportunity.

Mr. Kyros.

Mr. KYROS. Well, thank you, Mr. Chairman.

I want to welcome the Electronic Industries Association people here again. We saw you last year.

I am pleased to read this remark on page 2. Mr. Day, would you say the television industry has not opposed and doesn't oppose Federal regulation, and the industry is cooperating in the effort for reasonable regulation? I don't know if you recall or not, but there was a question

last year as to what powers of inspection investigation should be given within the law which we were trying to enact.

Apparently, as far as your knowledge is, the cooperation between the industry and the Government is such that no new laws are certainly necessary at this time; is that correct?

Mr. DAY. That is correct, Mr. Kyros, and I don't know of any situations where there has been even discussion of problems of getting information from the industry in connection with the studies that are being pursued now by the Bureau of Radiological Health.

Mr. KYROS. In your opening remarks you say that the Electronic Industries Association represents substantially all the manufacturers of television receivers, including some that are not members of the association. So that does cover them all?

Mr. DAY. It covers 98 percent of the production, of the American production.

Mr. KYROS. What about foreign imports? Have we had any problems, to your knowledge? No one discussed that, I don't think, this morning, on sets that came from foreign nations to the United States.

Mr. DAY. Well, there is a provision in the legislation relating to imports. Most of the foreign imported color TV sets to date are rather small-screen sets, and we expect the regulation, when worked out, to be applied to them just as much as they are to us. We aren't conscious of any particular problems.

The surveys that have been conducted usually pick up some foreign sets and there is nothing special there.

Mr. KYROS. I think you were present this morning during the hearings when testimony developed as to the performance standard of certain electronic products regarding which standards would be deemed necessary in connection with the health of the consumer. Is your association or is the industry, as far as you are concerned—let's stick specifically to color TV sets—prepared to recommend standards?

Mr. DAY. We do recommend the 0.5 mr. per hour as the standard. It was reaffirmed only a year ago by the NCRH, and it is as a practical matter an international standard.

It was set at that level to be 5 percent of background, taking into account the various features of exposure and the estimated viewing time of the population. We think that that is the standard that should be adopted.

NCRP. I said NCRH. I get my initials mixed up a little.

Mr. ROGERS. Will the establishment of a Technical Electronics Product Relations Standards Safety Committee, plus a standard, assist the industry, in your judgment, in insuring that adequate compliance is observed?

Mr. DAY. Well, I don't believe that the committee will have an active day-to-day part in compliance. The main purpose of the committee is to be an advisory group of experts from the three different segments as to what the standards should be, and then, from time to time, as to whether the standards should be changed. The committee is certainly an important part of this procedure, and if there should be differences of opinion develop as to where the standards should be set, we would expect the committee to play a very important part in that.

As far as enforcement, the main enforcement will be the obligation of the manufacturers to report, and if there should be any situation

where sets are in excess of the standards, then of course that is audited by the Department's authority under the bill to do their own checking.

Mr. KYROS. But the establishment of the standard itself on which the committee will be advising will then provide assistance to the industry in terms of establishing once and for all what the standards should be so they won't have public anxiety and concern as to whether television sets radiate harmful radiation or not; isn't that correct?

Mr. DAY. Yes, that is correct.

Mr. KYROS. Now, did you know that since this morning I found out that there have been made public some names of industry members that may well be members of the Advisory Committee, and I just want to ask you if you know George M. Wilkening of Bell Labs?

Mr. DAY. Well, I don't know them, but the various people, particularly the scientific people, connected with the industry are familiar with many of them. There is one man that is in the color television business that is in that group that has been put out in the preliminary statements.

Mr. KYROS. So, as a matter of fact, although there seemed to be vagueness this morning, the names of the public members, Government members, and industry members that have been requested to be members of this Technical Advisory Committee have already been known to the industry?

Mr. DAY. Well, I think you are looking at a publication that always amazes me, because I know it always knows everything before I can find it out, and it is usually accurate. So I think that that is probably correct, that this is no secret.

Mr. KYROS. I am looking at something called "Environmental Health Letter," dated May 1, 1969, and prior to seeing this after the hearing this morning, I wasn't aware that the names of the Advisory Committee had been made public. I didn't understand that from the testimony this morning, not that they withheld any information, but I didn't understand it.

