



MonH-215

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Contract No. W-35-058, eng. 71

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HEALTH PHYSICS DEPARTMENT

REPORT FOR MONTH ENDING NOVEMBER 30, 1946

**DECLASSIFIED** Per Letter Instructions Of  
*AFC 4-6-53*

K. Z. Morgan

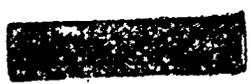
*md for  
5/29/53*

*N.T. Bray*  
SUPERVISOR GENERAL FILES  
ORNL

Date Received: 12/4/46

Date Issued: 12/9/46

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November 30, 1946

CLINTON LABORATORIES

MonH-215

HEALTH PHYSICS DEPARTMENT

by

K. Z. Morgan

A radioactive phosphorous solution reacted more violently than usual in the hot laboratory of the isotope separation building (706-D) and it was rushed to the decontamination room. Here it spurted up on the floor and ceiling and contaminated the clothing of several persons.

A heating unit in cell 1 of room 2 in the Chemistry building failed, causing a uranium solution to crystallize. Attempts to remove this solid caused several cases of contaminated hands and clothing and resulted in a spill on the floor which read 5.5 r/hr at 1 foot distance.

Films worn on the hands of the persons preparing the radium sources in building 204 do not indicate gamma exposures in excess of 5 mr per person for each source prepared.

Mr. J. C. Hart has been made supervisor of the Personnel Monitoring Group. He has eliminated the 12:00 to 8:00 a.m. shift and has placed male supervisors in charge of the other two shifts. These changes have made it possible to increase the duties of this group without adding additional manpower.

A number of the latest type of Victoreen pocket meters are on test. These meters contain the desiccant in a plastic capsule so it cannot sift out causing the instruments to leak and the threads of the meter cap to bind. The new meter cap is of the plug type and is held firmly in place by a polyethylene ring.

Mr. L. J. Deal has made an analysis of the pocket meter data of Clinton Laboratories since operations began in 1943. An examination of the data indicates that 922,898 meters had been read by November 1, 1946. Of this number, there were 42,074 single meters that read off-scale or greater than 200 mr. There were 2,030 pairs of meters that read off-scale. If all the double off-scale readings were due to the random chance of single meters reading off-scale, the expected number would be 959. Therefore, a little more than half of the off-scale double readings are due to radiation or to the fact that the factors which cause the discharge of one meter are not independent and are likely to cause the discharge of the pair if one meter is discharged.

The enclosed graph indicates that there are more false pocket meter readings during the summer months and that humidity is partly responsible for these false readings. The percent of high single and double pocket meter readings has been higher at Clinton Laboratories than at Hanford Engineering Works for several reasons, some of which are: (1) Higher humidity, (2) More radiation exposure, (3) Older meters with a constant meter shortage, and (4) Possibly less efficient pocket meter service at Clinton laboratories.

CLINTON LABORATORIES

MonH-215

HEALTH PHYSICS DEPARTMENT

K. Z. Morgan

DISTRIBUTION OF EFFORT FOR THE MONTH OF NOVEMBER, 1946

<u>Personnel</u>	<u>Monthly</u>	<u>Weekly</u>
Physicists (Assoc., Sr. & Prin.)	9	0
Chemist, Elect. Engr., H.P. Supv., Adm. Asst., Assoc. Chem.	5	0
Jr. Physicists & Research Assistants	24	0
Jr. Chemists	1	0
Laboratorians, Technicians & Clerical	0	31
	<u>39</u>	<u>31</u>

Number of Technical personnel added during month: 0

Number of Technical personnel terminated during month: 0

Allocation of time during November in Man-months:

Services

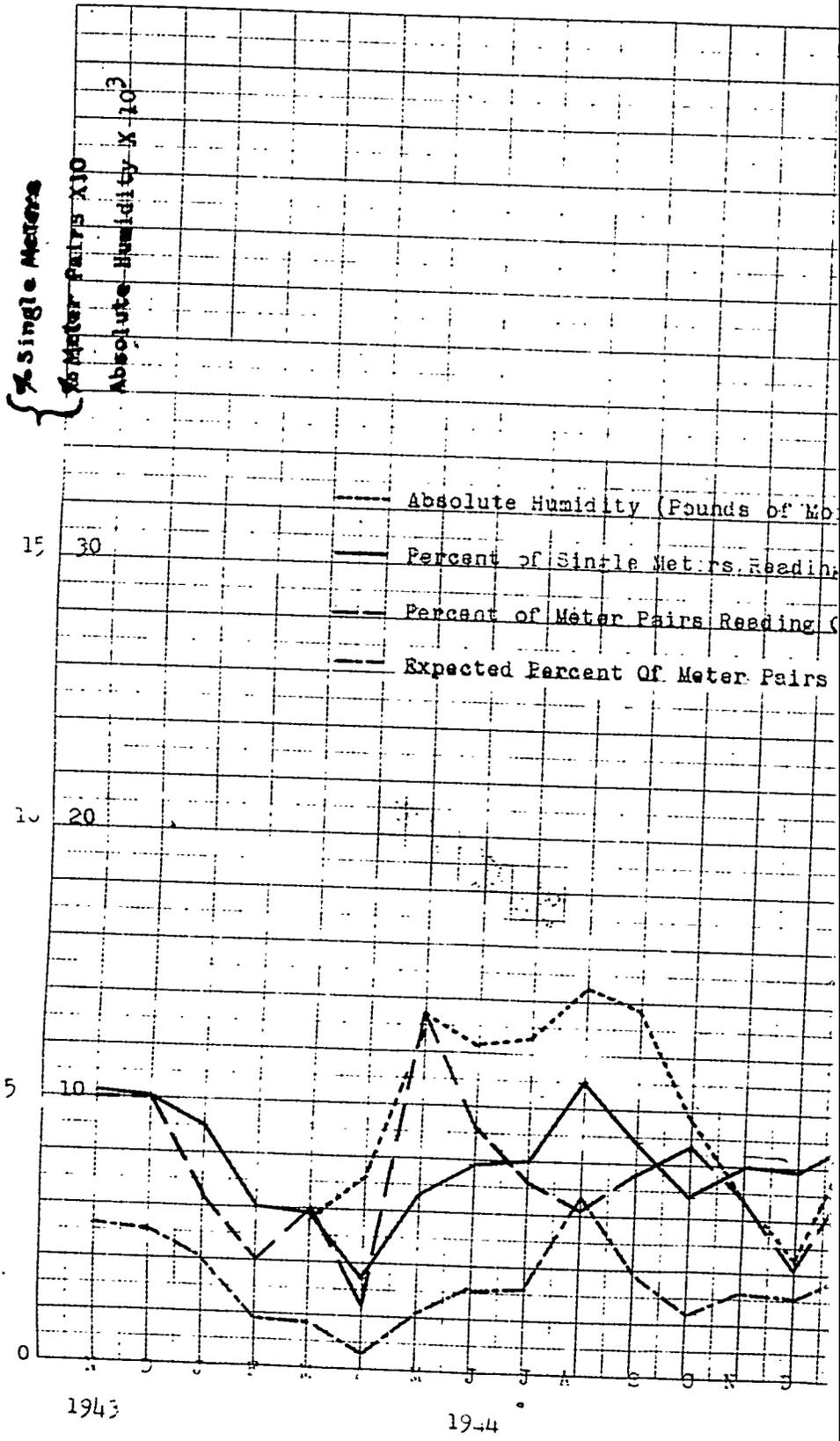
Pocket meters	2	8
Badge and ring meters	1	7
Neutron films	0	1
Hand, shoe and glove counts	0	1
Laundry counting	1/2	3
Instrument calibration and repair	1	2
Surveys - 100 Area and 706-B	2	0
Surveys - 200 Area	1	0
Surveys - 706-A	3	2
Surveys - 706-C, D	5	1
Surveys - Construction Area	1/2	0
Mud, water and Air Surveys	2	0
Consultation	1	0
Technical Instruction	1/2	0
Trainees	2	0

Research & Development

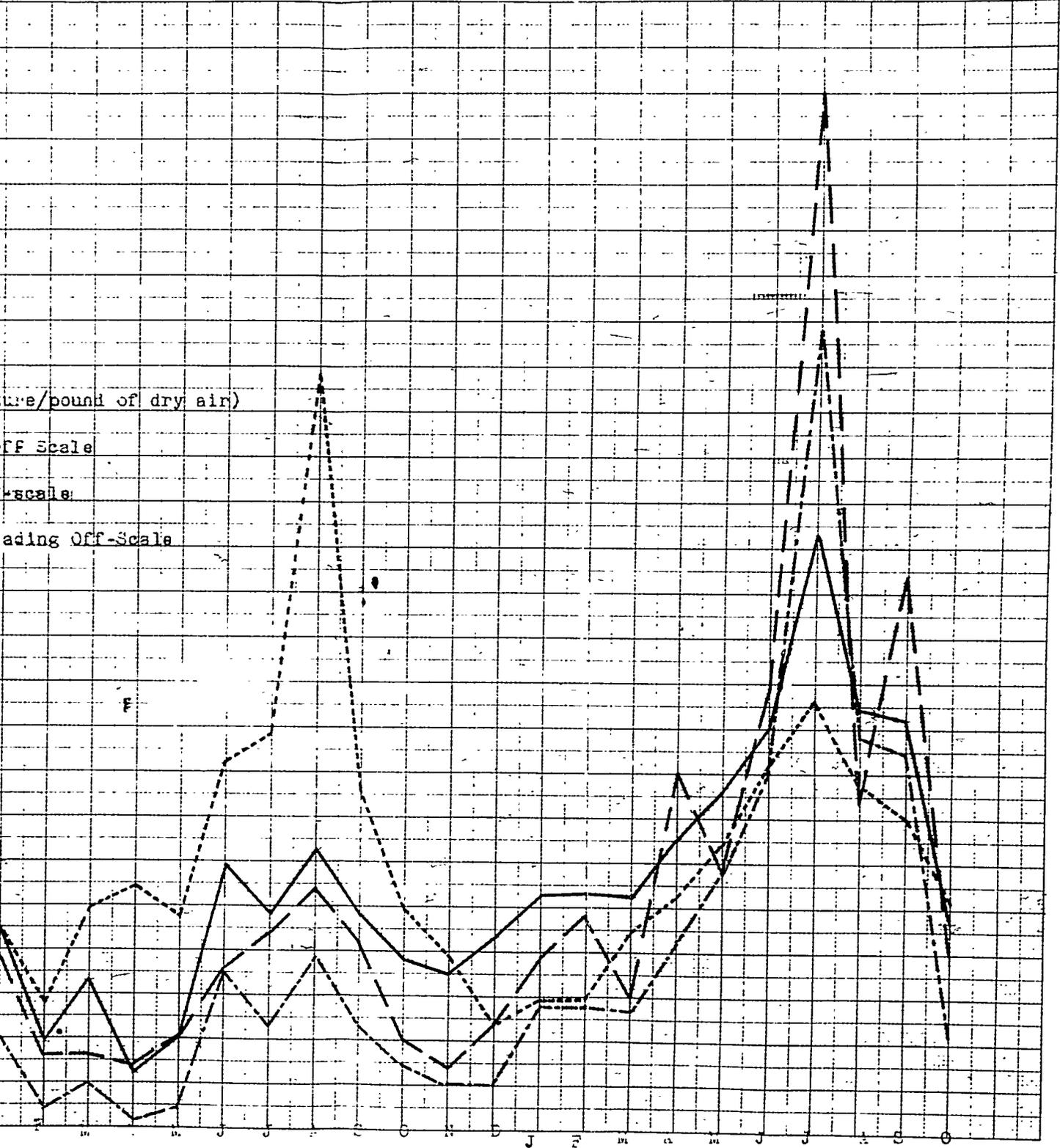
Improvement and development of instruments	2 1/2	0
Instrument tests	1 1/2	0
Physio-chemical effects of radiation	1 1/2	0
Neutron studies	1 1/2	0
Methods of detecting radioactive products in urine	2	1
Preparation of P.P.R.	1 1/2	0
Special problems and consultation	2	0
Development of laboratory facilities	1	0
Technical Instruction	1 1/2	0
Graduate School	2	0

Administrative

Office Personnel	3	0
<u>Vacations and leaves of absence</u>	0	4
	<u>1</u>	<u>1</u>
	<u>39</u>	<u>31</u>



#3085



ure/pound of dry air)  
Off Scale  
-scale  
Adding Off-Scale

1945

1946

Master Copy

MonH-247

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Contract No. W-35-058, eng. 71

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HEALTH PHYSICS DEPARTMENT

REPORT FOR MONTH ENDING JANUARY 31, 1947

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K. Z. MORGAN

**DECLASSIFIED** Per Letter Instructions Of  
AEC 4-6-53

Md for N.T. Bray  
5/24/53 SUPERVISOR CENTRAL FILES  
ORNL

Date Received: 2/5/47

Date Issued: 2/5/47

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January 31, 1947

MonH-247

Mr. L. J. Deal has made comparative tests of the average behavior of the old type Victoreen pocket meters and the new Victoreen pocket meters. They were dropped on end from a height of five feet. The dessicant and retainer ring were removed from the new Victoreen meters for this test because preliminary experiments indicated that they would slide out of place and completely discharge the meter by contacting the central electrode. Exclusive of complete discharge, the old meters discharged 7.8 mr/drop and the new ones 4.9 mr/drop. When the meters were dropped on the side, 50% of the old ones and 10% of the new ones discharged completely. Most of the complete discharges seem to be due to bending of the central electrode so that it shorts against the chamber wall. When the meters were placed twenty minutes in a commercial shaker the old ones discharged 27 mr and the new ones 16 mr. The stationary leakage of the old meters was 2.3 mr/24 hrs and 1.1 mr/24 hrs for the new. The significance of the test is somewhat obscured by the fact that the old meters have been in service for a long time, but it is believed that the new meter is an improvement over the old one. Other improvements in the new meter include: 1) a one-piece electrode system which will eliminate trouble due to loosening end nuts, 2) a shorter electrode terminal that cannot be shorted accidentally in removing or replacing the cap, 3) a conducting inner liner to replace the flaking aquadag of the older meter, 4) a friction cap which eliminates aluminum slivers from the threads which discharge the old type meter, and 5) the dessicant is contained in a plastic capsule which prevents its sifting into the meter.

The process developed for the analysis of urine for plutonium is limited by the alpha activity of some of the reagents, particularly lanthanum. Precipitation methods largely remove the activity for a few days, but the parent element remains and the daughter activity builds up again after several days. E. R. Tompkins has removed the alpha contaminant by a resin column extraction (described in report CL-ERT-1) so that only 0.01 counts per minute per milligram remain and there is no appreciable alpha growth over a period of two weeks.

A large number of the shipping containers that are used for shipping of radioisotopes continue to be returned to Clinton Laboratories in a contaminated condition. Twelve out of fifty-five containers returned from January 1 through January 23 had to be decontaminated. Such contamination is contrary to the national shipping regulations, now being written, which prohibit any such contamination outside the container. An effort is being made to impress upon the recipients of the radioisotopes the importance of preventing the spread of this contamination.

Radiation measurements were made twelve feet from the center of the thermal column on top of the pile when it was operating at 3,900 kw. With the shutters out and the source in, readings were recorded of 143% of gamma tolerance, 629% of thermal neutron tolerance and 50% of fast neutron tolerance or a total of 822% of tolerance. A guard is posted to prevent anyone entering this area during operation of the thermal column.

CLINTON LABORATORIES

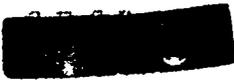
January 31, 1947

HEALTH PHYSICS DEPARTMENT

K. Z. Morgan

DISTRIBUTION OF EFFORT FOR THE MONTH OF JANUARY 1947

<u>Personnel</u>	<u>Monthly</u>	<u>Weekly</u>
Physicists (Assoc., Sr. and Prin.)	11	0
Chemist, Elect. Engr., H.P. Supv., Adm. Asst., Assoc. Chem.	5	0
Jr. Physicist and Research Assistants	25	0
Jr. Chemists	1	0
Laboratorians, Technicians and Clerical	0	31
	<u>42</u>	<u>31</u>
Number of Technical personnel added during month:	2	
Number of Technical personnel terminated during month:	0	
<u>Allocation of time during January in Man-months:</u>		
<u>Services</u>		
Pocket Meters	2	8
Badge and ring meters	2	7
Neutron films	0	1
Hand, shoe and glove counts	1	1
Laundry counting	1/2	2
Instrument calibration and repair	1	2
Surveys - 100 Area and 706-B	2	0
Surveys - 200 Area	1	0
Surveys - 706-A	3	3
Surveys - 706-C, D	6 1/2	0
Surveys - Construction Area	1/2	0
Mud, Water and Air Surveys	2	0
Consultation	1	0
Technical Instruction	1/2	0
Trainees	1	0
Plant H.P. Training	1	0
<u>Research and Development</u>		
Improvement and development of instruments	3 1/2	0
Instrument tests	1 1/2	0
Physio-chemical effects of radiation	1/2	0
Neutron studies	2	0
Methods of detecting radioactive products in urine	2	2
Preparation of P.P.R.	1	0
Special problems and consultation	2	0
Development of laboratory facilities	1	0
Technical Instruction	1/2	0
Graduate School	1/2	0
<u>Administrative</u>	2 1/2	0
<u>Office Personnel</u>	0	4
<u>Vacations and leaves of absence</u>	0	1
	<u>42</u>	<u>31</u>



MonH-263

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HEALTH PHYSICS DEPARTMENT

REPORT FOR MONTH ENDING FEBRUARY 28, 1947

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K. Z. MORGAN

**DECLASSIFIED**

Per Letter Instructions Of

AEC 4-10-53

7/29/53  
5729/53  
SUPERVISOR CENTRAL FILES  
ORNL

Date Received 3/4/47

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MonH-263  
February 28, 1947

The calibration curves which are used with each batch of personnel monitoring film (type 552) are constructed in practice from density readings of films which have been exposed to doses of several roentgens down to 100 mr and extrapolated from these to zero. The curves are normalized by adjusting the densitometer to read zero for a film that has not received any known amount of radiation. The question was raised as to whether or not one is justified in assuming that film density is directly proportional to roentgen exposure in the region below 100 mr where most of our radiation exposures occur. L. J. Deal and J. H. Roberson made careful measurements in this region and found no evidence of a threshold. The slopes of the curves from 0 to 100 mr, plotting density as a function of mr on Cartesian coordinate paper, were  $4.9 \times 10^{-4}$ ,  $6.8 \times 10^{-4}$ ,  $1.2 \times 10^{-5}$  and  $1.1 \times 10^{-4}$  density units per mr for the sensitive film with and without the 1 mm Cd shield and for the insensitive film with and without the 1 mm Cd shield respectively. These values of slope serve as justification for the practice of using films of two sensitive ranges. The average probable errors in reading the film over this range were  $\pm 4.5$  mr and  $\pm 6.0$  mr for the no shield and shield readings respectively. The probable errors when the films are read by the technicians are believed to be about double these values. Readings as low as 8 mr can be read with the densitometer if great care is taken. In practice, most of the film meters are worn for a one week period and little distinction is made between 0 and 10 mr readings which introduces a possible error of 2 mr/day. Exposures using an uncollimated radium source and a paraffin phantom (simulating a man) indicate a back-scattering of 5% to 10% for the shielded portion of the film and 25% for the film behind the open window of the badge. About 50% of the radiation is absorbed in passing through the phantom.

A new instrument has been installed in the laundry for making checks of the radioactivity from each incoming hamper of clothes. This instrument consists of a G.-M. tube and scaler with an output such that different colors of lights flash on for various counting rates. It reduces the time required to take a hamper count by a factor of six.

Two tantalum sources with a radium equivalent of about 8 curies each have been made available for laboratory use.

An instrument shop employee rang one of the portal octopus bells as he was passing out of the restricted area gate. His clothes were checked and spots on his coat were found reading 75 mr/hr at a distance of 4 inches. Such incidents justify the existence of the friskers and also emphasize the need for more persons to wear protective clothing.