Mr. DAY. The technical answer, I believe, Mr. Kyros, is the names of those that were suggested by the working level were circulated in the trade press some weeks ago. They went through various clearance processes. There has been at least one change, but the exact stage it is in now is invitation letters are sent out to those people asking them if they are willing to serve, and naturally they feel they can't announce the names formally until they get confirmation that those people are willing to serve.

Mr. KYROS. Well, to sum it up, is it correct that you would feel that the establishment of this committee which indeed may process electronic radiation safety standards to the Secretary for his opinions, on their own, the establishment would be a stabilizing influence on this concern all of us have had?

Mr. DAY. Yes, it would.

Mr. KYROS. Thank you very much.

Thank you, Mr. Chairman.

Mr. ROGERS. Is the industry agreed on the type of instrumentation that should be used for testing?

Mr. DAY. We are agreed on what the instrumentation should accomplish, but we are not totally in agreement with all uses of the

instrumentation that is being used by the Public Health Service. We feel that their instrument which they are using is valuable for scanning and searching, but from the standpoint of measuring with all controls as to just exactly what the amount of radiation from a given point is, we think that some of the instruments being used by the companies are preferable, and that is part of the difficulty that I referred to with the Suffolk County survey. They use an instrument that is intended for searching and scanning, and then it was not in that case, according to our information, even calibrated to take into account the differences in source and voltage, and was used to give out a result as to how much radiation.

We think that in order to say that there is a certain amount of radiation from a given point on a given set, a type of instrumentation which requires much more deliberate use is more appropriate. So I would say that that disagreement with the Public Health Service is not entirely over.

Mr. ROGERS. Well, I would be very interested in following this now, because I don't see how we can talk about studying any standards unless we are pretty well set on how we are going to measure what is coming out of these sets. Because if you feel certain amounts coming off the production line with a different measurement instrument and then the public health people go in and make surveys or checks on sets after they get out, I think we are talking about apples and oranges, and I don't think we will ever get together.

Isn't this a prerequisite for us to begin to get into the studying of standards and monitoring it?

Mr. DAY. I believe as a practical matter that we can work this out. I don't think there is a complete abyss here as far as the Public Health Service use of their instrument with the calibration which they follow and with the protections that they follow. We do feel that the Washington survey, although it was conducted with their instrument, checked out pretty well.

Mr. ROGERS. I would like to know this right away from Public Health and from the industry. If you would let this committee know, because otherwise, if we can't come to some agreement we will have to write into law the instrument used to determine. I think it would be better to leave that to an administrative decision, if possible.

But if we can't get an agreement, we will have to write it into the law as to what measuring instrument we will use; otherwise, I don't see how they can move anywhere in meeting the problem.

So if you can get together with Public Health and advise the committee within 2 or 3 weeks, it will be helpful.

Mr. DAY. We will be in touch with you on that.

(The following letter was received by the committee:)

SIDLEY & AUSTIN,
Washington, D.C., June 6, 1969.

Re May 23 hearing before Subcommittee on Public Health and Welfare.

Hon. PAUL ROGERS,
House of Representatives,
Washington, D.C.

DEAR CONGRESSMAN: As a result of a meeting yesterday between personnel of the Bureau of Radiological Health and an authorized representative of the television manufacturers, complete agreement was reached on instrumentation for measurement of radiation.

You will recall that during the hearing you expressed your particular concern with this subject and your desire to be advised as soon as possible.

Best wishes.

Sincerely,

ED DAY.

Mr. ROGERS. Now, is the industry using Underwriters Laboratory on this? Do they help check now, or not?

Mr. DAY. Yes; they do.

Mr. ROGERS. They are using, I guess, the same—what instrument are they using, the one that the industry has approved of, or do they use whatever the individual industry——

Mr. DAY. They use the one that we use, yes, most of the companies use.

Mr. ROGERS. Is there a difference in company use of measuring instruments?

Mr. DAY. Well, the approach is the same. The particular manufacturer may vary.

Mr. ROGERS. It is a different instrument?

Mr. DAY. Yes; but the Underwriters Laboratories, in addition to the care with instrumentation, has been active in improving their procedures as far as their sampling and that sort of thing. They have been quite active on that just in recent months for products generally.

Mr. ROGERS. I am going to ask counsel on our professional staff if he will ask Underwriters Lab if they would object to advising us of their procedures now and how they have improved it.

What about safety of employees within the plants? We had that question come up before. Are there any monitoring devices used now to decide if an employee has too much exposure to radiation? You might just comment, or maybe you would rather——

Mr. DAY. Yes, there are, Mr. Chairman. I have been checking on that for my own information just in the last few days, and while these other improvements have been going on there have been further steps taken by the various manufacturers to see that on any point along the assembly line where there may be high voltage that there are proper protections for the employees and proper checking equipment so that the employees are not exposed.

I viewed one of the assembly lines myself and observed this sort of thing, and the manufacturers generally are active on this front.

Mr. ROGERS. Good.

Would you let us have specifics on that from your member industries, as to what they are doing on the monitoring, and so forth, so we can have that for the record?

Mr. DAY. Yes. (See letter dated June 20, 1969, on p. 297.)

Mr. ROGERS. Thank you.

Do your members manufacture microwave ovens?

Mr. DAY. Well, one or two of them may, not generally. I believe that at least one does.

Mr. ROGERS. I think you have heard our concern expressed, and I think from what I have understood, one of the companies that was called in cooperated and wants to be helpful. I think that area particularly concerns the committee, and if you could let us know what member companies are involved in this work and what they are doing in order to try to meet the problems we have pointed up to the committee——

Mr. DAY. We will see that you get an answer on that, Mr. Chairman. Some of these companies, being in a great variety of products, belong to other associations for that type of a product.

Mr. ROGERS. I see.

Mr. DAY. And they may be in some other group that is working more actively on that. But we will see that your question is taken care of properly.

(The following information was received for the record:)

MANUFACTURERS OF MICROWAVE OVENS

The following is a partial list of the companies that make microwave ovens. A number of these make only an industrial or commercial model and only a few make a household model:

1. General Electric.
2. Amana Refrigeration, Inc.
3. American Microwave Inc.
4. Cryodry.
5. International Crystal.
6. Litton Industries-Atherton Division
7. Omnivend.
8. Raytheon.
9. George D. Roper.
10. Tappan.
11. Welbilt Corp.
12. Whirlpool Corp.
13. Admiral Corp.

[Editor's note: See also Microwave oven manufacturers, numbers of ovens produced, and geographical distribution," on p. 222.]

Mr. ROGERS. Or if you just let us know what companies, the committee could contact them directly, if you prefer us to use that approach.

Now, let me just ask you, I saw that they have had a meeting, and I am sure most of the industry had noticed, a meeting of the TV Service Associations. Mr. Krants is president there. They had a list of some 20 grievances—supposedly the service people—but I think the ones I saw, they listed seven major trouble areas, public relations, on trying to get new blood—I am not impressed with that—but serviceability, and I might go down these and you may not be in a position to respond now. If you could let us have some comment on them for the record I think it would be helpful.

Serviceability.—They ask manufacturers to improve TV set designs to help servicemen work on them easily and inexpensively for the consumer. For example, a pilot light, a 3-cent part, cannot be reached and replaced in many sets without the chassis being pulled.

For the sake of having something different, manufacturers install different types of bolts which need special tools in some sets, whereas no basic bolts exist in all sets.

Servicemen said TV sets are not built with service in mind, but for production ease. They feel money saved is spent on advertising the sets to consumers.

Second, retraining service technicians. A concerted effort of some kind was asked of manufacturers to eliminate duplication in instructions and to eliminate the great number of meetings which servicemen must attend at the expense of finishing work on sets.

Also, servicemen work on all TV sets, but are not instructed on new circuits by all manufacturers.

Third, standardization of parts or cross-reference index of parts. Too many parts, lights, fuses, tubes, and so forth, must be stocked and purchased by service dealers because manufacturers insist on making very slight changes in these parts for their sets.

There are serious shortages of parts to repair sets, a growing problem because of the number of TV sets manufactured offshore. Manufacturers and servicemen should compel distributors to stock sufficient inventory of all parts.

The next, special service information. Manufacturers must make all service information on sets available to all service shops. Some manufacturers favor their franchised service firms and capture service companies with inside information on set faults and repair, thus independent sericemen must spend more time searching for and correcting trouble spots at the expense of reputation in consumers' pocketbooks.

Manufacturers' use of warranties as sales tools and letting distributors, retailers, customers, and servicemen worry about getting the work done, if at all.

All of the confusion and dishonesty of warranties start with manufacturers, and they should shoulder the blame.

I am not necessarily saying I concur with all of these comments. These are comments that have been raised in an article in the Home Furnishing Daily, and at this meeting that I think you know about. So I want to put it in the record and get comments on it which you can give for the record.