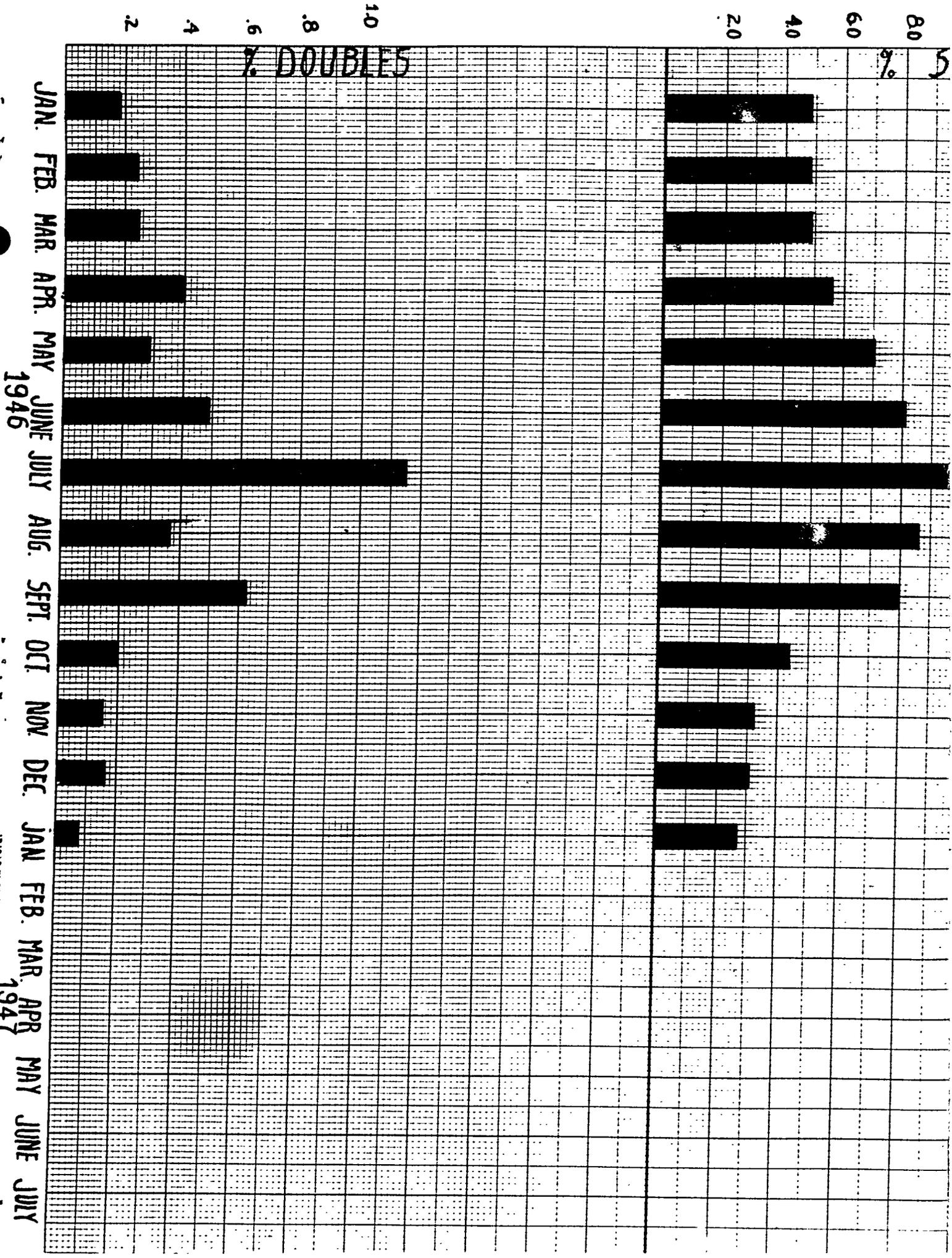
A spot on the floor in front of blister B-1 in the isotope building 706-D was found which read 33 roentgens/hour. It was cleaned up immediately.

Considerable effort has been spent assisting in setting up suitable laws for the shipment of radioactive materials. The present indication is that these new laws will be sufficiently conservative to prevent shipping personnel from accumulating overexposures but will be liberal enough not to impose undue hardships on the shipper. It is probable that the principal limiting factors will be: 1) There must not be more than 200 mr/hr at any readily accessible point on the surface of the package, 2) There must not be more than 10 mr/hr at a meter from the package, and 3) The exposure at 15 feet from the package during the period of shipment must not exceed 10 mr.

During February, 29,218 pocket meters were worn. Of this number 0.2% had lost caps, 0.1% had a lost pair and 0.4% were damaged, making a total of 0.7% that did not give recordable readings. The inclosed chart indicates the total number of pocket meters read during the past year, the percent of single off scale readings and the percent of double off scale readings. The large number of high readings during the summer months is partly explained by the high humidity at that time. The millionth pocket meter was read during the month.

DISTRIBUTION OF EFFORT FOR THE MONTH OF FEBRUARY 1947

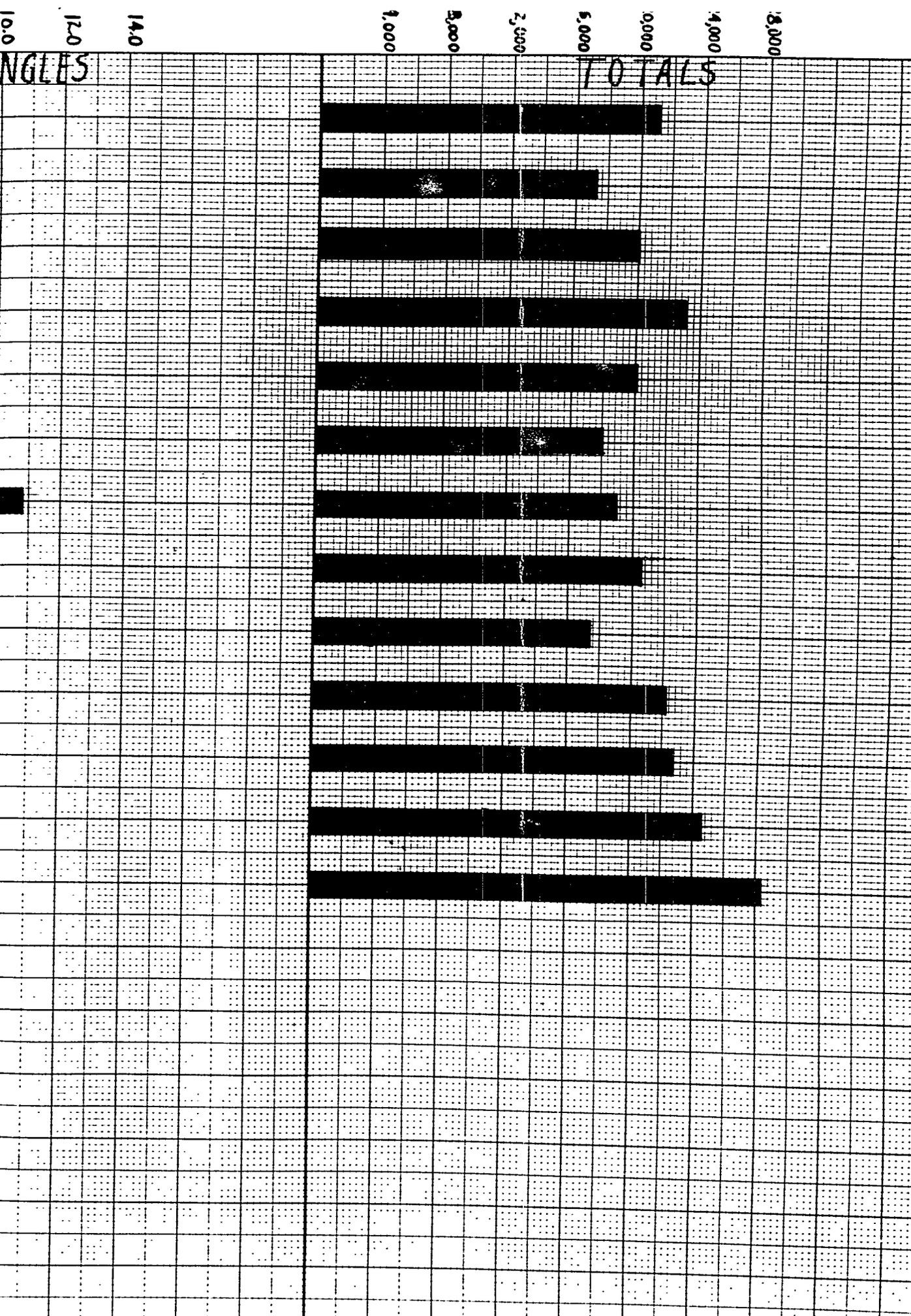
<u>Personnel</u>	<u>Monthly</u>	<u>Weekly</u>
Physicists (Assoc., Sr. and Prin.)	12	0
Chemist, Elect. Engr., H.P. Supv., Adm. Asst.	6	0
Jr. Physicists and Research Assistants	24	0
Jr. Chemist	1	0
Laboratorians, Technicians and Clerical	0	31
	<u>43</u>	<u>31</u>
Number of Technical personnel added during month:	2	
Number of Technical personnel terminated during month:	0	
<u>Allocation of time during February in Man-months:</u>		
<u>Services</u>		
Pocket Meters	2	7 1/2
Badge and ring meters	2	7
Neutron films	0	2
Hand, shoe and glove counts	1/2	1
Laundry counting and counting service	1	5
Instrument calibration and repair	2	2
Surveys - 100 Area and 706-B	2	0
Surveys - 200 Area	1	0
Surveys - 706-A	2	0
Surveys - 706-C, D	4 1/2	0
Surveys - Construction Area	1/2	0
Mud, Water and Air Surveys	2	0
Consultation	1	0
Technical Instruction	1/2	0
Trainees	3	0
Plxxt H.P. Training	1	0
<u>Research and Development</u>		
Improvement and development of instruments	3 1/2	0
Instrument tests	1 1/2	0
Physio-chemical effects of radiation	1/2	0
Neutron studies	2	0
Methods of detecting radioactive products in urine	2	2
Preparation of P.P.R.	1	0
Special problems and consultation	2 1/2	0
Development of laboratory facilities	1	0
Technical Instruction	1/2	0
Graduate School	1/2	0
<u>Administrative</u>	3	0
<u>Office Personnel</u>	0	4
<u>Vacations and leaves of absence</u>	0	1/2
	<u>43</u>	<u>31</u>



11-7082 NO. 7 A. M. CO. NY. N.Y.

11-7082 NO. 7 A. M. CO. NY. N.Y.

# POCKET METER PERFORMANCE CHART



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Contract No. W-35-058, eng. 71

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HEALTH PHYSICS DEPARTMENT

REPORT FOR MONTH ENDING MARCH 31, 1947

**DECLASSIFIED**

Per Letter Instructions Of

AEC 4-10-53

K. Z. MORGAN

*M.S. for N.T. Bray*  
6/25/53 SUPERVISOR CENTRAL FILES  
ORNL

Date Received: 4/2/47

Date Issued:

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During the four week period from February 16, 1947 to March 22, 1947 there were 78 cases in which either the pocket meters or film meters read greater than 250 mr per week. A study of these cases by L. J. Deal indicated that 23% were due to fogged film, contaminated film badges and/or processing errors. In 19% of these cases, the pocket meters were worn less than four times during the week. A comparison was made between the pocket meter and film readings from behind the cadmium shield of the meter of the remaining 58% of the cases and the pocket meter readings were about 25% lower than the film meter readings. This difference was to be expected from results of previous measurements.

A radiation survey was made of the 115 pile stack to determine the radiation hazards involved in the installation of navigation lights on top of the stack. In spite of the fact that the stack is discharging argon activity at the rate of about 500 curies per day, the activity measured with a Cutie Pie meter was a maximum of only 28 mr/hr at the top inside edge of the stack and near background outside and five feet below the top of the stack. A smear count taken from a smear made just inside the top of the stack read 19,000 counts per minute of  $\beta$  and  $\gamma$  activity.

From March 1, 1947 to March 26, 1947 there were 174 isotope carriers checked and/or rechecked for radioactive contamination. This checking of isotope carriers has required the services of two Health Physics surveyors almost full time. The proper surveying and smear testing of the isotope carriers is very difficult due to the high radiation background in the area. Plans are being made to construct a temporary low background building in which this work can be done.

Sand blasting has proved very effective in removing contamination from concrete. It gave better than a 50 fold reduction in surface contamination of the No. II cell walls in the 706-C hot Chemistry Laboratory.

A bottle of thorium carbonate was spilled on the floor of room 1-B of the semi-works. After using the vacuum cleaner and a floor mop, the air still indicated an alpha contamination 50% of tolerance. A complete painting by spraying of the room reduced the contamination to background.

J. S. Cheka is continuing to make tests of the fading of the latent image of the proton tracks in the alpha emulsion films. Using emulsions N4X17 and N4X18 and various developing techniques, he finds that the track fading can be reduced by a factor of three. A complete report is being prepared.

The report MonH-258 by J. S. Cheka and K. Z. Morgan, dated March 20, 1947, gives a discussion of the radioactive fission product contamination in the mud of White Oak drainage system.

The report MonH-218, Procedure for the Determination of Plutonium in Human Urine, by L. B. Farabee is ready to be issued.

DISTRIBUTION OF EFFORT FOR THE MONTH OF MARCH 1947PersonnelMonthly                      Weekly

Physicists (Assoc., Sr. and Frin.)  
 Chemist, Elect. Engr., H.P. Supv., Adm. Asst.  
 Jr. Physicists and Research Assistants  
 Jr. Chemist  
 Laboratorians, Technicians and Clerical

14	0
6	0
24	0
1	0
0	3.2
<u>45</u>	<u>3.2</u>

Number of Technical personnel added during month: 2

Number of Technical personnel terminated during month: 0

Allocation of time during March in Man-months:Services

Pocket Meters	2	7
Badge and ring meters	2	6 1/2
Neutron films	0	2
Hand, shoe and glove counts	1/2	1/2
Laundry counting and counting service	1	5 1/2
Instrument Calibration and repair	1	2
Surveys - 100 Area and 706-B	2	0
Surveys - 200 Area	2	0
Surveys - 706-A	2	0
Surveys - 706-C, D	3 1/2	0
Surveys - General Area	1	0
Mud, Water and Air Surveys	2	0
Consultation	1	0
Technical Instruction	1/2	0
Trainees	4	0
Plant H. P. Training	2	0

Research and Development

Improvement and development of instruments	4	0
Instrument tests	1 1/2	0
Special Chemical Studies	1/2	0
Neutron Studies	1 1/2	0
Methods of detecting radioactive products in urins	2	1 1/2
Preparation of P.P.R.	1/2	0
Special problems and consultation	2 1/2	0
Development of laboratory facilities	1	0
Technical Instruction	1/2	0
Assigned to Plant Management	1/2	0

AdministrativeOffice PersonnelVacations and leaves of absence

3 1/2	0
0	4
1/2	1
<u>45</u>	<u>30</u>

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CLINTON LABORATORIES  
Oak Ridge, Tennessee

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Contract No. W-35-058-eng-71

**DECLASSIFIED**

Per Letter Instructions Of

AEC 4-10-53

HEALTH PHYSICS DEPARTMENT

M.S. for N.T. Bray  
6/25/53 SUPERVISOR

Report for Quarter Ending August 31, 1947

by

K. Z. Morgan

September 1, 1947

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Date Received: 9/25/47

Date Issued: 9/15/47

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~~Defense of Government~~  
~~Confidential~~  
~~Security Information~~  
~~Atomic Energy~~



GENERAL

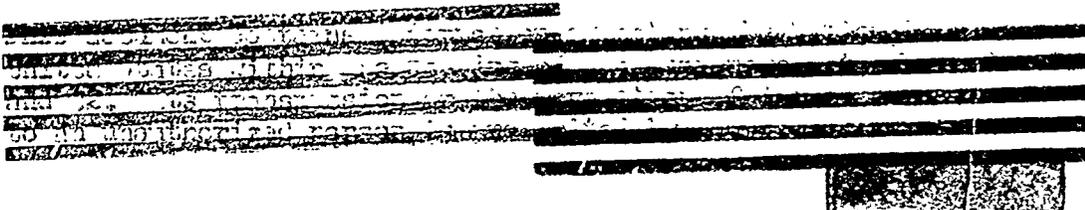
During the past quarter the Health Physics Department has continued to fall short of scheduled progress in the development of adequate facilities, staff, and program. This has been most pronounced in the Research and Development Section as noted below.

In addition to local demands on more experienced members of the department for consultation or information - one of the important functions of the department - demands from outside Clinton Laboratories have been particularly heavy, adding to difficulties of covering local demands. K. Z. Morgan has been active on or working with some eight national committees or subcommittees representing such groups as the National Research Council, the Bureau of Standards, the Bureau of Explosives, and the Atomic Energy Commission, and dealing with such subjects as the shipment of radioactive materials, instruments and techniques of radioactive measurements, radiobiology, tolerance for internal exposure to isotopes and tolerance for ingested alpha products. Additional demands on his time have come from more occasional requests from various governmental and industrial groups, universities, and other organizations confronted with radiation problems.

In the Service Section, much of the time of W. K. Fay, Section Chief, has been occupied with consultation work here and at other sites, while R. E. Hayden, O. D. Teague, and P. E. Brown have been loaned to other locations for short periods of time. Joe Deal has been loaned to Brookhaven for six months to set up a personnel monitoring system; and R. E. Hayden, formerly Supervisor of Area Surveys, and G. W. Morgan, formerly a Survey Group Leader, have been permanently released to the Atomic Energy Commission to fill positions requiring experienced Health Physicists.

In the Research and Development Section, J. H. Roberson, Experimental Group Leader, has been on loan to the University of Washington, contractor for a survey of Bikini, since June.

Security clearance has recently been obtained on Dr. Charles Perry, who will be assigned to the Service Section, and Dr. Francis J. Davis, who will be assigned to the Research and Development Section. Dr. Perry has had widely varied experience in administrative and developmental work in industry, and Dr. Davis has worked in the Radiation Section of the Bureau of Standards for the past several years.



In common with the remainder of Clinton Laboratories, we feel very keenly the existing delays, due to clearance and housing, incident to filling our acute personnel needs.

### RESEARCH AND DEVELOPMENT GROUP

Early in the year five junior men were shifted from the Research and Development Section because of conditions resulting largely from lack of working space and an adequate senior staff. It is felt that lack of definite prospects for laboratory space, until recently, have greatly augmented the difficulty of competing for able research and development personnel. During the past month, temporary space available to this group in Building 703-B has been approximately doubled, and with recent assurance of construction of a less temporary Quonset building for the Health Physics Department in the near future, efforts to augment the present skeleton staff are being renewed. Aid in the solution of some of the more urgent problems, such as the radioactive waste disposal problem, is being sought in the form of collaboration with the National Health Institute, the Tennessee Valley Authority, and other groups.

Much of the time of R. H. Firminhac, Section Chief, during the past several months has been devoted to the development of a Health Physics Instrument Shop. With the aid of Instrument Maker James Wilde, assigned to Health Physics by Research Facilities, it is felt that excellent progress in this direction has been made.

### Survey and Monitoring Methods for C<sup>14</sup>.

Mr. Firminhac has been investigating survey and monitoring methods for C<sup>14</sup>. Methods commonly used for other beta emitting isotopes are ineffective for C<sup>14</sup> because of the low maximum beta energy. For survey purposes, he has found it practical to use a Poppy with a probe containing argon with approximately 3 percent carbon dioxide. For this use, the probe is modified to make it gas tight with provision for running the gas mixture through it at a controlled, low rate. The nylon window presently used for alpha survey is satisfactory for the modified probe. Under proper conditions, propane gas may be used instead of the argon-carbon dioxide mixture, with a microburner to dispose of the effluent gas.

SECRET

Characteristics of Tissue Phantoms.

T. E. Bortner has been engaged in the study of the use of phantoms to simulate the physical interaction of tissue with gamma radiation. Factors studied include the composition of the phantom, using such substances as water, pressed wood, and a solution with approximately the percentages of chemical elements estimated for wet tissues in the body; geometrical conditions such as cross section and depth of the phantom and distance from radioactive source to phantom; and source energy, using as sources radium, cobalt, and antimony. Work is still in progress.

Monitoring for Neutrons.

J. S. Cheka has continued his study of the Eastman Fine Grain Particle Emulsion as an instrument for fast and slow neutron monitoring. The principal problems at the present time appear to be, (1) fading of tracks with time, (2) variation in sensitivity from batch to batch, (3) insensitivity, and (4) lack of a reproducible or even constant standard of fast neutron dosage. Efforts during the present quarter have been devoted to understanding and reducing the fading of tracks. Mathematical aid in investigating the hypothesis that, for given conditions of film manufacture and processing, the fading of an individual particle in any unit of time has a definite probability has been given by W. S. Snyder, Department of Mathematics, University of Tennessee, a consultant to this department.