Parts availability. There is a serious shortage for most TV sets. Servicemen are not advised that parts have become obsolete in sets and no longer are available and spend too much time learning it during repair work. Some parts exactly the same, and for the same TV sets, carry different model numbers, which also relates to confusion.

I think these are the main criticisms that I saw that I think the industry should be alert to, and we would be grateful for comment on your feeling about it and what should be done, if something can be done. Some of them may not be justified, but I did want to bring it to the attention of the industry.

(The following letter was received by the committee:)

SIDLEY & AUSTIN,
Washington, D.C., June 20, 1969.

Re Radiation Act of 1968, additional material requested for file in connection with May 23 hearing.

Hon. PAUL G. ROGERS,
House of Representatives,
Washington, D.C.

DEAR CONGRESSMAN: During the hearing on May 23 before the Subcommittee on Public Health and Welfare of the House Committee on Interstate and Foreign Commerce, additional material was requested for the file in connection with five subjects:

(1) Shielding of picture tubes.
(2) Improvements made in other components to reduce radiation.
(3) Agreement on instrumentation for measuring radiation.
(4) Protection of employees from X-radiation.
(5) Comments on grievances against manufacturers expressed by independent television service groups.

You will recall that under date of June 6 I advised that there had been agreement between the television manufacturers and the Bureau of Radiological Health on instrumentation. Point 3 above is, therefore, taken care of.

Enclosed please find the following:

(1) General responses on behalf of the industry to points 1, 2 and 4.

(2) Individual company responses from a selection of television manufacturers, giving replies to points 1, 2, 4 and 5.

We assume that in view of the detailed nature of the second set of enclosures referred to above, it will not be necessary to include this in the printed record, but that the purpose will be adequately served by including this material in the file of the hearing.

Very truly yours,

J. EDWARD DAY.

Enclosures.

(NOTE.—Company identification has been eliminated in the specific material furnished under item 2 above.)

[The enclosures contained with the above letter, and further responses from individual companies, are in the committee's files.]

Mr. ROGERS. Any other questions?

Mr. KYROS. No, sir.

Mr. ROGERS. I would like to ask one question.

Is there any particular manufacturer's secret that would prevent other manufacturers from doing away with the adjustment of voltage regulators? Is there any reason why all of the industry couldn't do this?

Mr. DAY. Well, I will give a general answer to that, Mr. Chairman, and perhaps some of the others will wish to supplement it.

We do feel that there are different approaches to achieving the same goal, and that certain companies may have a particular technique that they have developed. That doesn't mean there isn't another technique which will be equally satisfactory in achieving our purpose here, which is to minimize the chance of radiation.

There are some patented approaches to certain types of things, but there is no indication from anything I have learned that anybody is excluded in coming up with an effective answers to this problem because of any proprietary items.

Mr. ROGERS. Fine, and I presume as we get into the testing we will also have assurances as to which approach may be most satisfactory, if there are different approaches, to this problem?

Mr. DAY. Do you mean on the instrumentation?

Mr. ROGERS. Yes.

Mr. DAY. Yes, sir.

Mr. ROGERS. Is there a representative here from Underwriters Laboratory?

Thank you. Would you be able to furnish for the record your new procedures of what changes you have made in your procedures in working with the industry in testing of sets?

STATEMENT OF ARNOLD SMOOT, UNDERWRITERS' LABORATORIES, INC.

Mr. SMOOT. I have limited knowledge only.

Mr. ROGERS. Well, I don't mean now. I mean if you would furnish in writing for us, to the committee, and the counsel will talk to you about that. It is just so we can have it for the record. Would you give us your name?

Mr. SMOOT. Arnold Smoot, S-m-o-o-t.

Mr. ROGERS. And your address?

Mr. SMOOT. It is Underwriters Laboratories in Melville, N.Y.

Mr. ROGERS. Thank you, Mr. Smoot. I appreciate it.

(The following letter was received by the committee:)

UNDERWRITERS' LABORATORIES, INC.,
Melville, Long Island, N.Y., July 17, 1969.

Subject: Underwriters' Laboratories requirements for control of X-radiation emission from television receivers.

Hon. JOHN JARMAN,
Chairman, Subcommittee on Public Health and Welfare, Committee on Interstate and Foreign Commerce, Rayburn House Office Building, Washington, D.C.