M. M. Shapiro, of the Physics Division, in using lithium and boron impregnated photographic emulsions for another purpose, has given some consideration to the suitability of these emulsions for the monitoring of slow neutrons. Because of its potential interest to persons concerned with health monitoring, his discussion of the characteristics of these films is appended to this section of this report.

Product Determination.

L. B. Farabee has been principally engaged in putting the determination of plutonium in urine on a routine basis. The procedure used is the calcium oxalate one described in Report MonN-92.

Fifty-two analyses for plutonium were made on urine and blood samples from 39 persons exposed to plutonium. In only one case was a significant amount of plutonium found, and for this individual a subsequent check after two weeks gave a result only slightly above zero.

Possible interpretations are contamination of the first sample or very rapid elimination of a single comparatively large dose. Many difficulties arising in the process have been overcome. Efforts have been directed toward reduction of the background of the alpha counters. The normal background is now less than 0.15 counts per minute, but considerable trouble has been experienced with daytime disturbances which introduce unpredictable "counts."

Perhaps one-third of the time of Mr. Farabee and much of that of his assistant, Mrs. Pauline Blood, has been given to making lead determinations in urine and blood for the Health Department.

Miss Mary Jane Cook has continued work on the development of a practical procedure for the routine determination of uranium in urine. The copper ferrocyanide procedure now being studied appears promising but requires additional improvements to make it satisfactory.

#### Standard Air Chamber Measurements

P. W. Reinhardt has been engaged throughout the quarter in the design and construction (including shop work) of a manually controlled potentiometer and electrometer for standard air chamber measurements.

#### Improved Methods of Slow-Neutron Health Monitoring.

by Maurice M. Shapiro and John R. Barnes (Physics Division)

While using lithium-impregnated photographic emulsions for another purpose, it was found that the  $\text{Li}^6 (n, \alpha)$  and the  $\text{B}^{10} (n, \alpha)$  reactions provide two greatly improved methods of a slow-neutron health monitoring.

The present method\* of a slow-neutron monitoring employed in this laboratory depends on the  $\text{N}(n, p)$  reaction produced in Eastman "Special Fine-Grain Alpha-Particle Emulsions." This reaction is exothermic by 0.5 Mev. A proton of this energy typically creates a microscopic track 4 to 6 microns long, consisting of 3 to 6 silver grains. One-half the observable tracks consists of only 3 grains each, and hence are

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\* J. S. Chaka, "Neutron Monitoring by Means of Special Fine-Grain Alpha Emulsion Film," (memorandum), December 3, 1946

not easy to count. The number of tracks per  $\text{cm}^2$  obtained in a two-weeks' tolerance\* exposure is 4500. In terms of tracks per microscopic field of view ( $0.01 \text{ mm}^2$  in area) under high power magnification, this number is 0.45 track per field.

We have tried two kinds of emulsion of the new type C-2 manufactured by Ilford, Ltd., of London. One of these is impregnated with a lithium salt, the other with a boron compound. Both emulsions are 50 microns thick. When exposed to a source of slow neutrons, the Li-loaded plates show the  $\text{H}^3$  and  $\text{He}^4$  tracks arising from the  $\text{Li}(n, \alpha)$  reaction, which is exothermic by 5.3 Mev. Since the neutron contributes negligible kinetic energy, the two particles travel in opposite directions, producing what appears as a single composite track. The total track length consists of a  $46 \mu$  triton track and an  $8 \mu$  alpha-particle track. In the new Ilford emulsion both types of particles produce dense tracks, so that the composite track contains some 50 to 100 closely spaced silver grains. Consequently, the tracks are easily observed and identified not only because of their great length (about 10 times that of the proton tracks from nitrogen), but also because of their dense appearance.

Most important, however, is the high yield of these tracks. In a two-weeks' tolerance exposure,  $7.5 \times 10^3$  tracks/ $\text{cm}^2$  are produced. In terms of the same field of view described above, this is a density of 75 tracks per field, which is roughly 150 times the proton density obtained from the  $\text{N}(n,p)$  reaction. Thus, a two-weeks' tolerance dose can be measured with an accuracy of about 12 per cent by counting the tracks in a single field, an operation requiring about three minutes. If an actual exposure were considerably less than tolerance and it were desired merely to ascertain this fact, without actually measuring the dose, this could be done almost at a glance, certainly in less than a minute of microscopic inspection. Finally, if it were for any reason desired to measure a dose as low as one percent of a two-weeks' tolerance exposure, this could be done with an accuracy of some 20 percent by counting the tracks in about 35 fields. The track density in this instance is 3 tracks per 4 fields and the counting should require at most 5 to 10 minutes. Higher accuracies can, of course, be obtained by increasing the counting times.

The yield of tracks in the boron-impregnated emulsions exceeds the yield from the Li plates by a factor of 15. Multiplying this number by the factor 150 cited above, we see that a given dosage of slow neutrons yields more than 2000 times as many tracks as the Eastman plates now in use. These tracks, which are due to the alpha particles from the

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\* Currently considered to be 4700 neutrons/ $\text{cm}^2$ /sec for ten 8-hour days.

$B^{10}(n, \alpha)$  reaction\*, are only 5.5 $\mu$  long in the emulsion, one-tenth as long as the  $H^3-He^4$  tracks in the lithium plates, and about as long as the typical proton tracks from the  $N(n,p)$  reaction. Nevertheless, the alpha tracks are easier to detect than the proton tracks produced in the Eastman films. There are two reasons for this. First, the 1.6 Mev alpha particle emitted in the boron reaction ionizes more heavily in a given emulsion than a 0.5 Mev proton. Secondly, the same nuclear particle produces a denser track in the new Ilford emulsion than in the Eastman films currently employed\*\*.

Comparing the lithium-impregnated plates with the boron plates, it is clear that each possesses an advantage over the other. The lithium disintegration tracks are 10 times as long as those from boron, but the latter are about 15 times as numerous. For accurate measurement of exposures which are a small fraction of the two-weeks' tolerance dose, the boron plates will probably prove superior. For rapid health-monitoring surveys, the lithium plates may be more efficient. Either of these methods appears to be more sensitive by several orders of magnitude than the  $N(n,p)$  method. Their use should permit much higher accuracy, while reducing enormously the time and labor of microscopic track counting.

A more detailed report of this investigation is being prepared.

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\* The recoil path of the residual  $Li^7$  nucleus is too short to give a track.

\*\* It may be remarked that this property of the Ilford emulsions probably gives them an advantage over the Eastman films for fast-neutron detection as well, since the recoil protons produce denser tracks, and hence be more readily observed.

SERVICE SECTION

Routine activities of members of the Service Section are indicated in the Organization Chart and Distribution of Effort in the next section of this report. Some of the studies made by members of this section are considered to be of sufficient interest to report here.

Disposal of Radioactive Wastes in White Oak Basin and Clinch River.

A survey of the activity of the mud in parts of White Oak Basin, June 26, 1947, (Mary Buford to K. Z. Morgan, "Mud Assay for June, 1947") indicates increases in the specific activity of the mud of factors ranging from 5 to 15 during the preceding five months.

In cooperation with T.V.A., a radioactive survey of the Clinch and Emory Rivers within a radius of several miles of the town of Harriman was made June 3, 1947. (Mary Buford to T. H. J. Burnett, August 14, 1947.) Our interest in Emory River is due to the fact that, since the mouths of both lie in the Watts Bar Basin and the Clinch River is colder than the Emory River, water from the Clinch underlies Emory River water for several miles above its mouth.

Mud samples and five gallon water samples were taken at various points. Each five gallon sample of water was evaporated to one liter, filtered, and evaporated to dryness. The filtered silt and evaporated filtrate were counted. Backgrounds for comparison were established from four samples taken upstream on the Clinch River, in the vicinity of Norris Dam. Average values for these samples were one count per minute per liter of the original sample when counted as described above;  $2.7 \times 10^{-4}$  microcuries per gram of suspended silt; and  $1 \times 10^{-4}$  microcuries per gram of mud.

The averages of results from seven samples from the Clinch River were two times background for the activity of water, three times background for the activity of suspended silt, and approximately background for the activity of the mud. The averages of results from eight samples from the Emory River were below background (referred to samples from Norris) for water, two times background for suspended silt, and approximately background for mud. While these results are not alarming from the point of view of hazard to persons using water from the Clinch and Emory Rivers, in view of the philosophy expressed a few months ago by the Commission's Medical Advisory Board, they indicate that expanding operations will necessitate much more efficient removal of radioactive wastes from the effluent waters of Clinton Laboratories.

Dependence of Airborne Activity Upon Temperature Inversion and Wind Conditions.

A memorandum to W. H. Ray from T. H. J. Burnett, August 13, 1947, on this subject gives the results of observations made over a 70-day period from April 23 to July 1, 1947. At stations near Buildings 115-B, 735-B, and 706-A, the activity accumulated on a cylinder of filter paper, through which air was forced at a constant rate, was counted by a G-M tube and recorded continuously. Temperature inversion data from points at various elevations on the water tower were recorded by a micromax, and wind speed and direction were recorded from anemometer and windvane signals.

Temperature inversions were recorded for 49 of the 70 days. Marked increases in air activity were recorded for 47 of these, while for the other two no data on activity were collected. Of the 21 nights for which no inversion was recorded, in 10 instances no marked increase in activity was observed, while in 11 instances increases were observed. Mr. Burnett suggests that more complete temperature data might indicate some inversion beyond the range of the elevations used. He also suggests that the rate of decay of the activity on the filter papers after the end of an inversion period indicates that the activity is largely due to 110 minute argon.

Graphical records are appended to the memorandum.

Personnel Monitoring

Victoreen pocket meters of the type formerly used at Clinton Laboratories have been replaced by the new Victoreen 352. The new meter has a much lower probability of accidental discharge. Discharge due to dropping is reduced by a supporting insulator inserted at the middle of the central electrode as specified on the basis of studies made by L. J. Deal, and discharge by desiccant or desiccant retainer has been reduced by enclosure of the desiccant in a capsule and improvement of the retainer.

During the month of August, of 39,000 pocket meters worn, 332 gave off-scale readings. Only three of the 332 were paired with another meter giving an off-scale reading, so that under present conditions, nearly 1 percent of the meters worn are subject to complete accidental discharge.

Statistical studies of the comparative performance of meters with and without capsules of desiccant in their caps have been carried on through the past quarter. During the month of August, approximately

12,250 pairs of meters, one with and the other without desiccant, were carried and read. Of these, 7,167 pairs showed no readable exposure for either the meter with or the meter without desiccant. The total number of meters with desiccant which read zero was 8,772. Of the 8,772 non-desiccated meters paired with these and consequently assumed to have been subject to no significant radiation, 82 percent showed no readable exposure and 95 percent gave readings within the range of zero to 20 mr/hr. It appears that the desiccant was of no value in at least 82 percent of the meters tested. Further study of the data shows no significant difference between the performance of the meters with and those without desiccant.

DISTRIBUTION OF EFFORT FOR THE MONTH OF AUGUST, 1947

	<u>Monthly</u>	<u>Weekly</u>
<u>Personnel</u>		
Physicists (Assoc., Sr., and Prin.)	16	0
Chemist, Elect. Engr., H.P. Supv., Adm. Asst.	7	0
Jr. Physicists, Jr. Elect. Engr., and Research Assistants	23	0
Jr. Chemist	1	0
Laboratorians, Technicians, and Clerical	0	37
Trainee	<u>2</u>	<u>0</u>
	49	37
Number of Technical personnel added during month	2	
Number of Technical personnel terminated during month	1	

Allocation of Time During August in Man-Months:

<u>Services</u>		
Pocket Meters	2-1/2	8
Badge and Ring Meters	2	7-1/2
Neutron Films	0	2
Hand, Shoe, and Glove Counts	1/2	1
Laundry Counting and Counting Service	1/2	3-1/2
Instrument Calibration and Repair	1	3-1/2
Instrument Development	2	0
Surveys - 100 Area and 706-B	2	0
Surveys - 200 Area	2	0
Surveys - 706-A	3	0
Surveys - 706-C, -D	7-1/2	0
Surveys - General Area	2	0
Mud, Water, and Air Surveys	3	0
Consultation	2	0
Plant H. P. Training	2	0
Trainee	2	0
<u>Research and Development</u>		
On Loan to Brookhaven National Laboratory	1	0
On Loan to University of Washington (Bikini Expedition)	1	0
Improvement and Development of Instruments	1	0
Instrument Tests	1/2	0
Neutron Studies	1/2	0
Methods of Detecting Radioactive Products in Urine	2	2
Special Problems and Consultation	1-1/2	0
Assigned to Plant Management	1/2	0
Trainee	1	0
<u>Administrative</u>		
Office Personnel	3	3
Vacations and Leaves of Absence	<u>3-1/2</u>	<u>2-1/2</u>
	49	37

CLASSIFICATION CHANGED TO **TOP SECRET**  
BY AUTHORITY OF: *n Johnston T10-1116*  
BY: *11-29-58 mj*

MonH-446 *cy 3f*

CLINTON LABORATORIES  
Oak Ridge, Tennessee

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Contract No. W-35-058-eng-71

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HEALTH PHYSICS DIVISION

Report for Quarter Ending November 30, 1947

by

K. Z. Morgan

December 1, 1947

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Date Received: 12/9/47

Date Issued: 12/9/47



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DISTRIBUTION:

1. C. A. Hochwalt
2. 706-A
3. 706
4. 706-A
5. 706-B
6. Biology Library
7. Biology Library
8. Training School
9. Central Files
10. Central Files
11. Central Files
12. Central Files
13. Central Files
14. J. Murphy
15. M. Weinberg
16. J. Coe
17. J. S. Dalton
18. A. Hollander
19. K. Z. Morgan
20. H. L. Fisher
21. W. A. Johnson
22. E. Longacre
23. Gale Young
24. W. H. Bridges
25. C. Clinton Laboratories Division
26. A. Clinton Laboratories Division
27. Forrest Western
28. W. E. John
29. L. Farabee
- 30-37. Argonne National Laboratories
- 38-41. ~~Argonne National Laboratories~~
- 42-45. University of California Radiation Laboratories
46. New York Directed Operations
- 47-48. Hanford Engineer Works
- 49-50. General Electric, Schenectady
- 51-65. Technical Information Branch
- 66-68. AEC, Washington
- 69-72. Los Alamos
73. ~~Los Alamos~~

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## Health Physics Quarterly Report

December 1, 1947

I. General

During the past quarter several organizational changes have been made in the Health Physics Division. These have been designed to better integrate our activities and to make it possible to meet the increased local and outside demands for Health Physics services.

The Health Physics Service Section, of which W. H. Ray was Section Chief, has been reorganized into two separate sections--the Personal Monitoring Section, headed by J. C. Hart, and the Radiation Survey Section, headed by C. H. Perry. W. H. Ray's primary assignment now is to head and coordinate consultant activities of the Health Physics Division, both within Clinton Laboratories and with respect to other sites.

R. S. Thackeray has been given the special assignment of heading and coordinating the Health Physics Educational Program for Clinton Laboratories' personnel, as well as for approved trainees from other organizations that are concerned with radiation protection problems.

Representatives of the Atomic Energy Commission, the U. S. Public Health Service, and the Tennessee Valley Authority held conferences with the Health Physics Division of Clinton Laboratories during this quarter, preliminary to arranging for their participation in a training and research program in problems of radioactive waste disposal.

Conferences were held between representatives of the various instrument development companies and the Clinton Laboratories Health Physics Division regarding the development, improvement, and possible manufacture of certain radiation detection and monitoring instruments.

II. Research and Development Section

The construction of a new low-background type alpha counter, begun by R. H. Firminhac and continued by F. J. Davis, is complete. The final background obtained is approximately 0.1 count per minute, which is about the same as that achieved already by L. B. Farabee and by other investigators. A full report on this work is being prepared.

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In connection with the program for improvement of survey instruments, a study was made of the variation of sensitivity of six new cutie-pies produced in the Clinton Laboratories' Instrument Shop. The sensitivity varied between 74 and 140 mr/hr for full scale deflection on the most sensitive scale. The ratio of the resistances, accepting the manufacturer's value, appeared to be correct to within ten percent. The inconsistency is due to non-uniformity in amplification of the Victoreen electrometer tubes and of the high resistors.

The project to build our own breath-radon measuring equipment has been shelved for the present. To fill the immediate need, F. J. Davis has demonstrated proper breath-sampling technique to the Health Division and will continue to assist when necessary. Samples of expired air are sent to the Bureau of Standards for analysis.

Work has begun on a determination of total radioactivity in the air by R. H. Firminhac and F. J. Davis. The air to be analyzed will be drawn through a precipitator, a charcoal trap, and a trap at liquid air temperature. A pressure chamber, either with an electrometer or with a pulse counting circuit, will be used to measure the alpha and beta activity collected.

The neutron film study is being continued by J. S. Cheka. Recent results on the fading of latent images were presented at the Information Meetings on October 14, 1947. This data together with more recent results are outlined in Appendix I.

The effect of inserting a glass backed neutron emulsion into the film meter was investigated by J. S. Cheka. His conclusion was that 1 mm thickness of glass in the film meter changed the response to gamma radiation sufficiently to make the use of glass inadvisable. Detailed results are given in Appendix II. Perhaps it should be pointed out also that these film badges are frequently worn on the clothing backwards, and in such cases the glass backed film would seriously interfere with the open window beta ray readings. The present 0.010 inch cellulose acetate film base does not have sufficient rigidity for ease in counting neutron tracks, and it is for this reason that consideration was given to the use of glass backed film. Since the use of glass backed films has been ruled out, consideration is being given now to procurement of a neutron monitoring film using a 0.03 inch base.

At the request of Mr. Stapleton of the Biology Division, an estimate was made of the amount of scattered radiation to be expected outside the exposure cage which is being built at Y-12. Their arrangement was

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simulated in the Health Physics laboratory by T. E. Bortner and J. H. Roberson, and it was found that scattered radiation comprised less than 10% of the expected total. Similar experiments of a more general nature have been contemplated, and may be undertaken when better space and facilities are available.

A study of absorption of gamma rays in the walls of lead shipping containers is being made by J. H. Roberson, using a variety of radioactive substances. A simple means of calculating the absorption of the primary radiation and of the scattered Compton radiation has been developed, and the calculated results agree with measured results within acceptable limits. The experiments will be continued for several additional gamma ray sources and the results submitted in a separate report.

The free-air chamber has been completed by J. H. Wilde and P. W. Reinhardt, but is not yet operative. It is a replica of the Bureau of Standards' chamber. The high voltage supply, consisting of a 2 X 2 half-wave rectifier and a 2 C 53 regulator, has a voltage ripple of only 13 volts at 2200 volts output. A Lindemann electrometer with projected fiber-image is used in a null deflection circuit for chamber current measurement.

Minor design changes in Chang and Eng have been made by P. W. Reinhardt, and several members of the Survey Section have been instructed in its calibration and proper use.

#### Radioactive Waste Disposal,

by T. H. J. Burnett and R. H. Firminhas

General air activity in the neighborhood of Clinton Laboratories was not of serious level during the quarter, excepting for one instance, October 14, when a value of 82% of tolerance persisted several hours and three lesser instances in November, the worst of which was 62% of tolerance for two hours. These values are estimated from data supplied by outdoor continuous air monitoring equipment.

Waterborne activity surveyed during the quarter showed a quarterly average in gamma radiation of 0.107 mr/hr for water discharged from the Settling Basin into White Oak Creek, and of 0.009 mr/hr for the water flowing over White Oak Dam into the Clinch River. This reduction is accomplished by dilution, radioactive decay, and removal.

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Mud activity along the course of White Oak Creek as surveyed during the quarter shows no substantial difference from that found in the previous quarter and remains higher than at the corresponding date last year by a factor of about 10.

A memorandum to W. H. Ray from T. H. J. Burnett, September 10, 1947, gives the results of computations of a theoretical geometry from the dimensions of the constant air monitors as 17.3%. This was then checked by empirical methods using approximations of point sources of different activities and an average value of 17.2% obtained.