DEAR MR. JARMAN: At the time of the hearing held before the Subcommittee on Public Health and Welfare of the Committee on Interstate and Foreign Commerce on May 23, 1969, Hon. Paul G. Rogers, Acting Chairman of the Subcommittee, requested that I submit to the Subcommittee Underwriters' Laboratories Requirements for Control of X-Radiation Emission from Television Receivers. Because we have been in the process of changing our requirements and measuring procedures for x-radiation from television receivers, we have delayed until now to send you this information.

The statement attached to this letter represents the requirements that are now in effect for the investigation of television receivers in order to determine their eligibility for Listing. Modification of these requirements are under consideration and are expected to be put into effect in the near future. If you desire more information on this subject, please let us know.

Very truly yours,

A. W. SMOOT, *Research Engineer.*

UNDERWRITERS' LABORATORIES' REQUIREMENTS FOR CONTROL OF X-RADIATION EMISSION FROM TELEVISION RECEIVERS

182. *X-radiation test.*—The X-radiation of an appliance, when measured as described in paragraph 183, shall not exceed a dose rate, averaged over an area of 10 square centimeters, of 0.5 milliroentgens per hour at any external location five centimeters from the outer surface of the overall enclosure of the appliance.

183. X-radiation measurements are to be made with suitable measuring instruments,[1] under the following conditions:

A. The appliance is complete, except mechanical parts that need to be removed during user servicing may be omitted if they are, (1) not necessary for the functioning of the appliance, (2) not exposed to view during normal operation, and (3) not held captive by a chain, hinge, loose rivet, etc.

B. The voltage of the supply circuit is 130 volts if the rating of the appliance is within the range of 105–130 volts, and 260 volts if the rating of the appliance is within the range of 210–260 volts.

C. After measurements have been made with the supply voltage specified in Item B, the supply voltage is adjusted to any other voltage within the mentioned ranges that results in greater X-radiation.

D. All controls that can be adjusted without major disassembly of the appliance (such as the removal of a chassis) are to be adjusted to cause maximum X-radiation during appliance operation with acceptable sound and viewable picture that (1) is in synchronization, (2) presents viewable although perhaps poor quality intelligence, and (3) fills the viewing area.

E.[2] In addition to the adjustments described in Item D, all controls, regardless of location, are adjusted for maximum X-radiation during appliance operation with acceptable sound and a usable picture.

F. Unless it has been investigated and found to be reliable, a rectifier, tube, protective device (fuse, circuit breakers, etc.), electrolytic capacitor, transistor or other solid-state device is disabled singly (short circuited for electrolytic capacitor, opened for protective device, and short circuited or opened for others), unless disabling the components does not permit operation with acceptable sound and a usable picture.

[1] To become effective Apr. 1, 1970.
[2] In UL's tests to date, a Victoreen Model 440RF survey meter has been used.

G. For a multiple-function appliance, measurements are made with the appliance in any mode of normal operation, such as one with a video-tape playback unit operating at any one of its speeds that will produce a usable picture.

H. When measuring X-radiation, picture information is injected into the appliance through the antenna terminals by means of a suitable signal generator. The picture display is to be a vertical bar or checker-board test pattern of symmetrical and approximately equal black and white areas. The minor dimension of the white area measured is to be larger than the window of the measuring equipment.

183A. *X-radiation under servicing conditions test.*—Unless there is a suitable marking to warn service personnel of the potential X-radiation hazard, the appliance shall comply with paragraph 182 (X-radiation test) under all conditions of a serviceman's servicing. See paragraph 403 (X-radiation under servicing conditions marking). Serviceman's servicing includes the removal of shields, windows, cages, covers, with or without the chassis removed from its enclosure.

403. *X-radiation under servicing conditions marking.*—Appliances that do not comply with the requirements of paragraph 183A (X-radiation under servicing conditions test) shall have a suitable warning located on the chassis where readily visible during servicing. The marking shall be legible and permanent, in letters not less than 7/64 in. high, and consist of the following or the equivalent, "Serviceman—Warning—To avoid possible exposure to X-radiation, take X-radiation protective measures (see service manual) for personnel during servicing."

404. The service manual should point out X-radiation generating parts and guide the serviceman as to the proper precautions to take during servicing, e.g., wearing protective clothing, etc.

Mr. ROGERS. Any other questions?

Thank you very much. You have been most helpful.

This will conclude the hearings at this point.

(The following letters were received for the record:)

THERMO-KINETICS, INC.,
New Iberia, La., June 6, 1969.