A memorandum to R. H. Firminhac from T. H. J. Burnett, November 3, 1947, gives the results of preliminary studies of the decrease in activity progressively in the water's course along White Oak Creek. When evaluation is given to the effects of successive dilutions obtained in the different parts of the drainage basin from watershed runoff of average rainfall, and the decay of short half-lived components initially present, the decrease observed in activity present per unit volume is accounted for with little if any decrease due to actual removal of activity. Mr. Burnett suggests that the lower dike across the creek be repaired to give an area of slow flow rate and permit settling, as an improvement to the present situation.

#### Analyses of Toxic Metals

by L. B. Farabee

The program of urinalysis for plutonium is now being carried out on a routine basis. The calcium oxalate procedure (Mon-N 92) is being used to isolate plutonium from urine samples. The Bismuth Phosphate method has been discontinued due to alpha activity in the Bismuth. All attempts to eliminate this activity so far have been unsuccessful.

Sixty-nine analyses for plutonium were made on urine of 63 persons exposed to plutonium. The results of these analyses are used to estimate a body content of plutonium on a basis of an elimination rate of 0.01% per day. None of the analyses indicate a body content in excess of 0.02 micrograms.

A consistently low background of alpha counters is necessary for determination of extremely small quantities of plutonium. Numerous changes in electric circuits and elimination of interfering electrical disturbances has resulted in a counter background of an average of approximately 0.12

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counts per minute. An isolated motor-generator set is to be installed soon to provide a supply of electric current for the alpha counters. It is hoped that a consistent and decreased alpha background can be achieved.

Lead analyses, in duplicate, were made for 32 urine samples and 13 blood samples. These analyses were performed as a service to the Medical Department and the results of the analyses were reported to them for their interpretation.

### III. Radiation Survey Section

#### Pile Area

The pile has been shut down approximately 40 times during the past quarter..

There are, on the average, 40 isotopes shipped from the 105 Building each month.

A biologist contaminated the south stairway of the building with active phosphorous. Some spots were found reading 3 r/hr. Several people received contaminated shoes because the contamination was not reported. The contamination was properly cleaned off the stairway by operations.

Only on one occasion during the quarter did the air activity for beta-gamma exceed tolerance ( $1 \times 10^{-7}$   $\mu$ c/cc of air). Two chemists, by improper handling of uranyl sulfate in a hood, caused the atmosphere of the room to exceed tolerance.

#### Chemistry Building

This quarter has been marked by a general increase in contamination at the first of the quarter and a successful effort, later, to prevent further contamination.

At the first of this period, three bad spills occurred in the semi-works; the highest reading 13 r/hr at 3 feet with a Cutie Pie W.O. Also, in one 15-day period, 15 pairs of shoes were contaminated.

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In Room 78 two body overexposures were received, and several overexposures of hands because of a faulty barricade. This was remedied with a new barricade and remote control apparatus.

There has been a large amount of new construction and maintenance work done in this building recently. Most of this has been done to correct heating and ventilating faults. The usual Health Physics safety measures were taken during the construction.

There was one fire in the building during this period. No active material was involved and air samples taken next morning as soon as power could be obtained showed no high air activity.

Throughout this quarter, only two air samples from the Chemistry Building showed serious air contamination. Neither of these was above tolerance.

#### 200 Area

The most outstanding radiation protection event in this area during the period was the work done on the 706-D off-gas system. The system had definitely been a radiation hazard prior to this time. Work done consisted of: 3/4 of an inch of lead shielding up to 12 feet above ground level added to the lines where they emerge from the ground at the southeast corner of the 205 building; the erection of a concrete block wall on the roof at the east end of 205 to shield the sampling area of the hot pilot plant; new steps up to the 204 level (away from the duct); and a fence which completely encloses the duct system, fans, and stack on the stack level. In addition to this, a concrete pad was poured under the jet systems at the stack to ease decontamination of the area in the event any of the jets leak again.

Repeated smear surveys and air samples taken in Cell 5 (isotope separation) convinced operations that changes should be made. The first change called for a hold-up of the waste sulfur in a tank vented to the off-gas system to allow fumes and vapors to pass off before the sulfur was drawn off to be discarded. This change dropped the air contamination hazard during this step from 768 percent of mask tolerance ( $10^{-8}$   $\mu\text{c}/\text{cc}$ ) to ~5 percent of tolerance (barring accidents or faulty functioning of the equipment). This improvement removed the great danger of excessive air contamination.

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Barium Separation (706-D)

On September 2, 1947, there was an  $I^{131}$  spill in North Hot Lab. The floor read 1 r/hr @ 3", and the work bench, 3 r/hr @ 3" C.P.W.O. Some of this solution dropped on Newton's arm, and he washed immediately. A count was made @ 1" with a scaler and it recorded 51,547 c/m, and at 2-1/4", 8229 c/m. On September 6, 1947, his arm was checked again @ 1", and read 19,518 c/m. On September 8, 1947, it read 4,527 c/m. On September 9, 1947, it read 2,057 c/m. After a considerable amount of washing and use of a chemical potassium Iodine, he lowered the count on his arm to below tolerance on September 10, 1947.

On September 5, 1947, a spill occurred in the West Hot Lab when E. C. Hendren dropped a bottle of  $I^{131}$ . The floor read 4 r/hr @ 4" C.P.W.O., and Hendren's shoes read 72 mr/hr @ 3" C.P.W.O. The shoes were confiscated and the West Lab decontaminated immediately.

A product carrier from the burial ground was placed in the decontamination room. After decontaminating the carrier, the reading was 9 r/hr @ 2 feet and at 6" the reading was 60 r/hr. Both readings were taken over the top of the carrier. After several days of work this carrier was cleaned below 12.5 mr/hr.

On September 13, 1947, H. T. Russell was found to have 4,556 c/m on his nose. The source of contamination was from  $P^{32}$  fumes from Cell 5 or from his gloves. He lowered this count below tolerance by washing.

On September 16, 1947, N. Hot Lab was restricted because of a sample behind the barricade reading 60 r/hr @ 1', and readings of 24 mr/hr at the west entrance to the Hot Lab.

On October 13, 1947, as Ba run #21 was nearing completion, it was discovered that a large portion of the final product was lost. A portion of the run was discovered in tank A-9 during a repeat run. Seemingly, it was coated to the sides of the tank and removed with the subsequent process in the tank. The final product was removed and shipped October 20, 1947.

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On November 5, 1947, J. T. Lemon's shoes were found to be reading 1.3 r/hr @ 1" C.P.W.O. This radiation was possibly obtained from the Sr set-up where he had been working.

Isotope Building (706-C)

A spill occurred at the doorway of Cell III, Bank I on September 19, 1947. The activity was mainly element-61 and, having an extremely soft beta radiation was difficult to detect. The area was immediately roped off and cleaned up with acids. The entire area was cleaned until < 200 c/m was counted on smears taken.

A high field of radiation was experienced during the handling of ten Th<sup>232</sup> slugs from Hanford, Washington, when brought to Building 706-C. These slugs were 3 months old and were very hot. Monitoring of this operation gave the following readings.

<u>Location</u>	<u>Geometry</u>	<u>mr/hr</u>
Carrier (top off)	@ 3"	25,000 (maximum)
Carrier (top on)	@ 3"	2,000 (maximum)
Carrier (top off)	@ 10'	1,400 (maximum)

An inversion or some type of unusual happening occurred over the week end of the 11th and 12th of October in room #12. All exhausts to the hoods, the hot sink exhaust, and the hot storage lab exhaust were seemingly blown back into the room. The degree of contamination in a clean hood, #15, was 150 mr/hr @ 3" of the floor.

The existence of a high field of radiation, of 3 r/hr @ 3" from the lines to tank W-11, finally lead to an excavation of an inspection hole to two lines leading to the tank farm from 706-D building. The radiation was found to be due to a partially clogged line and not a leak as previously thought.

General Area

Frequent surveys of the cafeteria and canteen show no radiation or contamination above background. Two tables from 735-B canteen were found to

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be slightly contaminated with beta and gamma, reading  $> 300$  c/m. Isolated spots of beta and gamma contamination were also found on the floor of 735-B canteen. The contaminated tables have been removed and thorough scrubbing has failed to remove the contamination from the floor.

Regular surveys are made of trucks, heavy equipment, tools, etc., which are used in the restricted area but are not assigned to that area. Only low level radiation was detected on any of this equipment. The contaminated items were sent to 101 building to be cleaned.

Core drilling has been in progress at the east burial ground by J.A. Jones Company. Close surveys have been made of equipment and the personnel have been provided with protective clothing. No radiation or contamination above background has been detected.

Twenty-four loads of alpha contaminated waste from Dayton were buried during this period. Highest beta and gamma reading on any of the material was 400 mr/hr @ 6" from one of the barrels, with C.P.W.O. Highest alpha reading was  $> 60,000$  d/m with Zeuto.

One shipment of alpha contaminated waste from Dayton, on November 14, 1947, had some barrels which were 'leaking, after the trucks left Dayton. One of the trucks was sent back, when the leak was discovered. The clothing of all the drivers was checked for possible contamination. One spot of alpha contamination was found on one of the drivers trousers, reading 15,000 d/m with Zeuto.

#### IV. Personnel Monitoring Section

From a review of the records of pocket and film meter readings for the 26-week period, December 28, 1946 to June 28, 1947, the probable maximum and minimum values of the average daily gamma ray exposure has been calculated. The results, shown in the table below, are based on the records of 1,489 individuals who wore personnel monitoring meters and were employed at Clinton Laboratories for all or part of the 26 weeks.

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Probable Limits of Average Daily Exposure  
(All values listed are in milliroentgens)

	<u>From Pocket Meter Readings</u>	<u>From Film Meter Readings</u>	
		<u>Open Window</u>	<u>Behind Shield</u>
Maximum Value	4.82	7.33	2.82
Minimum Value	2.83	1.57	0.52

The probable limits given in the table were calculated from the total exposure recorded for the individual in the following way:

$$\text{Minimum mr/day} = \frac{\text{Total Recorded Exposure}}{\text{Number Calendar Days}}$$

$$\text{Maximum mr/day} = \frac{5}{7} \frac{\text{Total Recorded Exposure}}{\text{Number of Days the Person Wore Pocket Meters}}$$

The minimum value calculated represents the average daily exposure if all exposures received by the person were recorded. Records indicate that pocket meters were worn on only 60% of the man-work days during the period. The maximum value is based on the assumption that the average meter reading represents the true average exposure.

The pocket meter values are believed to be the most reliable of those given in the table. The discrepancy between pocket meter and shielded film meter results arises from the greater sensitivity of the pocket meters in the range of low exposures. Film meters do not give significant readings for exposures less than 30 mr. Therefore, film meter records show zero, except for those weeks during which the wearer received an exposure somewhat greater than the average weekly exposure. The open window portion of the film meter has a very high response to soft gamma radiation, and the readings are not as accurate a measure of gamma ray exposure as are the readings of the shielded portion.

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The average pocket meter reading for each time worn was 6.74 mr. High readings due to leakage or meter failure have been practically eliminated. The ratio of pocket meter to film meter readings was 2.5, largely because of the inadequacy of the film meter in recording low exposure. A complete report of this personnel monitoring meter record is being prepared.

### V. Health Physics Consultant and Education Section

#### Consultant Activities

by F. H. Ray

The plans for the new Metallurgical Laboratory and Health Physics Laboratory quonset huts have been reviewed, leading to certain changes in the designs. This is in line with the proposed functions of this new office, which will consider Health Physics problems presented to the division by representatives of Clinton Laboratories and other sites with special emphasis on the review of building designs and problems related to plant construction. A number of other building plans are under consideration.

Some time during this period was also invested in consultant work on Contract AT-30-1-Gen-150.

#### Educational Activities

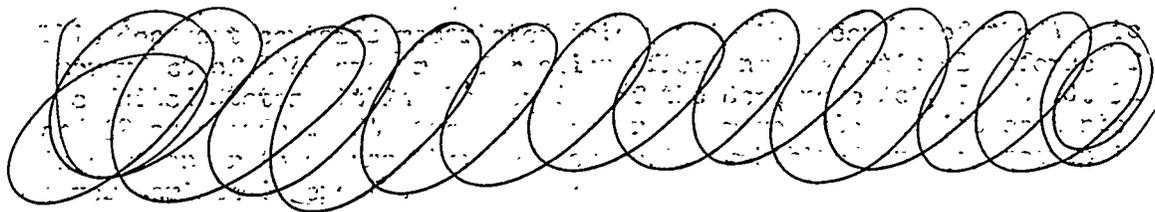
A six weeks' concentrated orientation program for Health Physics Radiation Surveyors, conducted by W. H. Ray, has just been completed. This course was designed to prepare radiation surveyors for apprenticeship at Clinton Laboratories and to allow other members of this division to broaden their knowledge in the field of Health Physics.

A number of temporary employees and non-employees were permitted to attend this orientation program. They included representatives from the A.E.C. Isotopes Division, Westinghouse Electric Corporation, Navy, Army, K-25, and the New York Directed Operations of the A.E.C.

The activities of the Plant Personnel Training Program were under the direction of R. S. Thackeray and G. C. Warlick. During this period,

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twenty-five Health Physics plant orientation and indoctrination sessions were held. Speakers were provided for a number of these sessions and the training strip film "Radiation and Health Physics at Clinton Laboratories" was used in others. In addition, Health Physics educational literature was distributed to Clinton Laboratories' personnel.



DISTRIBUTION OF EFFORT FOR THE MONTH OF NOVEMBER, 1947

<u>Personnel on Payroll for Entire Month</u>	<u>Monthly</u>	<u>Weekly</u>
Physicists (Assoc., Sr., and Prin.)	17	0
Chemist, Elect. Engr., H.P. Supv., Adm. Asst.	7	0
Jr. Physicists, Jr. Elect. Engr., and Research Assts.	24	0
Junior Chemist	1	0
Laboratorians, Technicians, and Clerical	0	42
	<u>49</u>	<u>42</u>
H. P. Trainees from other organizations	15	
Number of technical personnel added during month	1	
Number of technical personnel terminated during month	1	

Allocation of Time During November in Man-Months:

Services

Pocket Meters	1-1/2	11
Badge and Ring Meters	1-1/2	7
Pocket-Film Meters, Distribution, Repair and Calibration	1/2	2
Neutron Films	0	2
Hand, Shoe, and Glove Counts	0	1
Laundry Counting and Counting Service	1	6
Instrument Calibration and Repair	1	2-1/2
Surveys - 100 Area and 706-B	2	0
Surveys - 200 Area	1	0
Surveys - 706-A	3	0
Surveys - 706-C, -D	7	0
Surveys - General Area	2	0
Consultation	2	0
H. P. Education and Training	5-1/2	1

Research and Development

Waste Disposal Problems	3	1
On loan to Brookhaven National Laboratory	1	0
Improvement and Development of Instruments	2	0
Instrument Tests	1	0
Neutron Film Studies	1	0
Methods of Detecting Radioactive Products in Urine	2	1
Special Problems and Consultation	2	0
On loan to Health Department	0	1
Academic Leave-of-absence	2	0

Administrative

Office Personnel

Vacations and Leaves of Absence

	4-1/2	0
	0	5
	<u>2-1/2</u>	<u>1-1/2</u>
	49	42

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## APPENDIX I

The Investigation of the Fading of Latent Images of Neutron-Induced Proton Tracks in Special Fine Grain Particle Emulsions

by J. S. Cheka

The evaluation of fine grain particle emulsions for neutron monitoring using proton tracks from H recoils for fast neutrons and N (n,p) reactions for the thermal neutrons has been reported in a previous paper, 12/3/46. The present paper deals with a phase of this problem that had not been noted at that time.

Several Eastman alpha emulsions of the type NTA were investigated. A number of films shielded by four inches of lead were exposed together to fission neutrons of about 0.5 n-units (an n-unit being the dose of n<sub>f</sub> which will discharge a Victoreen r-meter as much as will 1 r of X-rays). The films were then developed after delay periods ranging from 0 to 58 days. Variations were also made in development techniques, i. e., Eastman's D-19 and Du Pont X-ray developer were used, and various development times other than those recommended were used. The films were read on a microscope with a dark field using a magnification of 900 X.

The several emulsions showed differing neutron sensitivities both as to track density and track length in terms of number of silver grains. A track is recognizable only if it has three or more grains in a row. Track decay is here defined as the decrease in the number of recognizable tracks per unit area in films developed after any time interval compared to the number per unit area due to the same exposure when developed immediately.

It was found that the decay rate of tracks was not uniform, but increased after a week or more, and also that this change of rate was less when the original tracks were longer in terms of the number of grains per track. It seems that the individual grains, originally sensitized are rendered undevelopable in the course of time, and consequently a longer track may lose a larger percentage of its grains before becoming unrecognizable.

The phenomenon has recently been studied by other observers working with fine grain particle emulsions. It does not occur in photographic emulsions, in which latent images have been noted to remain stable for years.

Dr. W. S. Snyder, consultant from the University of Tennessee, collaborating on this problem, calculated the probable rate of disappearance of tracks, assuming that individual grains decay at random with a uniform half life and that less than three consecutive developable grains remaining constitute the loss of a track.

Disappearance rate is expressed by:

$$A_n = qA_{n-1} + qpA_{n-2} + qp^2A_{n-3} \quad \text{for } n > 2.$$

Where n is the number of grains originally activated in a track

A<sub>n</sub> is the probability of loss of track of n grains.

## APPENDIX II

Effects of Glass in Badges, and Front and Rear Cadmium Shield  
Removal on Densitometer Readings of X-ray Films

by J. S. Cheka

Considerable time is spent by microscopists in mounting neutron films on glass slides for reading. This mounting is, in many cases, not satisfactory because even a slight convex buckling of the film takes it beyond light focus, since the total thickness of glass and film falls just within the focal distance of the dark field condenser. This necessitates a remounting of the film.

Other methods of holding without the use of glass were tried, but the flexibility of the film, and the high value of the surface tension of the immersion oil made focusing of the objective difficult.

The use of glass plates, cut to fit the badges, was considered to eliminate this difficulty. Consequently, a test calibration through 1000 mr was made of the standard X-ray films with glass behind them to determine scatter and/or absorption effects which might affect gamma exposure monitoring. At the same time exposures were made on X-ray films using the back of the badge without the front, and also using the front of the badge without the back. Blackening was read on the Ansco-Sweet densitometer.

The accompanying figure shows the effects of these exposures, compared to a standard calibration made with the complete badge. Only the readings on the sensitive film of the pack are shown. Darkening on the insensitive film in this range was too low to give significant readings.

As was expected, open window readings on films in the standard or complete badge, the badge without the back, and the badge without the front were essentially the same, so of the three only the standard was plotted. Open window readings on film backed by glass were  $\sim 8\%$  higher than the standard throughout the range measured. A cadmium sheet behind the open window increased the blackening by about 15%.

Blackening of the shielded portion of the film was lessened about 9% compared to the standard film meter by insertion of the glass plate. Removal of the back portion of the film badge, so that no material was present to contribute blackening due to backscatter, gave values coincident with those for the film meter containing glass. The inference from this data is that the glass gives no appreciable backscatter of the radium gamma rays which have been filtered through the cadmium shield on the front of the badge, but that the glass does absorb almost all of the soft radiation scattered back toward the film by the inner cadmium shield. In addition to shielding the film from scattered radiation, the glass serves to separate further the film from the scatterer.

From these results, it would appear that insertion of a glass plate into the film meter would reduce its sensitivity for gamma ray measurement. In addition, it would so screen the open window portion of the meter that it would record beta and soft gamma radiation coming from one direction only.

$p$  is the probability of activated grains remaining activated.

$q = 1 - p$  is the probability of activated grains not remaining activated.

Specific values were then calculated for  $A_n$  ( $n \geq 3$ ). For  $n = 3$ , the track density decreases with a half-life approximately three times shorter than that assumed for individual grains. For larger  $n$ , the decay rate is not exponential, but is slower at first, approaching an exponential decay rate after an initial slower rate.

It was also found that increasing the development time, while not affecting track density on immediate development, decreased the decay rate of recognizable tracks when the development of the films was delayed. Emulsion No. N4X17 developed in D-19 for 4, 5 and 6 minutes lost half latent tracks in 12, 16 and 23 days, respectively. Emulsion No. N4X18 when developed in D-19 for 4, 5 and 6 minutes showed half times of 14, 17 and 20 days, respectively. The limit of developing time is determined by chemical and dichroic fog, which appears with long development, and makes track counting difficult.

Du Pont X-ray developer brought out 10 to 20% more tracks at no delay, and was also found to decrease the decay rate. Emulsion No. N4X17 developed in Du Pont X-ray developer for 3, 4 and 5 minutes gave half times of track density in 15, 23 and 38 days respectively; N4X18 gave half times 15, 20 and 23 days respectively.

It was also noted that aging of the developer, even for short times, after mixing had a marked effect of decreasing its efficiency in bringing out latent tracks. This is being investigated further.

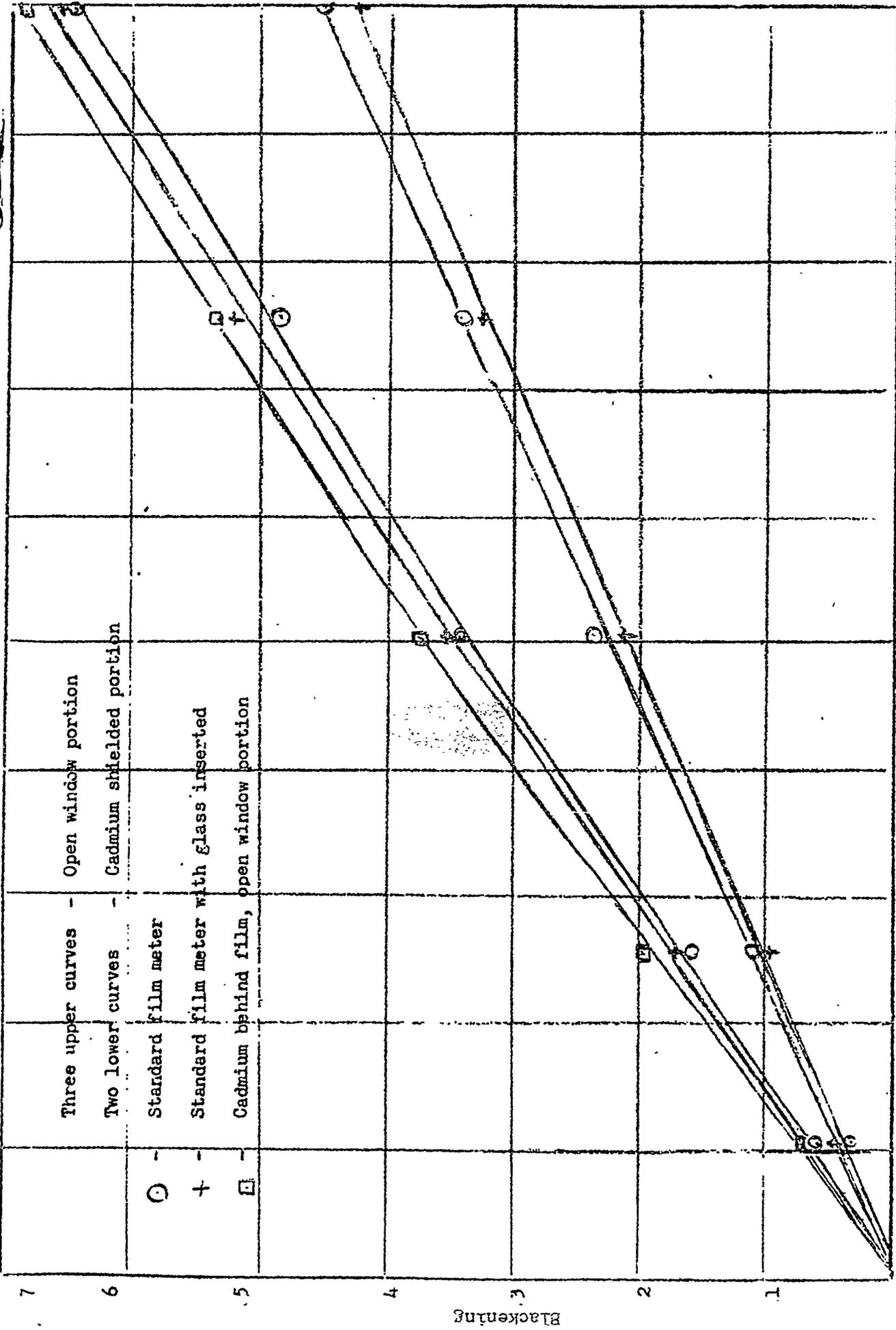
This decay has significance in personnel monitoring since it limits the time a film may be worn by an individual before it must be turned in for development and reading. From the point of view of statistical accuracy and convenience, it would be advantageous to have a film worn for a long period, provided that the film exposure records were additive. However, because of the comparatively rapid loss of the latent images of proton tracks it is impossible to correct for this effect over a long period since the exact time at which the exposure occurred is not usually known and the rate of exposure is not likely to be uniform.

Dr. W. F. Swann of the Eastman Kodak research laboratory has been working with us on developing a particle emulsion film with greater latent image stability. He has submitted an emulsion, designated as type NTB, for tests. It consisted of plates coated with emulsion type NTB (15  $\mu$  thick), and is designed to be more sensitive to light particles than NTA, or alpha emulsion film.

Four of the plates were used to calibrate for sensitivity. They were exposed to 0.69, 0.92, 1.38 n-units, and "background" respectively. They showed an average of  $(2.79 \pm 0.51) \times 10^5$  tracks/cm<sup>2</sup>/n-unit. This compares favorably with  $(2.72 \pm 0.38) \times 10^5$  shown by the present batch of NTA coated films, which have emulsion thickness of  $\sim 30 \mu$ .

The rest of the plates were exposed to 0.92 n-units, and developed after delay periods of 1 to 35 days. Results showed  $\sim 10\%$  track loss in 20 days and  $\sim 20\%$  loss in 35 days. This is a great improvement over the present NTA film which shows  $\sim 17\%$  loss in 7 days, and  $\sim 50\%$  loss in 19 days. Also the average track length in terms of number of grains is greater for the NTB plates.

Effect on Reading of Film Meter of 1 mm. Thick Glass Plate Placed behind Film



Gamma Ray Exposure in Milliroentgens

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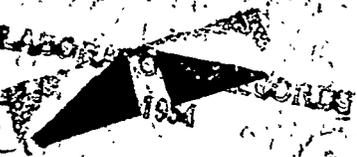
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Per Letter Instructions

710-1113  
W.B. Brown

For: H. T. Gray, Supervisor  
Laboratory Records Dept.  
ORNL



HEALTH PHYSICS DIVISION

QUARTERLY REPORT FOR PERIOD ENDING AUGUST 31, 1948

CLASSIFICATION CANCELLED

KARL Z. MORGAN, DIRECTOR

DATE 6/12/80 (ORNL Review Order)

*R.S. Baker*

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DATE 10-13-99, R.T. DUM, 1003

P. S. BAKER, ORNL/CO JS, 1/30/80  
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HEALTH PHYSICS DIVISION

Karl Z. Morgan, Director

QUARTERLY REPORT FOR PERIOD ENDING AUGUST 31, 1948

This report covers the activities of those groups in the Health Physics Division primarily engaged in Applied Research or Development. More or less routine activities of the Survey-Monitoring Section are covered in the Laboratory Weekly Progress Report.

INSTRUMENT DEVELOPMENT

Organization of the section was begun March 1st with the employment of Mr. W. M. Hurst as Section Leader. During the past quarter four men have been added to the group.

A primary objective of the Instrument Development Group is to improve the present Health Physics radiation instrumentation to a level comparable to that enjoyed by instruments produced in quantity by reliable production concerns. A program to achieve this end includes the following major activities.

- (1) A critical study of existing radiation instrumentation and instrumentation needs; both within and without the AEC.
- (2) Electrical and Mechanical Development by the group.
- (3) Production Design Engineering and Specification Writing.
- (4) Utilization of the highest skills and best techniques presently available in the field of commercial instrumentation.

Much of the time during the past quarter has been spent in the provision of laboratory facilities and in the orientation of personnel. These processes are incomplete.

Specifications have been written and contractual negotiations practically completed for the development and production of a number of oscilloscopes especially adapted to photographic, as well as visual, observation of random pulses with extremely short rise time. Specifications are contained in Report No. 9258 of the Hazeltine Electronics Corporation July 1, 1948, together with a supplement by W. M. Hurst, July 30, 1948.

Considerable effort has been devoted to the objective of making the Walkie Poppy (Alpha Survey Meter) the subject of a suitable commercial development contract.

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T I O N

Development projects in progress within the group include:

- (1) Improvement of instrumentation used for the detection of Pu in body fluids;
- (2) Exploration of preferred materials for portable instrument cases;
- (3) Instrument coatings to permit easy decontamination;
- (4) Design of a shake table suitable for determination of resonance points, structural weaknesses, and operational characteristics of instruments and components subjected to vibrations of known frequency and amplitude.

#### WASTE DISPOSAL STUDIES

A program involving the reorganization and expansion of waste disposal studies in the division was launched in July with the addition of Mr. Roy J. Morton, Sanitary Engineer, as Section Leader. The program is a joint undertaking with Oak Ridge National Laboratory, U. S. Public Health Service, Tennessee Valley Authority, and the Office of Research and Medicine of the Oak Ridge Directed Operations as participants. Major objectives of the program are:

- (1) To evaluate and minimize radiation hazards incident to our own practices in the disposal of radioactive wastes;
- (2) To provide fundamental information on the behaviour of released radioactive wastes as a basis for intelligent public health policies and protection standards; and
- (3) To obtain information which may contribute to our national defense.

Senior members included now in the group are O.R. Placak, Sanitary Engineer assigned to ORNL by the U. S. Public Health Service for a two year period from April 1; L. R. Setter, Sanitary Stream Engineer, assigned to ORNL by TVA since May, and Conrad Straub, Sanitary Engineer, assigned to ORNL by the U. S. Public Health Service for a two year period beginning September 1. The activities of this group will be a part of a broader program participated in by Professor Paris Stockdale, Geologist of the University of Tennessee and Mr. J. Z. Holland, Meteorologist of the U. S. Weather Bureau. The geological and meteorological programs are being sponsored by the Office of Research and Medicine, Oak Ridge Directed Operations of the AEC.

During the past quarter members of the section have been engaged largely in orientation, preliminary analysis of problems, tentative planning, procurement of supporting personnel; and setting up a laboratory. Orientation work has included some participation in routine activities of the Waste Monitoring Group of the Survey Monitoring Section of this division and study of Waste Monitoring records. Observation on the relation of radioactive contamination to plant life in the Settling Basin are contained in a memo from L. R. Setter

to W. D. Cottrell June 1, 1948. Considerable study has been given to possible improvement of White Oak Dam to increase the effectiveness and safety of White Oak Lake in the storage of radioactive materials entering White Oak Creek.

Definite plans for preliminary surveys of the Watts Bar Reservoir, in cooperation with two branches of the TVA, the Fish and Wildlife Branch and the Stream Sanitation Branch, have been completed. The surveys will be begun in September, and will include studies of representative samples of water, sediment plankton, algae, and fish. It is expected that the results of these preliminary surveys will form the basis for more extensive joint studies with these agencies in the future.

An exploratory meeting with representatives of the TVA, U. S. Public Health Service, Tennessee Department of Public Health, and AEC Division of Engineering was held at Chattanooga, August 24, to discuss the general range of interests in problems of radioactive wastes and possible coordination among several public agencies.

### THEORETICAL PHYSICS

#### Evaluation of Relative Stopping Power

Bloch's formula (Heitler, "Quantum Theory of Radiation", p. 218) for energy loss per cm of path is used to calculate the relative stopping power for alpha and beta particles. For fixed energy the relative stopping power per electron is a linear function of  $\log Z$ . This is plotted on Figure I and II for energies above 1 Mev in the case of alphas and above .01 Mev in the case of betas.

The method is certainly not accurate much below these energies but seems trustworthy for higher energies and particularly on high atomic numbers. Comparison with Mano's experimental values for 6 Mev alphas reveals a maximum discrepancy of the order of 5% over the entire range of  $Z$ . The calculated values for 1.8 Mev betas are in substantial agreement with the experimental results of Gray, though here the data seems less trustworthy.

#### Evaluation of Slow Neutron Tolerance (Problems Incomplete)

The collision density due to bombardment of tissue by thermal neutrons is investigated under the following assumptions: (1) The tissue is represented as a slab 30 cm in thickness, the other dimensions being infinite. The total scattering cross section was taken as 2.95 barns and the absorption cross section as .023 barns (2) a monoenergetic beam of neutrons impinges normally on one face of the slab with density of 1 neutron/cm<sup>2</sup>/unit time, and the resulting distribution is assumed to have attained equilibrium. Backscattering from the surrounding space is assumed to be absent. (3) The energy of the neutron is assumed to remain constant during its passage through the tissue and scattering is assumed to be isotropic in the laboratory system of coordinates.

With these assumptions, the collision density,  $f(x)$ , is given at depth  $x$  by the integral equation,

$$(1) \quad f(x) = e^{-x} + \frac{\lambda - \lambda_a}{2} \int_0^{30-x} f(y) E_1(y-x) dy$$

$E_1(x)$  is the exponential integral,

$$E_1(x) = \int_1^{\infty} \frac{e^{-tx}}{t} dt$$

This problem has been attacked by the "Monte Carlo" method. At each collision the neutron has three alternatives: (a) to go back a given distance (b) to go forward a given distance, and (c) to be absorbed. The probabilities of (a), (b) and (c) can be computed under the conditions (1), (2) and (3) of the problem. The solution of the problem is then effected by selecting a succession of random numbers whose interpretation decides the fate of the neutron at each step of its path. The interpretation is determined in such a way that the alternatives (a), (b) and (c) have the computed probability of occurrence at each step. By taking a large sample the resulting distribution of collisions is, in principle, the solution of Equation (1).

Actually a sample of 100 neutrons giving about 1800 collisions was taken. The data was smoothed and iterated in equation (1). The curves obtained are indicated in the accompanying graph (Figure III).

At present it seems desirable to do further work with the solution curve both by performing further iterations and by attempting to fit an analytical formula to the curve. The aim will be to obtain as complete information as possible and also to get some absolute bound for the error. Some preliminary work has been done in these directions, but the work is now awaiting the availability of further computational assistance.

Problems Under Study

(1) Radiation Effects due to Fast Neutrons

(2) Bremsstrahlung - It is intended to make the following evaluations:

(a) Determine cross sections  $\sigma(k, E)$  for the lower energy ranges to make them applicable for B. S. arising from the beta radiation of pile produced activities. In computing the cross sections account will be taken of errors involving the use of Born's approximation, screening effect and collision losses during time intervals separating two Bremsstrahlung encounters.

(b) Determine the frequency spectrum of radiation emitted by electron of initial energy  $E$ .

(c) Apply the above results and investigate problems concerned with health hazards arising from Bremsstrahlung.

## EXPERIMENTAL PHYSICS

The personnel and facilities of this group have been largely devoted to problems for agencies other than the AEC. Measurements involving absorption and reflection of radiation under rather specific conditions are given in the following reports or memos:

- (1) Shadow Shield Experiment, Roberson, Morgan and Rucker, July 30, 1948. Reflection of radiation from Lanthanum-140 by a right spherical unguia of air is determined.
- (2) ORNL-145 - T. E. Bortner, 8-31-48. Reflection of radiation from Tantalum 182 by various materials under certain specific geometrical conditions is determined.

Results of other activities for outside agencies are not available for publication at the present time.

The paramount problem from our own laboratory has been the particulate radioactive contamination of the atmosphere in the ORNL area. Through the joint efforts of this group and the Survey group, some progress has been made in evaluating the extent of the contamination, but as yet the data are very incomplete. Data are given in memoranda by K. Z. Morgan, 8-2-48 and 9-15-48; and J. S. Cheka and H. J. McAlduff, 8-24-48.

### Status of Problem of Particulate Contamination

Investigations to the present time indicate that:

- (1) Large numbers of radioactive particles are carried by the air used to cool the pile and discharged through a 200 foot stack;
- (2) The particulate contamination of the atmosphere from the pile may be much greater than normal during and immediately following the removal of a ruptured uranium slug from the pile;
- (3) At certain times and locations the majority of the particles in the air are in dust swept up from the ground by traffic and wind; and
- (4) Certain chemical operations may add to the particulate contamination of the atmosphere.

Particles ranging in size from 400 microns to 80 microns have been isolated, observed under a microscope, and counted for alpha and beta activities. Due to irregularities in shape, estimates of volume based on linear measurements are very rough, but perhaps the greatest variation to be expected in the results of experimental determinations of specific activities is, for alpha content, age in the pile and, for beta content, age out of the pile. Specific alpha activities ranging from  $6 \times 10^{-12}$  to  $10^{-7}$  microcuries per cubic micron and specific beta activities ranging from  $2 \times 10^{-8}$  to  $10^{-6}$  microcuries per cubic micron have been reported.

Particles smaller than 80 microns have not been isolated for observation under a microscope. Such particles are most readily detected by long exposure of an x-ray film in close proximity to the dust in which the active particles are collected. Rough indications of the activities of the particles are afforded by the diameters of the blackened spots on the developed film after exposure for a definite length of time. Extrapolations from the range of specific activities determined for large particles, while not reliable, indicate the size of particles observed autoradiographically probably extend down into or through the neighborhood of one micron.

No basis exists for an overall estimate of the hazards associated with radioactive particulate atmospheric contamination. Whether an individual particle has a finite probability of producing serious damage if taken into the lungs is not known. Lacking such knowledge it becomes desirable to reduce to negligible value, in the shortest possible time, the probability of breathing radioactive particles into the lung. Coordinated efforts in this direction by plant management and the various plant divisions are being undertaken by the Activity Hazards Committee.

#### EDUCATION AND TRAINING

The time of the Section Leader has been divided between participation in the Radioisotopes Training Program of the Oak Ridge Institute of Nuclear Studies and the planning and preliminary negotiation for the presentation of a 12 to 15 month course in radiation protection for holders of bachelor's degrees in science and engineering. The course structure and content have been worked out and discussions are being held with the University of Tennessee Physics Department and Graduate School to see if arrangements could be made for them to present the background material, administer the program and grant a master's degree on the strength of it. The University has so far indicated great interest and a meeting will soon be held to consider details of financing, technical direction etc.

During the month of July the Section Leader spent perhaps 30% of his working time on loan to the ORINS as instructor and radiation protection man for the Radioisotopes Techniques Course. The August session required considerably less time, though the September presentation will again require about 30% participation because the Institute is losing several of the instructors from the earlier courses.

A program to provide textual and reference material in the field of Health Physics has gotten under way with the employment of a junior physicist (Aug. 15) and a technical stenographer (September 15) to assist in the compilation, editing, and production of appropriate materials.

In addition to these major developments, consideration has been given to numerous requests for short term training, long term individual apprenticeships, and various consultative activities. We have completed in this period the training of 2 one year students, and 4 ninety day trainees and still carry

at this time four 1 year students.

CONSULTATION

In addition to the more or less routine on-and-off-Area Consultation, Mr. W. H. Ray has designed for the New York Directed Operations, a model Radiochemical Laboratory, which, with some alterations, is now on display at the New York Golden Jubilee. He has also designed and constructed, with the cooperation of the Engineering Division, and ORNL display for the September meeting of the A. A. A- S. at Washington. This display consists of 12 booths featuring protection from radioactivity by prevention of inhalation, control of contamination, and control of irradiation dosage.