Congressman PAUL ROGERS,
Rayburn House Office Building,
Washington, D.C.

DEAR CONGRESSMAN ROGERS: It was a pleasure to talk by telephone with you today concerning microwave ovens and the possible hazards in door leakage involved. As I mentioned to you on the telephone, we conducted several tests here attempting to cook eggs out in front of the microwave oven with the door open. The exact data that we took are as follows:

With our oven which is nominally a two kilowatt oven, an egg can be soft boiled in the center of the cavity with the door closed in about ten seconds. When we open the door the time required to cook the egg went up to two minutes and thirty seconds. This of course is because most of the energy is radiated into space and essentially makes only one pass through the egg rather than multiple passes through the egg which it would make if the door was shut and the energy was bouncing back and forth in the cavity. If we move the egg from the center of the cavity to the front edge of the cavity with the door open, the time required to soft boil it goes up to ten and a half minutes. With the egg eight inches in front of the door and the door open we cooked it for twenty-six minutes after which time the half of the egg facing the cavity was partially cooked, the half of the egg away from the cavity was uncooked. Then we moved the egg out eighteen inches in front of the oven, left the door open with full two kilowatts operating and exposed it for one hour. At the end of this period of time the average temperature of the egg had risen approximately three degrees centigrade and there was no evidence of any cooking. The only evidence of anything was that the yolk was beginning to dry out slightly.

As a comparison test we put an egg six inches from a 250 watts reflector flood lamp and exposed it for thirty-five minutes after which the egg was literally burned to a crisp. I suppose that the conclusion here is that if one uses the rate at which an egg can be cooked as a safety indicator our oven with the door wide open and operating as is safe as or safer than a 250 watt reflector flood lamp.

As we discussed it is my opinion that the ten milliwatt per square centimeter safety level generally accepted by industry has a tremendous safety factor built into it. As evidence of this I point out that while we were exposing an egg for a solid hour in front of our oven with the door open we were generally working within eight to ten feet of the oven and were undisturbed by the energy. It has also been our experience that the field intensity has to get up to somewhere between twenty and thirty milliwats per square centimeter before we begin to feel it, and up into the order of a hundred milliwatts per square centimeter before it becomes uncomfortable.

As you pointed out, I am sure there are cases where persons have been injured by extremely high powered radar systems. On the other hand, insofar as I have been able to find out from my associates within the industry there has never been a case that we know of, of a microwave operator accidentally being injured by unsuspecting radiation from the unit. We feel that if there is any living testimony to the safety factor built into the ten milliwatt square cenimeter level that that is it.

Again, let me emphasize that we are extremely interested in cooperating and helping in every way possible to see that reasonable and appropriate safety standards are established particularly in respect to measurement technique, instrumentation calibration. On the other hand, it would be of considerable value to the industry, particularly to small companies such as ours, if all the regulatory agencies involved in microwave ovens such as Federal Communications Commission, Underwriters Laboratories, National Sanitation Foundation and Health, Education and Welfare would all get together and agree on standards and specifications that are either consistent or at least compatable with one another. We find for example to make a design change on a microwave oven even if it improves the product, requires so much retesting and recertification that the cost of improving the product for a small company becomes prohibitive. Another thing that hurts a small company such as ours quite seriously is for adverse publicity to be circulated around the country concerning hazards of microwave ovens or potential dangers of mysterious radiation leaking from microwave ovens certainly to a restauranteur or a person who is not engineering or biologically oriented words like 'potential hazard' and 'radiation' can generate substantial fear which serves no purpose except to retard the development application and utilization of the microwave oven.

The enclosed brochure will tell you a little about the product that we are currently manufacturing. I do hope that you will keep me in mind and keep us informed on developments in your committee. We stand ready to help and cooperate in any way possible.

Sincerely,

MARK R. PHARR JR., *President.*

UNDERWRITERS' LABORATORIES, INC.,
Melville, Long Island, N.Y., August 7, 1969.

Subject: Underwriters' Laboratories requirements for control of X-radiation emission from television receivers.

Hon. PAUL G. ROGERS,
Acting Chairman, Subcommittee on Public Health and Welfare, Committee on Interstate and Foreign Commerce, Rayburn House Office Building, Washington, D.C.