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August 31, 1948  
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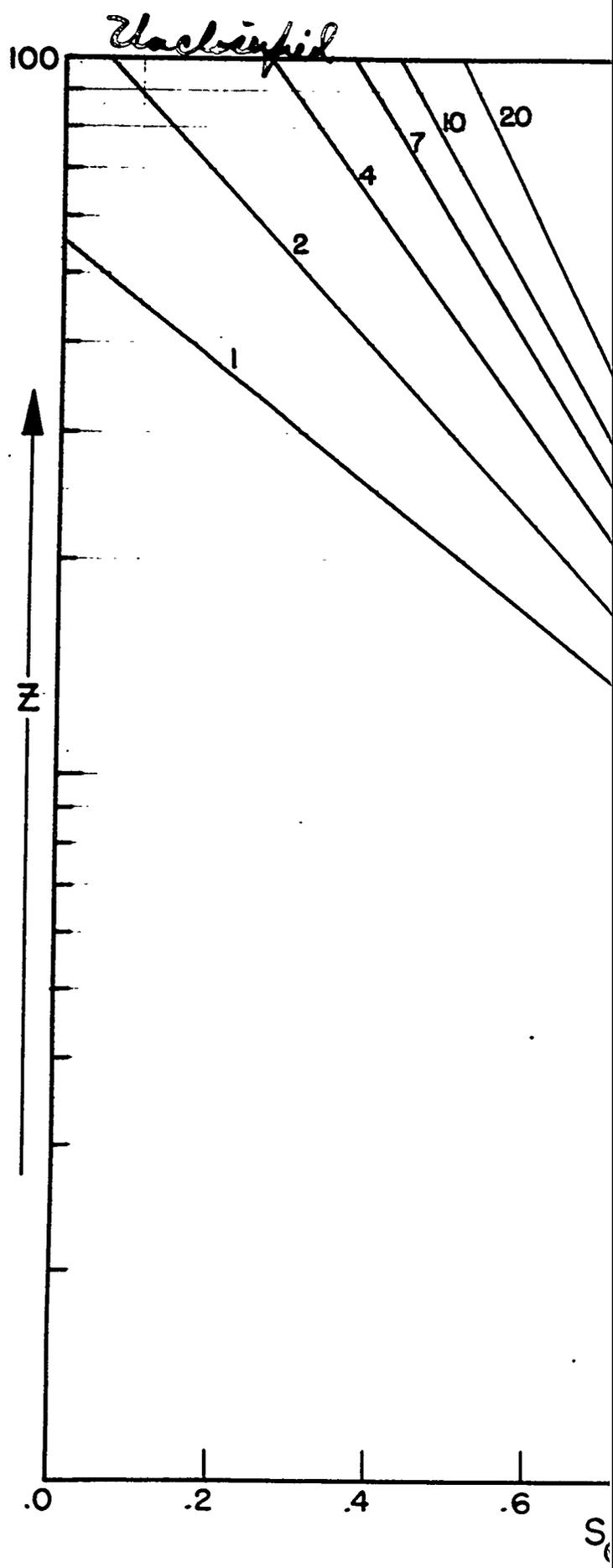
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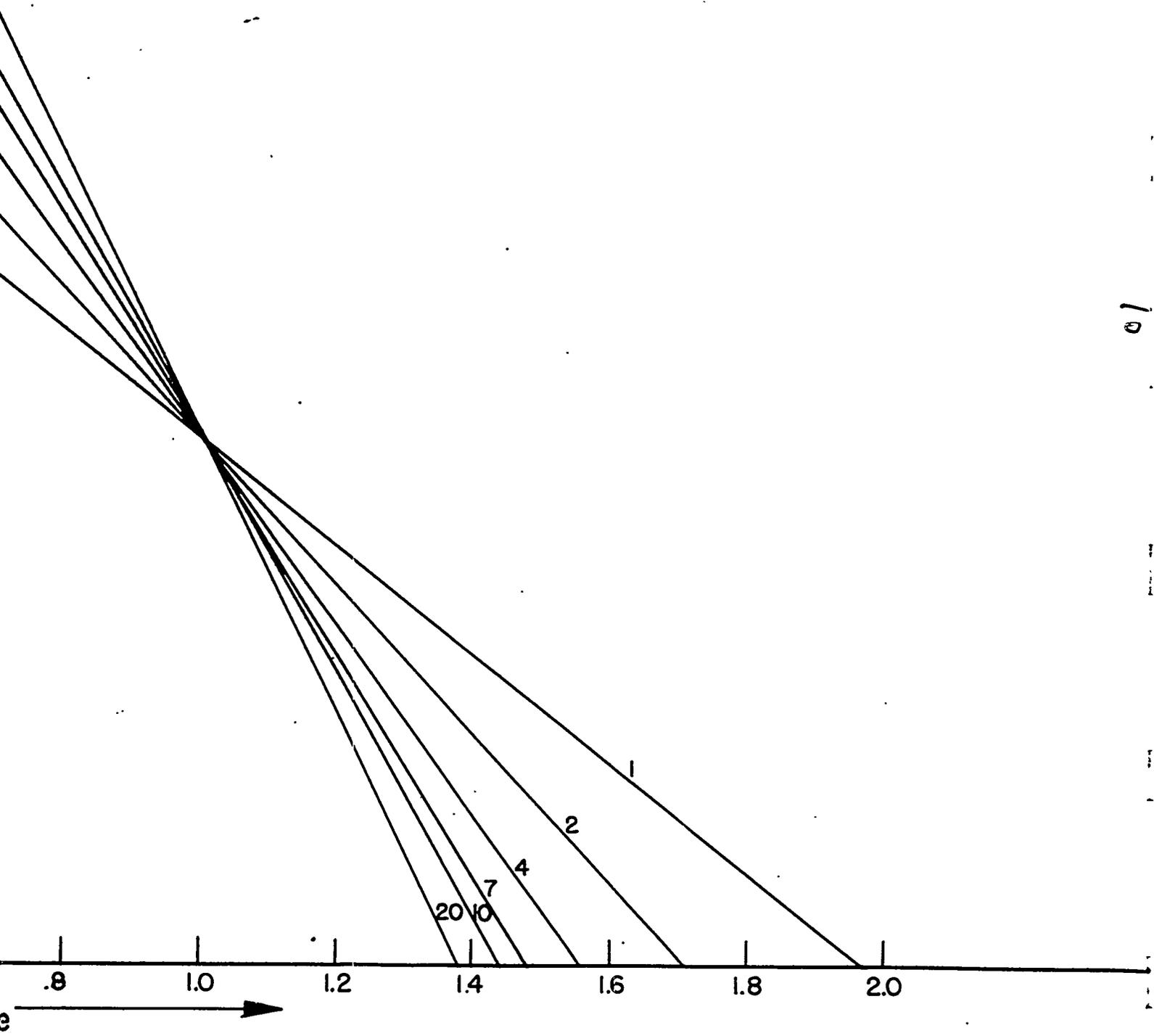
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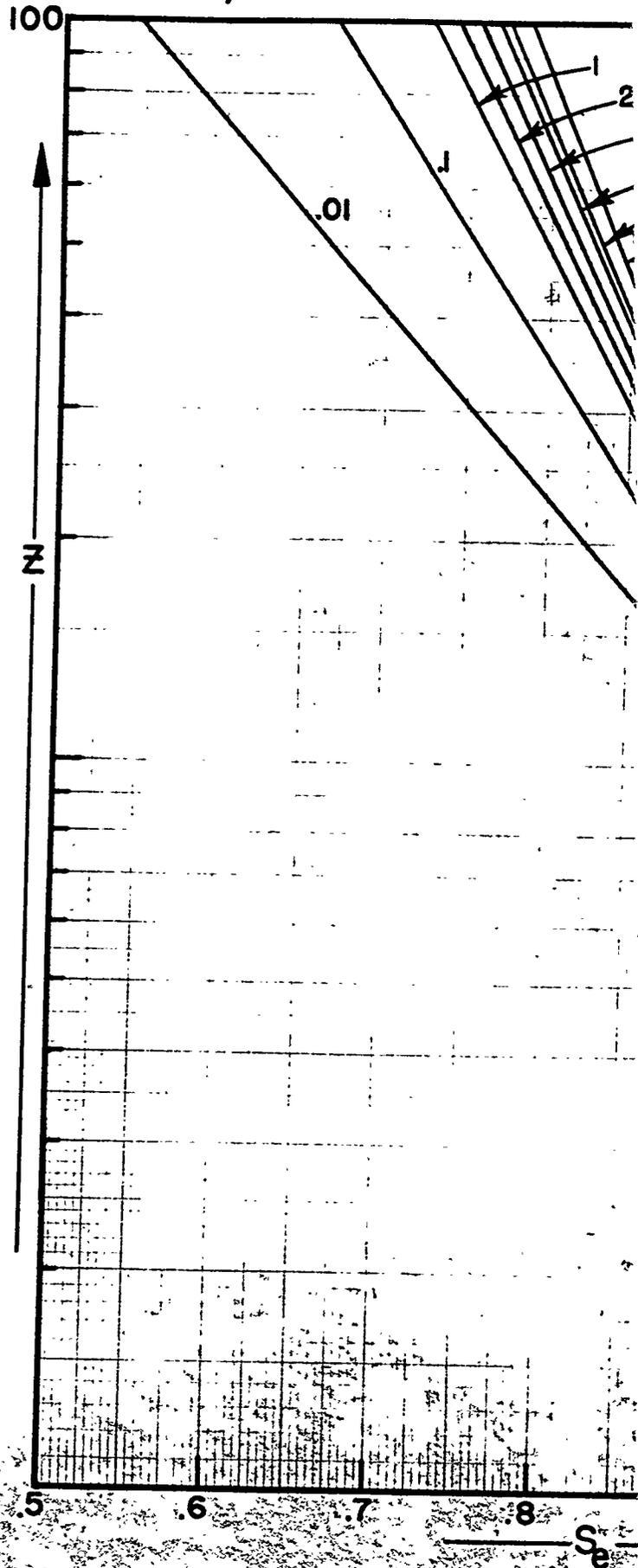
— Fig. 1 —

$S_e$  FOR  $\infty$  PARTICLES  
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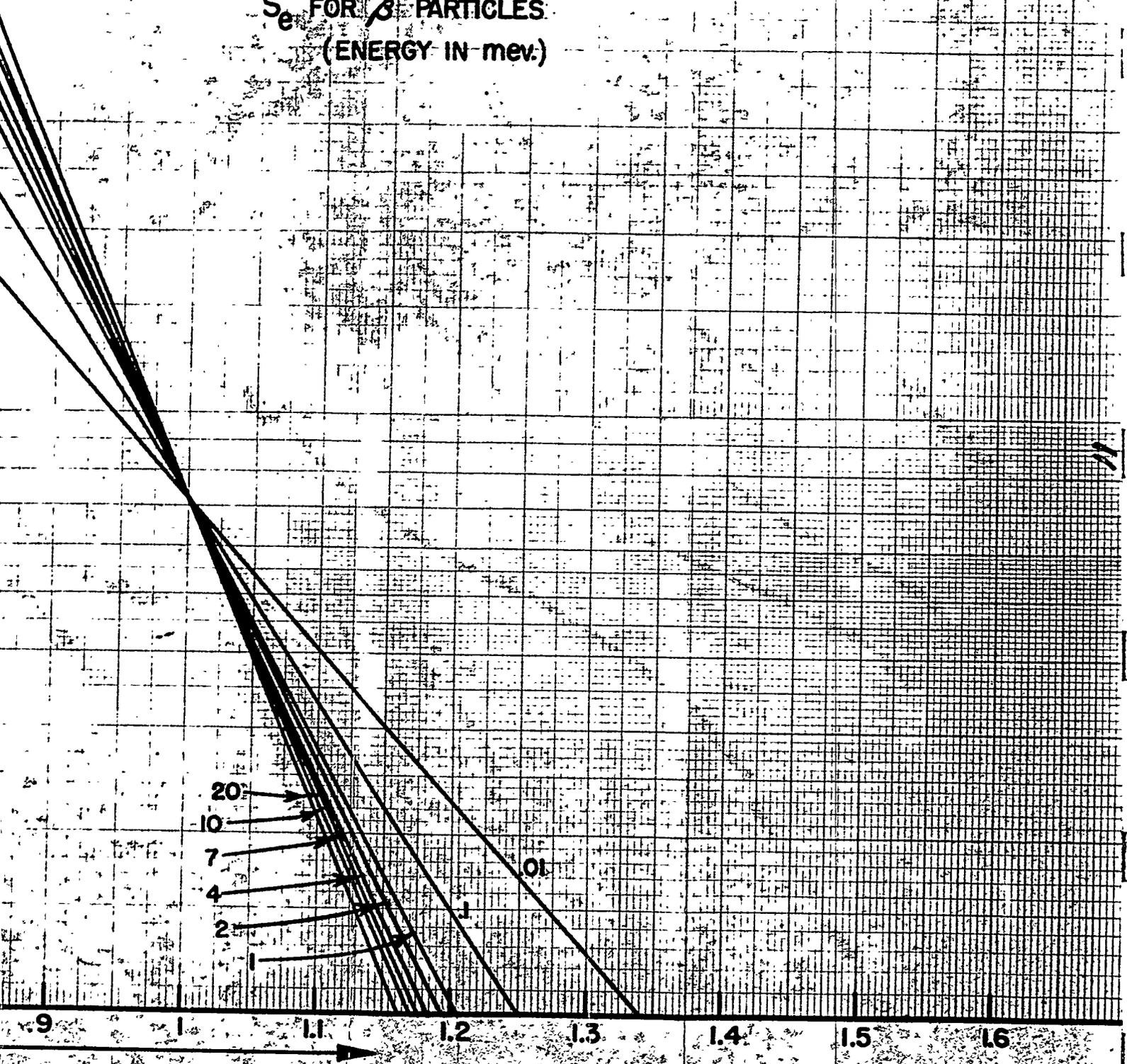
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Fig. 2

$S_e$  FOR  $\beta$  PARTICLES  
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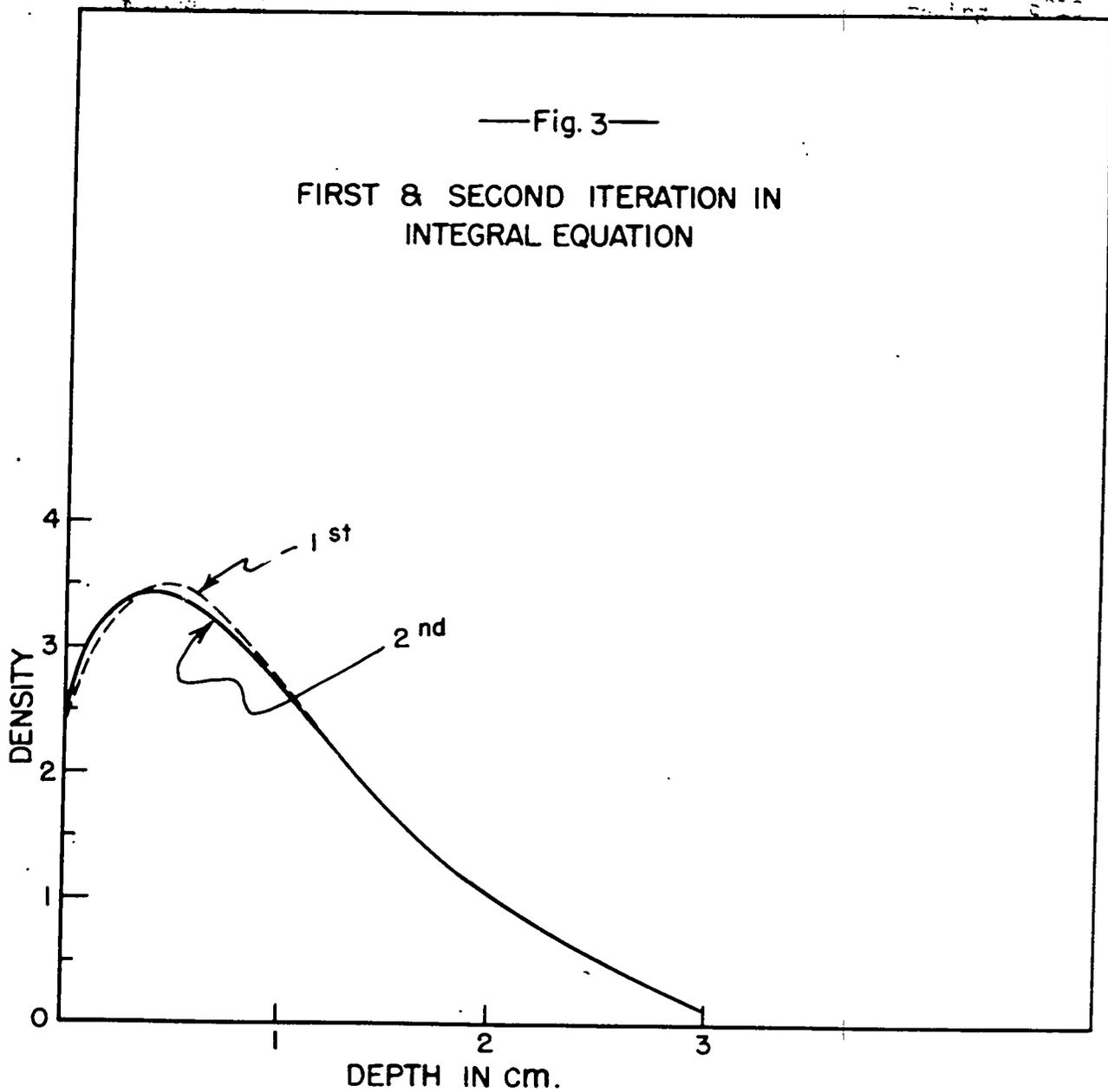


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T-10-1116  
W.C. Brown

For: H. T. Gray, Supervisor

Laboratory Research Dept

~~LABORATORY REPORT~~

INV. 52



HEALTH PHYSICS DIVISION

QUARTERLY REPORT FOR PERIOD ENDING NOVEMBER 30, 1948

K. Z. MORGAN

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HEALTH PHYSICS DIVISION

QUARTERLY REPORT FOR PERIOD ENDING NOVEMBER 30, 1948

K. Z. Morgan

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HEALTH PHYSICS DIVISIONQUARTERLY REPORT FOR PERIOD ENDING NOVEMBER 30, 1948

K. Z. Morgan

This report covers the activities of those groups in the Health Physics Division primarily engaged in Applied Research or Development. More or less routine activities of the Survey-Monitoring Section are covered in the Laboratory Weekly Progress Report.

INSTRUMENT DEVELOPMENT

Considerable progress in providing suitable laboratories for the Instrument Development Section has been made. An additional electrical engineer joined the Section November 1, making a total of six members.

A purchase requisition for the development and production of 20 units of an improved oscilloscope, Hazeltine Model 1421, was issued November 8. Of these, 10 units are to be distributed outside Oak Ridge National Laboratory by the AEC Radiation Instrument Branch. This instrument is to be adapted to photographic and visual observation of random pulses with extremely short rise times.

Efforts to interest one of the larger manufacturers in a contract for the development of the Walkie-Poppie (Portable Alpha Survey Meter) were not successful. Progress in the development of this instrument within the section has been made. At the present state, the Walkie Talkie will detect a source of approximately 135 dpm, and will operate through a range of 700 volts probe potential. The latter feature eliminates the necessity for voltage regulation and may eliminate the necessity for a voltage adjustment control. A pre-amplifier has been built within the probe, and the amplifier has been simplified. Work on the improvement of the high voltage supply is in progress. Three interim models are to be constructed for field testing and criticism by the Survey Monitoring Section.

The improvement of instrumentation for the detection of Pu in body fluids is in progress. An alpha amplifier has been made and has the following measured characteristics:

Max. output	- 24 volts to scope or scaler
Max. input	- for distortion less than 20% the maximum input at 50 KC is 0.8 millivolt.
Gain	- $3 \times 10^4$ at 50 KC

The noise level at input is approximately 30 microvolts. This corresponds to a noise level of 1 volt at output.

Alpha Chamber and Preamplifier work indicates the necessity for improvement in that field. Some work is being done to realize the best signal to noise ratio in a combined alpha chamber and preamplifier. This is considered to be a part of the overall low background alpha counting problem of the Urinalysis Laboratory.

A Keleket Alpha Scaler, Model K-262 is being examined and tested by this section for reliability and accuracy. The installation of another unit of this model in the Urinalysis Laboratory has reduced somewhat the pressure on the project discussed above.

Instrument decontamination by the removal of a peelable plastic coating has been demonstrated and the materials and procedure given to the Survey-Monitoring Section.

Work by the Chemistry Division on an Alpha Sweep Pulse Analyzer is being adapted to the needs of Health Physics to provide a suitable instrument for the rapid analysis of alpha contamination resulting from laboratory operations.

In addition to uncompleted projects listed in the last quarterly report, work in progress includes improvement of instrumentation for the measurement of fast neutrons in a gamma field.

A detailed discussion of the activities of the Instrument Development Section is given in a quarterly report by Wm. M. Hurst.

#### WASTE DISPOSAL STUDIES

The organization of this section as covered by the current budget has been completed. During the past quarter, Comdr. R. B. Krum has joined the group for half-time; and one Research Assistant, one Chemical Engineer, and one Chemist have been added to the group. A laboratory for the analysis and processing of samples, in connection with surveys and experiments, has been completed; and provision made for the counting of such samples in the divisional counting room.

The preliminary surveys of Watts Bar Reservoir mentioned in the previous quarterly report have been completed and the data have been tabulated in preparation for a report on this project. These included the collection of water, sediment, and algae samples from ten stations during September, with cooperation of the TVA Stream Sanitation Branch. During October fish from these areas were collected and examined with cooperation of the Fish and Wildlife Section of the TVA.

Considerable study has been given to measurement of water runoff and radioactivity in the White Oak Creek drainage system. A report covering an analysis of runoff data collected by the Area Monitoring Group during 1948 has been prepared by L. R. Setter and will be released soon. A study of two small floods on November 19-20 and again on November 28-29 is in progress. These studies are of special interest because of the artificially regulated and sometimes low stream flows in Clinch River and the fact that Watts Bar Reservoir is used as a source of water supply at several points some miles down stream.

Preliminary laboratory studies of water and waste treatment processes have been begun. These include, at present, coagulation and absorption experiments. Guided by the results obtained, systematic laboratory-scale experiments with a variety of processes are anticipated.

Detailed descriptions of the activities of the Waste Disposal Section during the past quarter are given in monthly reports for September, October, and November, written by R. J. Morton.

Preliminary plans, estimates of cost and a definite proposal have been made for an experimental plant to study water and sewage treatment methods and equipment. If provided, the plant will allow intensive study of conventional water and sewage treatment plant units and processes, both on a laboratory and pilot plant scale. Interviews with manufacturers' representatives and with several sanitary chemists and sanitary engineers have been had in the development of plans for the experimental plant.

Problems of instrumentation are recognized as basic in waste disposal studies. Especially important is the development of instruments for field use in: (1) scanning of fish; (2) detection of radioactivity in wet masses of material such as muds and algae; (3) detection and delimitation of radioactive materials in streams and other surface waters; and (4) continuous monitoring of water or liquid effluents to detect and measure radioactivity. A special instrument for the scanning of fish was completed through cooperation of the Experimental Physics Section and the Research Instrument Shop of this Division and was used in the preliminary fish study. With further improvement this instrument should prove generally useful in the Waste Disposal program. A blanking die and spinning tool were completed by the Research Instrument Shop to make metal counting dishes. A preliminary trial indicates that these have definite advantages and they will be produced from several metals and in quantities as needed.

On two occasions officials of the TVA have visited the Division and conferred with representatives of the Laboratory and of the Atomic Energy Commission concerning the basis of a cooperative agreement for a future long range program of Waste Disposal Studies. It is expected that a general agreement for such a program will be formulated during December or January.

Dr. Paris B. Stockdale, a consultant to the Oak Ridge office of the Atomic Energy Commission is beginning an active program of geological studies in this and surrounding areas. The Health Physics Division is especially interested in these studies as they may give information on the underground flow of water in this vicinity. The Waste Disposal Group has had several discussions with Dr. Stockdale and expects to cooperate more closely as his studies progress.

#### PERMISSIBLE INTERNAL DOSE FROM RADIOISOTOPES

In cooperation with the sub-committee of the National Committee on Radiation Protection, dealing with this problem; the laboratory has employed Dr. C. H. Perry to serve as working secretary of the sub-committee. Working

under the direction of the Director of the Health Physics Division, who is Chairman of the sub-committee, it will be Dr. Perry's assignment to keep up with all reports dealing with this subject; to collect the data, ideas, and interpretations from persons interested in this problem, and to maintain a current list of permissible internal dose values. These lists of prepared information regarding the various radioisotopes will give the maximum permissible amounts in the body, the maximum permissible concentration in air and in water and the concentration in urine, feces and expired air that corresponds to the maximum permissible amount in the body. This requires the evaluation of vast amounts of available data as well as the obtaining of additional pertinent data from biological laboratories in various parts of the country. The following outline is somewhat categorical and lacks of detail, however it gives some indication of the scope of the assignment:

- A. Catalog Present Research Data
  - 1. Make search for both published and unpublished documents which contain data pertinent to the general problems of permissible internal dose, and to catalog these data.
  
- B. Review and Evaluate Present Research Data
  - 1. The distribution, fixation and toxicity of the various radioisotopes will depend largely upon the physical and chemical form in which they are administered to the animal or person. This is an example of one of the many items which require evaluation before being used in the calculation of the permissible internal dose.
  
- C. Prepare Itemized List of Required Data
  - 1. The accuracy of the calculation of the permissible internal dose of a given radioisotope will depend upon the accuracy of the data itself as well as the completeness of the data. For this reason it is mandatory that sufficient data be available so as to make it unnecessary to approximate in a critical calculation. For this purpose an itemized list of "required data" will be prepared, which will indicate what research is required.
  
- D. Prepare List of Available Data
  - 1. After the "required list of data" has been agreed upon as being pertinent, feasible and complete, prepare charts of the various isotopes, indicating the available data. These charts will automatically show which data are required in order that precise calculation of the permissible internal doses may be made.
  
- E. Obtain Unavailable
  - 1. After it has been determined that certain definite additional data are required, obtain the research assistance of the various biological laboratories to obtain these data which will be used in the calculations of the permissible internal doses.
  
- F. Publish List of Permissible Internal Doses
  - 1. After the acceptance by the committee of the various calculated permissible internal doses, these values are to be published with substantiating data.

THEORETICAL PHYSICS

Evaluation of Slow Neutron Tolerance

Work is continuing on the slow neutron problem by seeking an approximate solution of the following equation:

$$f(x) = e^{-x} + \lambda \int_0^{\infty} E_1(|x - y|) f(y) dy$$

It has been proven that if a trial solution  $F(x)$  has the property that

$$F(x) \gg e^{-x} + \lambda \int_0^{\infty} E_1(|x - y|) F(y) dy, \text{ for all } x$$

then  $F(x)$  lies everywhere above the true solution. Similarly if a trial solution

$$G(x) \ll e^{-x} + \lambda \int_0^{\infty} E_1(|x - y|) G(y) dy$$

for all  $x$ , the  $G(x)$  lies below the correct solution. This method, which seems to be new, gives in principle, a method of determining a band in which the correct solution must be up to the choices for  $F(x)$  as follows:

$$F(x) = 5.16$$
$$F(x) = Ae^{-\alpha x}$$

Some progress has been made in getting a closer upper band for the solution and this work is continuing.

Beta Ray Decay

A study has been undertaken to determine the angular correlation between the direction of electron and neutrino escaping from the nucleus during the beta ray decay. To determine such correlation, it is required to have a preliminary knowledge of the relativistic equation of an electron in Coulomb field subject to the condition that at infinity the electron behaves itself as an outgoing particle. From the survey of literature it appears that such an equation has not been derived yet and various approximate formulations are not applicable to the problem. A suggestion has been made to use the relativistic equation of the electron scattered by the field of a nucleus (Mott, Proc. Roy. Soc. A, 135 (1932) 429). The feasi-

bility of this suggestion is being investigated.

#### Technical Assistance

This section has supplied technical information needed for the recalculation of absorption coefficients for Compton effect, photoelectric effect, pair production for air, aluminum, carbon and oxygen. This work is continuing.

#### EXPERIMENTAL PHYSICS

The time of three persons has been spent upon continuation of a project for an Agency outside the Atomic Energy Commission.

Studies on the problem of particulate contamination of the atmosphere have continued through the quarter. A filter plant was installed in the pile exhaust system and put into operation November 15. A summary of observations by this division is given in a progress report by J. S. Cheka and H. J. McAlduff, ORNL-211, December 9, 1948. Work of the Chemistry and Physics Divisions on this problem is to be issued as ORNL-197.

During the study of general particulate contamination of the atmosphere, it was observed by a member of the Chemistry Division that the level of contamination in the Pile Building was much higher than in other buildings. Extensive monitoring of pile operations by a Health Physics Surveyor assigned to the 105 Area disclosed that, despite the low pressure at which the interior of the pile is maintained, most pile operations were dragging radioactive particles out into the surrounding atmosphere. Engineering work to correct this condition is in progress.

#### EDUCATION AND TRAINING

The first "Professional Health Physics Training Course" for persons holding National Research Council Technical Fellowships in this field, was initiated, November 30, with 10 students. This number represents half of those currently being trained in Health Physics under the Fellowship program; a similar group is being trained at Rochester.

After considerable negotiation; the course content and the organization for instruction have become firm, and are reviewed briefly here:

Because of the general inadequacy of the students' background in physics and mathematics, instruction has begun with a two-month period of group tutoring in these subjects. After January 1, 1949 the group will have formal lecture courses in physics, health physics and instrumentation, and will do laboratory experiments to supplement the instrument work. In addition to this they will work half time in the operating and research sections of the Health Physics Division.

The cooperation of the Oak Ridge Institute of Nuclear Studies and the University of Tennessee has been secured so that some of the courses may be taught in classrooms at the Institute building in Oak Ridge, and so that the burden of teaching the background physics and preparatory material are borne mainly by the staff members of the University.

The health physics and instrumentation course will be taught by staff members of the Health Physics Division, and the necessary laboratory experiments are being designed and equipment constructed within the Divisions' facilities.

It is expected that this initial presentation of the Professional Health Physics Training Program will last until November 1, 1949, though some of the students may leave earlier to enter upon formal graduate study for an advanced degree. It is impossible as yet to predict the probable size, or even the existence of such a course next year.

Other activities have included the continued training of five one year apprentices and several people who could spend only a shorter period here. We have continued to supply a seminar leader in health physics to each of the Oak Ridge Institute's radioisotopes training programs.

The only major future program of which we are at present well informed calls for the training of ten Army, Navy, and Public Health Service medical officers for four months, beginning approximately April 1, 1949. This course will be largely field work in health physics and instrumentation.

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HEALTH PHYSICS DIVISION

QUARTERLY REPORT FOR PERIOD ENDING FEBRUARY 28, 1949

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HEALTH PHYSICS DIVISION

QUARTERLY REPORT FOR PERIOD ENDING FEBRUARY 28, 1949

K. Z. Morgan  
F. Western

This report covers the activities of those groups in the Health Physics Division primarily engaged in Applied Research or Development. More or less routine activities of the Survey-Monitoring Section are covered in the Laboratory Weekly Progress Report.

INSTRUMENT DEVELOPMENT

The resignation of one member of the group and the assignment of another full-time to the physical preparation and teaching of a laboratory course in instrumentation for the A. E. C. - N. R. C. fellowship course in health physics has reduced the effective size of the group to four men.

Re-engineering of the performance characteristics of the Walkie-Poppy (portable alpha survey meter) is considered complete except for some modification of the probe to permit satisfactory operation in an ambient of 100% relative humidity.

The principal effort of the group is presently directed at the development of satisfactory survey instrumentation for fast neutrons. Three possible methods of measurement are being studied:

- A. Proportional counting of recoils to exclude effects of gamma radiation;
- B. Fission counting; and
- C. Ionization, by modifications of the Chang and Eng.

It is tentatively planned to continue the development of a chamber and preamplifier for low level alpha counting as a completely battery operated, dessicated and singly housed unit to avoid spurious counts due to power line transients, voltage variations, and high humidity.

WASTE DISPOSAL STUDIES

A preliminary report by L. R. Setter, "Discharges of Radioactivity into White Oak Creek and the Clinch River, January 1 to November 27, 1948" Central Files Number 48-12-293, was issued December 30. Further studies of the White Oak Creek drainage system from the points of view of both rates of discharge of radioactive materials and control of rate of flow of water, have been made.

Studies on the distribution of radioactive materials in Clinch River fish, taken in a preliminary survey last October, have continued, with emphasis upon methods of identification of the principal radioisotopes involved. Difficulties stem primarily from the low levels of activity involved and from uncertainties

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as to the histories of the fish relative to location in the river. In view of these difficulties, it is planned to make the next series of studies on fish taken from White Oak Lake.

Plans for an experimental plant for the study of relationships between radioactive wastes and water and sewage treatment plants have been completed and forwarded to the AEC for consideration. A series of studies, on a laboratory scale, of the problems is under way. General plans have been made, in cooperation with other groups, by which data on filtration at the K-25 water plant and specimens of water, sediment and filter sand scrapings from representative water plants downstream on the Clinch and Tennessee rivers can be obtained.

The office of Biology and Medicine of Oak Ridge Operations of the AEC has coordinated discussions leading to plans for an initial ecological survey of the White Oak drainage system by a Biological Studies Section of the Health and Safety Division of the T. V. A. It is believed that such a study might disclose any significant radioactive effects to date on the life of the system and would form a basis for comparisons in possible future studies of the region.

Detailed descriptions of the activities of the Waste Disposal Studies Group appear in monthly reports for December, January, and February written by R. J. Morton primarily for distribution within the Health Physics Division .

#### EDUCATION AND TRAINING

The program of the Education and Training Section is unchanged since the issue of the last quarterly report. A group of nine medical officers of the Armed Forces who have been receiving basic scientific training at regional AEC training centers is scheduled to arrive April 1 for six months field training in health physics.

#### THEORETICAL PHYSICS

##### Evaluation of Slow Neutron Tolerance

Progress has been made in estimating upper and lower bounds for the collision densities in tissue, following the method outline in the report of last quarter. Present estimates indicate that the maximum collision density is at least on the order of two times and not substantially more than four times the incident flux. The method for a rather precise estimate of the lower bound is well in hand and such an estimate should be forthcoming within a few weeks.

##### Evaluation of Fast Neutron Tolerance

A study has been undertaken of the effect of fast neutrons impinging upon a phantom and to determine the energy spectrum of neutrons at different depth for the purpose of evaluating tolerance.

The preparatory work has been completed and further work on the problem is contingent upon the availability of the computation machine.

ORNL- 346  
February 28, 1949

### Evaluation of Bremsstrahlung Effects in Solutions of Radioactive Substances

The investigation is limited to Bremsstrahlung effects in the low energy region (for electron energies  $\leq 3$  Mev) which are of particular interest in determining the spectral distribution and the total energy of gamma rays produced in storage banks with solutions of beta ray emitting substance. Approximate evaluations have been made by Parker (Radiation Hazards of Bremsstrahlung - MDDC1012) who completely neglected collision losses in evaluating Bremsstrahlung effects. The purpose of this investigation is to obtain more accurate results.

At present the plans are to use an averaging process for the ionizing collisions and to use its cross section for radioactive collisions from Heitler (Quantum Theory of Radiation - page 170). The validity of the method is at present being investigated.

### Recalculation of Various Gamma Ray Cross Sections

The calculation of the cross sections for the photoelectric effect, Compton scattering, and pair production of gamma rays in H, C, N, O, A, Al, Cu, Ag, Sn, Pb, Ta, U, air, water, tissue have been computed from the theoretical formulas of Heitler (Quantum Theory of Radiation, pp 124-5; 157; 2017), for energies from .01 Mev. to 1000 Mev. The various graphs and tables are now ready for drafting and a detailed report on the project is being written.

### EXPERIMENTAL PHYSICS

The time of two persons has been spent in continuation of a project for an agency outside the Atomic Energy Commission. It is anticipated that our participation in this project will be completed within the next six weeks.

The current phase of study of the problem of particulate radioactive contamination of the atmosphere is nearing completion with the writing of a report summarizing observations over the past nine months. Routine observations of particulate contamination of the atmosphere will be made by the Survey-Monitoring Section of the Health Physics Division. Some consideration has been given to the desirability of establishing a small, long range program in the field, but definite plans have not been formulated.

A series of tests on the pocket ionization meters presently in use for monitoring of exposure of personnel to hard gamma radiation has been made to obtain an indication of their reliability under conditions of high radiation intensity. With levels of radiation obtainable from a two gram radium source, and within the accuracy of the minometer commonly used to read such meters, errors due to lack of saturation at high rates of exposure have not been found.

Analyses of Body Fluids for Radioisotopes

One person is presently engaged in cooperation with the Radiobiochemistry Group of the Biochemistry Section of the Biology Division, in the development of methods of analyzing body fluids for below tolerance concentrations of some of the beta-gamma emitting radioisotopes considered most hazardous in ORNL operations. In addition to chemical difficulties, problems associated with such analyses included uncertainties in ratios of quantities excreted to concentrations in critical tissues and lack of instrumentation for reliable counting at the low levels of activity involved.

A method of analysis for uranium, developed to meet the need for a method sufficiently sensitive for monitoring significant body content of  $U^{233}$ , has been put into routine operation. The method consists essentially of the following steps:

- (1) Heating of urine in 0.1 N HCl to destroy urea.
- (2) Separation of anions by Dowex-50 cation exchange resin.
- (3) Elution of total cations in 6 N HCl.
- (4) Evaporation to a convenient volume in  $HNO_3$ .
- (5) Diethyl ether extraction of the uranium from a solution which is 2 N in  $HNO_3$  and 2.0 M in  $Al(NO_3)_3 \cdot 9H_2O$ .
- (6) The ether is stripped with water which is evaporated to dryness.
- (7) A repeated extraction similar to step (5) above in which the volume of the feed is held to 10 ml; concentration of  $Al(NO_3)_3 \cdot 9H_2O$  is 2.5 M and the acidity in  $HNO_3$  is 0.2N.
- (8) The ether is evaporated to dryness over  $\sim 1/2$  ml  $H_2O$ .
- (9) The liquid is transferred to a platinum plate and is evaporated to dryness.
- (10) The alpha activity is counted on a standard linear amplifier alpha counter.

The overall efficiency of the above procedure has been checked with  $U^{233}$  tracer. A recovery of 80 to 85% can be expected.

During the past six months 158 uranium analyses have been made on urine specimens. An average alpha activity of 0.43 cts/min. above background has been found in the samples analyzed to date. Eleven samples gave a value of greater than 0.82 c/m/500 ml of urine. The highest value was 1.66 cts/min. A group of un-

ORNL-346  
February 28, 1949

exposed personnel had an average urine count of 0.34 counts/min. so there was no significant difference between the potentially exposed and the control group. With utilization of Chauvenet's criterion the limiting value of 0.82 counts/min. was obtained thus excluding the eleven highest values over 0.82/counts/min. The probability of counts occurring by chance that are three standard deviations greater than the mean of controls (greater than 0.79 counts/min.) is 0.003. Therefore, it seems likely that most of the potentially exposed persons to  $U^{233}$  did not have appreciable amount of  $U^{233}$  in their systems but that the persons with the highest readings did have some  $U^{233}$  in their systems. Our knowledge concerning the tolerance of  $U^{233}$  is very limited but the present evidence is that no one in the laboratory has as yet fixed in his system quantities of  $U^{233}$  greater than the maximum permissible amount.

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**HEALTH PHYSICS DIVISION  
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for Period Ending July 15, 1949**

K. Z. Morgan, Director  
F. Western, Assistant Director

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## TABLE OF CONTENTS

Instrument Development	4
Waste Disposal Studies	5
Theoretical Physics	7
Experimental Physics	7
Special Problems	8
Urinalysis	8
Consultation and Radiation Protection Engineering	9
Education and Training	9
Divisional Organization	9

## HEALTH PHYSICS DIVISION QUARTERLY REPORT\*

This report covers the activities of those groups in the Health Physics Division primarily engaged in Applied Research or Development. More or less routine activities of the Survey-Monitoring Section are covered in the Laboratory Weekly Progress Report.

*Instrument Development.* During this period the manpower of this group has been increased by the transfer of one engineer from the Special Problems Group of the Health Physics Division and by the transfer of a draftsman from the Technical Division.

Work on a fast neutron portable survey meter during this period indicates the feasibility of a portable instrument indicating direction of source, and measuring the dosage due to neutrons ranging in energy from 0.1 Mev to 10 Mev. However, immediate attention has been given to the production of a breadboard model of a simplified version, of less weight, which indicates only fast neutron flux. This model has been well received in the field and has proved to have very stable operating characteristics. It utilizes a proportional counter, with a probe of approximately 1 in. internal diameter and 8 in. in length, filled with methane at atmospheric pressure. A central wire potential of 2000 volts renders it operative in the proportional region. Fast neutrons, of energy greater than approximately 0.1 Mev, give pulses of sufficient size to fire the thyratron after one stage of amplification. The inherent simplicity is due in part to the fact that individual secondary electrons from gamma radiation give pulses too small to operate the thyratron. In fields of radiation greater than 0.4 r/hr coincidence pulses from such electrons become significant.

Due to some reduction in local pressure for an improved low level alpha counter, this problem has been assigned secondary priority and little time has been devoted to it during the past quarter.

Recent development in the techniques of scintillation counting suggest the possibility of interesting applications in the field of Health Physics instrumentation. One member of the group has been given the assignment of studying present techniques with a view of adapting them to our problems wherever they may offer advantages.

\* Due to a change in the scheduled dates for Health Physics Quarterly Reports, the period covered by this report extends from March 1, to July 15.