DEAR MR. ROGERS: In reply to your letter of July 24, the Victoreen meter referred to in our requirements is the same meter that has been selected by the Electronics Industries Association as their primary measurement meter. The personnel at the Bureau of Radiological Health uses this same meter for many of their measurements of X-radiation from color television receivers, but this is not the only instrument that they employ. I am not aware that they have standardized on a single design of instrument.

In reference to your request for samples of warning labels and repair manual handbooks, the warning labels that are located on the television receiver will have the exact wording that is specified in paragraph 403 of our requirements. I have not enclosed any samples of these labels because I do not have any in my possession at this time. I have enclosed with this letter a copy of a page from a manufacturer's service manual, which covers a color television receiver. The information on this page is for the purpose of assisting the serviceman to accomplish troubleshooting and servicing of the receiver without subjecting himself and others to excessive X-radiation.

In my letter to you dated July 17, I stated that the statement attached to this letter represents the requirements that are now in effect for the investigation of television receivers in order to determine their eligibility for listing. I have been reminded that this statement is overly optimistic and that not all of these requirements are in effect as of this time. Changes are now being made in the performance characteristics of the glass that forms the faceplate of the color picture tube and when these changes have taken place, the manufacturer should have no difficulty in complying completely with the requirements. Because there has been some delay in producing the new picture tube in sufficient quantity to supply all television receiver manufacturers, the time for complete compliance with these requirements by all manufacturers will be some time in the near future. It is our intent to make these requirements effective at the earliest possible date.

Very truly yours,

A. W. SMOOT,
Research-Engineers.

SAFETY NOTE

SERVICE PROCEDURES TO MAINTAIN SOFT X-RADIATION PROTECTION DESIGN STANDARDS IN PHILCO-FORD COLOR TELEVISION RECEIVERS

Service technicians engaged in the service and repair of Philco-Ford color television receivers should observe certain procedures to maintain protection against soft X-radiation. Philco color receivers are designed and manufactured to limit soft X-radiation below certain specified levels. These levels are in accordance with the standards established by the National Council on Radiation Protection and Measurement (NCRP) and by Underwriters' Laboratories.

The three primary sources of soft X-radiation in a color television receiver are the pictutre tube, high-voltage rectifier tube and, in those sets which incorporate it, the high-voltage regulator tube. The amount of radiation is dependent upon, among other things, the setting of the high voltage.

1. High-voltage setting.—One of the first steps in servicing the color receiver should be to check the setting of the high voltage to assure that it is set in accordance with the specifications for the particular chassis and not above it. It is important that the setting be made as specified in the Philco service literature and for the specific operating line voltage with a reliable and accurate voltmeter. For example, the specifications for Philco chassis type 18QT85 is 26 kilovolts at 120 VAC with zero beam current (brightness turned off.)

When returning the chassis to the customer's home after shop service, the technician should again check and set the high voltage. There can be a variation between shop test setup facilities and the CRT assemblies in the customers set. This is particularly so in those cases where the technician employs a "universal" test setup.

Philco receivers without shunt regulator

[In kilovolts]

Measured a.c. line voltage:	*High voltage adjustment* [1]	Measured a.c. line voltage:	*High voltage adjustment* [1]
105	23	120	26
110	24	125	27
115	25		

Philco receivers with shunt regulator

[In kilovolts]

Measured a.c. line voltage:	*High voltage adjustment* [1]	Measured a.c. line voltage:	*High voltage adjustment* [1]
105	21	120	24
110	22	125	25
115	23		

[1] Tolerances: (−1,000 volts to +0 volts).

Following the final adjustment of the high voltage, its regulation should be checked by rotating the brightness control through its entire range while observing the voltmeter connected to the high voltage test point. The high voltage reading should not exceed the limits specified at zero beam current (brightness turned off).

2. *Shielding.*—When testing a chassis with power "on", the technician must be certain that all of the shields provided by the manufacturer are in place. These shields not only provide shock hazard protection, but when required, radiation protection as well. If a set is received for service with a missing shield, it must be replaced as a normal service procedure.

3. *Trouble shooting in the high voltage section.*—When trouble shooting inside the high voltage cage, the set should be inoperative. The door of the cage or shield should be closed whenever "hot checks" (operating test runs) are performed.

4. *Replacing high voltage rectifier and regulator tubes.*—When replacing high voltage tubes in either the regulator or rectifier stages, use only those tubes specified by the manufacturer. Be sure that any shields provided for these tubes are replaced or restored to normal condition.

(Whereupon, at 2:45 p.m., the committee adjourned.)

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