In studying the relative merits of various films for use as window material for the alpha survey meter, comparisons of the rates of diffusivity of moisture through nylon and pliofilm have been made. For these tests silica gel was placed in containers capped with the film under test. With the use of sealing tape around the rims of the containers, cups were formed of which the bottoms were the samples of the film to be tested. Water was kept in these cups through the duration of the tests. It was found that the rate of diffusivity of water vapor through nylon is greater than that through pliofilm by a factor of 34.

Progress in the development by a commercial manufacturer, of an improved oscilloscope, mentioned in the quarterly reports for periods ending August 31, and November 30, 1948, has indicated the desirability of some revision in the specifications for this oscilloscope. In cooperation with a member of the Physics Division, some time has been spent with the contractor in discussing the problems involved in raising the instrument from its present level of development to that desired. New specifications have been written for submission to the contractor for his consideration.

To assist in the design and testing of portable instrumentation, where we are concerned with instrumentation life expectancy and reliability, two items have been added to our laboratory equipment. These are (1) a vibration fatigue testing machine model, 25-HA, made by the All American Tool and Manufacturing Company, maximum load 25 lbs at 10 g, total displacement adjustable 0-0.125 in, frequency adjustable 10-60 cps, and (2) a stroboscope (631-B Strobotac) for visual observations of apparatus being tested.

Detailed activities of the Instrument Development Section during this period are described in a quarterly report prepared for limited distribution by W. M. Hurst.

*Waste Disposal Studies.* The Waste Disposal Research Group includes research workers and assistants employed in the Health Physics Division and also personnel assigned on loan from other agencies. During this quarter there has been no change in the permanent staff of employees. Of the assigned personnel, L. R. Setter, of TVA accepted a position elsewhere and left the group June 3, 1949. Lt. Comdr. R. B. Krum of U. S. Navy was transferred for duty elsewhere effective May 1, 1949. Additions to the group have included Lt. Thomas R. Ostrom, of U. S. Army, assigned, for a period of one year or longer, for full time work and experience in this section; and two trainees, Lt. Col. John H. Rust, III, and Mr. A. Emmons, who will participate part time for several months from about May 1.

The principal survey project during this quarter was the collection and study of an extensive sample of fish from White Oak Lake with cooperation of TVA Game and Fish Section. Fish were collected May 2 and 3, and throughout the month of May were processed and examined to determine the amount and kinds of radioactive material present in particular tissues of different species and from several locations in the lake. Lt. Col. Rust selected various specimens and several hundred microscopic sections are being made for more detailed study.

Studies of more or less conventional water treatment methods as a possible means of decontamination of radioactive liquid wastes have been continued. A laboratory with small treatment units for semi-works trials of these processes has been established in the old water plant building, pending action on a request for an experimental laboratory and pilot plant which would house an extensive projected program in the field of water plant and sewage disposal studies.

"A Preliminary Report on Studies of the Removal of Radioactivity from Waste Water by Adsorption on Clay Particles" was submitted to R. J. Morton by R. A. Lauderdale about June 1, 1949.

Considerable attention has been given to the proposed experimental laboratory and pilot plant. Since the original proposal was submitted for approval, discussions have been held with representatives of the AEC and other interested groups. The original proposal has been modified in an effort to include more adequately the probable interests of these various groups.

The question of sewage treatment for the Laboratory has been of special interest as a source of sewage materials for Waste Disposal Research studies, and close contact has been maintained with the Engineering and Maintenance Division and the Austin Company in the development of sewage plans. To assist in obtaining more adequate data on sewage flows and sanitary chemical conditions, a special project was carried out during the first two weeks of June in which members of the Waste Disposal Section analyzed hourly samples of sewage collected by the Austin Company. After assembly of the analytical data a special report was prepared and distributed and has been discussed with the design groups on several occasions.

Work on waste disposal instrumentation problems has been mainly toward the development of a satisfactory portable probing instrument for the detection of radioactivity in the water and bottom deposits of streams or lakes. Three models of such an instrument have been developed and constructed and several

testing and sampling trips on Norris Reservoir and on Clinch River have been made.

Representatives of the Atomic Energy Commission have formulated and discussed tentative plans for a comprehensive ecological and biological survey of White Oak Creek and Clinch River areas. This project is of fundamental interest and importance in relation to radioactive waste disposal research studies and, if the proposed plan is adopted, members of this Section will cooperate and participate in the project.

Detailed activities of the Waste Disposal Research Section are covered by monthly reports prepared for limited distribution by R. J. Morton.

*Theoretical Physics.* A preliminary report covering the proposed method for the evaluation of ionization excitation losses in tissue was submitted to the Division Director June 8, 1949. The proposed method is now awaiting appraisal by one or more consultants.

The collision density due to a beam of thermal neutrons normally incident on a half-space of tissue has been computed under the assumption of isotopic scattering and constant energy. Tolerance calculations based on this information are being computed and a detailed report will be issued upon their completion.

One member of this section is working jointly with the Physics Division on the problem of the neutron scattering coefficient of NaCl crystals at various temperatures. The other member of this section is participating in the Summer Shielding Session being held at Oak Ridge National Laboratory.

*Experimental Physics.* The aerial survey project in which members of this section were engaged for several months, in cooperation with the Air Forces, has been written up and a limited report, ORNL 341, has been issued.

An experimental study of the attenuation of the activity of stack gases from X-10 to K-25 is being made. Measurements are being made with an air conductivity measuring apparatus which has been developed to be used as a gaseous air monitoring device. The apparatus, essentially an ion collector, responds to the intensity of ionization in the air passing through a tube. It has the following advantages: a response proportional to the energy radiated by radioactive gases, higher sensitivity than ion chambers or G-M tubes, short time constant, and simplicity. It has the disadvantages of being somewhat affected by smoke or fog in the air and of being more difficult to calibrate.

A continuous recording moving filter unit with beta and alpha counters measuring particulate activity continuously at periods of 20 minutes and 4-1/2

hours after collection is in process of construction. This will give valuable data on the variation of natural background activity of radon and thoron, by measuring their decay products, as well as on other particulate activity.

A cooperative effort with the Weather Bureau is getting underway. A study of the activity of the stack effluent at different locations and meteorological conditions is anticipated. At present six balloon borne beta G-M counters have been constructed and a balloon ionization chamber is being developed where the balloon itself is the ion chamber.

*Special Problems.* Two members of the Special Problems Section have devoted their efforts to the design and assembly of instrumentation for the Waste Disposal Research Section. One of these members has recently been transferred to the Instrument Development Section.

A number of activities have been in connection with problems of interest to the Division and to the Laboratory. These have included accurate measurements of radiation from cobalt and tantalum sources; observations of scattering of radiation from floor and walls during calibration of instruments; perfection of a convenient vacuum tube electrometer for accurate radiation measurements and the construction of various thin-walled ionization chambers for measurement of  $\beta$  radiation.

A preliminary redetermination of the radiation from the surface of natural uranium metal gives a value of 240 mrep/hr in close agreement with the value reported at the last Health Physics Information Meeting by Bass, DiGiovanni, and LeVine of the New York Office of Directed Operations, AEC. An improved extrapolation chamber has been designed and is under construction. Detailed studies have been made of the absorption of  $\beta$  radiation from uranium,  $P^{32}$ ,  $Sr^{90}$ , and  $Bi^{210}$ , by a number of absorbers including Al, Ni, Cu, Mo, Cd, Pb, polyethylene, cellulose acetate, cellulose, cellophane, teflon, glycerine, rubber and a black conducting paper which has been found useful for the construction of thin-walled ionization chambers.

*Urinalysis.* A program directed at the development of methods of analyzing body fluids for low tolerance concentrations of some of the  $\beta$ - $\gamma$  emitting radioisotopes which are considered most hazardous in ORNL operations has progressed to the stage that the method can be used for analyses of urine specimens for these radioisotopes. Development of these methods has been done by the Radiobiochemistry Group of the Biochemistry Section of the Biology Division, with the cooperation of one member of the Chemistry Group of the Health Physics Division. Procedures will be published soon in a report, ORNL 368, entitled "Procedure for the Radiochemical Analysis of Barium, Strontium and Rare Earths in Human Urine" by Paul C. Tompkins, L. B. Farabee and J. X. Khym.

The procedure is essentially quantitative for lanthanum and yttrium. The recovery of barium was found to be around 95%, while that of strontium was approximately 90%.

*Consultation and Radiation Protection Engineering.* One member of the section has been on loan to another AEC operation since April 26, 1949.

Major activities have included study and consultation on possible radiation hazards involved in the recently constructed evaporator for concentration of radioactive wastes, the new Isotopes Separation area, the projected Research Laboratory, and the Physics of Solids Building.

Field tests for possible flaws in lead slabs to be used in numerous shields in the Isotopes Separation Area have been made using a nine curie cobalt source of radiation.

*Education and Training.* Current training in Health Physics includes three more or less formal programs for the following groups:

(1) Nine N. R. C. Health Physics Fellowship Students for a 12 months period from November 1, 1948.

(2) Eight Medical Officers for a six months period from April 11.

(3) Fourteen officers from the Armed Forces engaged in a three year program in radiation and assigned to this laboratory for an eight weeks' period of field training, from July 7.

During this period three persons from Brookhaven spent ten days each with this Division and one person from New York Directed Operations spent five days.

Substantial contributions to the success of the Health Physics Training Programs has been and continues to be made by the cooperation of other laboratory groups. In addition to the field work made possible by the operations of the laboratory and production groups, personnel from some of these groups have given lectures on specialized subjects. The Biology Division has been especially generous in this respect.

*Divisional Organization.* To provide a bird's eye view of the activities of the Division, a divisional organization chart is appended to the current report.

HEALTH PHYSICS DIVISION ORGANIZATION CHART

July 1, 1949

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Ass't Director - Forrest Western

Assistant to Director - C. E. Haynes

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RADIOISOTOPES - COMMITTEE ON PERMISSIBLE INTERNAL DOSE

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M. Doherty

WASTE DISPOSAL RESEARCH

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T. A. Brockett  
R. A. Lauderdale  
V. I. Knobf  
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T. R. Ostrum\*  
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QUARTERLY PROGRESS REPORT  
for Period Ending October 15, 1949

K. Z. Morgan, Director  
F. Western, Assistant Director

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## TABLE OF CONTENTS

INSTRUMENT DEVELOPMENT	5
Fast Neutron Survey Meter	5
Portable Alpha Survey Meter	6
Cathode Ray Oscilloscope, Hazeltine Model 1424	6
Scintillation Counter	6
Continuous Water Monitoring Instrumentation	6
WASTE DISPOSAL STUDIES	8
Water and Sewage Treatment	8
Survey Studies of White Oak Lake and Clinch River	8
Instrumentation	9
Miscellaneous Activities	9
THEORETICAL PHYSICS	10
Gamma Ray Absorption Coefficients	10
Determination of the Variation of the Charge of an Ion with Its Velocity	10
Determination of Energy Loss of Particles	10
EXPERIMENTAL PHYSICS	11
Backgrounds	11
Distribution of Gaseous Activity from X-10 Stacks	11
Consultant Service to the Geological Survey	13
SPECIAL PROBLEMS	14
Neutron Monitoring	14
Atmospheric Contamination	14
Studies on $\beta$ Radiation	15
URINALYSIS	16
CONSULTATION AND RADIATION PROTECTION ENGINEERING	17
PERMISSIBLE INTERNAL DOSE	19
EDUCATION AND TRAINING	20

This report covers the activities of those groups in the Health Physics Division primarily engaged in Applied Research or Development. More or less routine activities of the Survey-Monitoring Section are covered in the Laboratory Weekly Progress Report.

## INSTRUMENT DEVELOPMENT

During this period one man has been transferred out the group and another has been transferred into the group but loaned 90% of his time to the Waste Disposal Research Section.

*Fast Neutron Portable Survey Meter.* A second experimental model of the simplified fast neutron portable survey meter has been made and is being routinely used with excellent results by Health Physics men in the reactor building. This model measures fast neutron fields ranging from 10 to 10,000 neutrons/cm<sup>2</sup>/sec. Pulse counting by earphones is used for low values and the conversion factor is:

$$\text{counts per minute}/3 = \text{neutrons/cm}^2/\text{sec.}$$

High values are indicated on a single (modified logarithmic) scale rate meter. This design philosophy includes accuracy at approximately neutron tolerance levels, and only rough indications for higher values. Gamma fields, of 1 R/hr or less, have negligible effect. On a future model the logarithmic rate meter will be replaced by a linear scale three ranges meter for increased accuracy.

An AC operated (and portable) continuous duty version of the above is now being constructed. It will include a non-directional proportional counter, an RF-HV supply, a circuit lighting a lamp and operating an alarm relay when the flux density reaches tolerance level, and an output meter with linear scale, ranges 0-50, 0-1,000 and 0-10,000 neutrons/cm<sup>2</sup>/sec. The proportional counter will be connected by a 10 ft cable permitting its use as a survey instrument. Two identical instruments are to be made.

Proportional counter development in relation to fast neutron measurements will continue with emphasis on:

1. Testing, by pulse analysis, their conformance to Gray principle.
2. Counter efficiency for various monoenergetic neutron fluxes.
3. Material and process controls required to duplicate characteristics.

This phase of the program is regarded as being the most important, as the fast neutron instrumentation must be based upon a complete and thorough knowledge of the proportional counter and its various possibilities.

A final objective of the program is the development of a fast neutron survey meter which considers both the flux density and pulse heights, and gives

an output meter reading in energy lost (in tissue) in ergs per gram, where the neutron energy range is anywhere between 0.1 and 10 Mev. Progress has been made such that an operating preliminary model of this instrument is expected before the end of December, 1949.

This version of the fast neutron meter is of immediate interest in connection with the shielding program of the Technical Division, to enable them to evaluate the effectiveness of various neutron shields in terms of permissible exposure to personnel.

A problem of measurements encountered in personnel monitoring neutron film calibration has been discussed, and a fast neutron meter for particular application to that calibration work will be made. It will include a smaller proportional counter, modified amplifier, battery operated, output meter to read in arbitrary units of  $n/cm^2$ . A major requirement is reproducible results at a relatively high neutron flux level.

A preliminary article by G. S. Hurst on the subject "Fast Neutron Measurements for Health Physics" was published in the September, 1949, (Vol. 2, No. 4) issue of Ra-Det. The interim model No. 2 fast neutron portable survey meter is described, sufficiently to permit other areas to duplicate that instrument, by G. S. Hurst, in his report "Portable Fast Neutron Survey Meter" ORNL 485.

*Portable Alpha Survey Meter.* Models of this instrument are now being field tested by the Health Physics Survey-Monitoring Section. Preliminary reports are favorable. A report describing the design, construction and required process controls is to be written.

*Cathode Ray Oscilloscope, Hazeltine Model 1424.* A contract for the development and manufacture of 20 improved oscilloscopes for ORNL and other groups discussed in Quarterly Reports of August 31 and November 30, 1948, and January 15, 1949, has been cancelled. At the time of cancellation it was concluded that the needs to be met by these oscilloscopes could be more economically met by the use of a combination of models now available and under development by other companies.

*Scintillation Counter.* The first application of this technique to some of our problems will be in the form of an instrument for low level alpha counting. The immediate problem is to achieve good counting efficiency with a low (3 counts per hour) background as has been reported from another (NYO) area.

*Continuous Water Monitoring Instrumentation.* The AEC, Office of Research and Medicine, Oak Ridge, is sponsoring an engineering purchase order for the subject apparatus. The specifications have been tentatively set at:

1. Detect gamma radiation, and beta radiation of energies higher than about 0.1 or 0.2 Mev.
2. Alarm at an arbitrary radiation level (presently not specified).
3. Operate 24 hr/day.
4. Sufficient models to only prove the design, performance and drawings to be constructed by engineering contract.

This work is at a low priority compared to the instrumentation listed in the preceding paragraph.

## WASTE DISPOSAL STUDIES

During this period there has been no change in the permanent research staff of this section. Of the assigned personnel, two sanitary engineers from the U. S. Public Health Service and one from the U. S. Army have remained; a sanitary engineer of the Stream Sanitation Section, Tennessee Valley Authority, reported July 25, on loan to this group for a period of at least one year or longer.

Personnel assigned to this section from other groups within the Health Physics Division numbers 2.5 persons.

*Water and Sewage Treatment Process.* Good progress has been made in water and waste decontamination studies. A small model water treatment plant has been operated for three experimental runs of three to five days each, two to test the plant for normal water treatment results and one for efficiency in removal of  $P^{32}$  from turbid water. Much additional laboratory work has been done in order to extend the range and assist in the interpretation of results of these experiments. Progress reports on the first two runs have been prepared and released and a draft of the third report completed. A duplicate model of this semi-works water treatment plant, constructed of stainless steel and including a Spaulding type precipitator, has been completed.

Other studies of treatment processes have included a continuation of laboratory tests of ion exchange materials and preliminary work on domestic sewage using a small contact aerator constructed previously in the Health Physics Research Shop. The work on domestic sewage is directed toward studies both of the effectiveness of biological slimes in removal of radioactive materials from sewage streams and of radioactive hazards due to the accumulation by such slimes of radioactive materials in sewage lines.

*Survey Studies of White Oak Lake and Clinch River.* Studies of radioactivity of fish collected from White Oak Lake have been continued using the samples collected in May and another collection August 1 and 2. Samples from the latter collection were assayed to supplement the earlier analysis and also were prepared and sent to the Chemistry Division for chemical analysis, a report of which has been received. A number of laboratory experiments have been made upon fish tissues and similar material to determine the loss of activity during digestion with acid or ashing by heat. A special press has been designed and

constructed for distribution of such materials in counting dishes for assay after air or low temperature drying.

Tentative drafts of several reports on survey studies of conditions on White Oak Lake and Clinch River have been reworked and are practically ready for final revision and release. Also the entire survey program is being restudied and outlined with a view of improvement and selection of work assignments for the remainder of this fiscal year.

*Instrumentation.* In instrumentation the principal effort has been toward the development of continuous measurement and recording of both water levels to provide indicating recording and alarm instruments at the ORNL area. Investigation and cost estimates of equipment and construction necessary for such a system have been obtained and proposal with recommendations that the system be installed has been prepared and submitted.

*Miscellaneous Activities.* Members of the group have spent considerable time in cooperation with others engaged in related work. A second series of analyses of sewage samples collected by the Austin Company on August 7 was carried out by members of this group. The purpose was to determine the effects of various settling times upon the treatment processes to be employed in the Laboratory sewage treatment plant. Preliminary plans and design criteria for the sewer system and sewage treatment plant have been reviewed and discussed with representatives of the Engineering and Maintenance Division and the Austin Company.

A small amount of assay work has been done on samples collected from White Oak Creek in connection with the ecological survey being conducted by the Tennessee Valley Authority by arrangement with AEC, ORO. Also some continuing joint work with the K-25 Health Physics has been maintained, including discussion of problems of mutual interest, exchanges of information, and minor assistance in the examination of survey samples.

Detailed activities of the Waste Disposal Research Section are covered by monthly reports prepared for limited distribution by R. J. Morton.

## THEORETICAL PHYSICS

*Gamma Ray Absorption Coefficients.* As a result of the participation of one member of this group in the Summer Shielding Session at ORNL, a report on these studies is being issued shortly with the Shielding Session report.

*Determination of the Variation of the Charge of an Ion with Its Velocity.* Graphs are being prepared showing the relationship between the nuclear charge  $Z$  of an ion, its electronic charge,  $ne$ , and the energy  $I_n$  required to extract the outermost electron from the ion.

*Determination of Energy Loss of Particles.* This investigation is concerned with evaluation of excitation and ionization losses of particles having velocity  $\beta c$  with  $\beta < Z/137$  where  $Z$  is the atomic number of the stopping substance. Preliminary estimates have been made and the work is in progress.

## EXPERIMENTAL PHYSICS

The Experimental Physics Group has been brought up to its former strength of three members by the transfer of one junior physicist from the Instrument Development Section.

*Backgrounds.* The variation of the radon and thoron content of the atmosphere for the past two months has been continuously recorded by a moving filter monitron unit. This unit collects the particulate matter containing the active deposit of radon and thoron from the air at a rate of about six cubic feet per minute. The filter moves under two alpha counting chambers so that the activity of the particulate matter is counted at intervals of 20 minutes and 4½ hours after it is collected. The alpha count at 20 minutes after collection is due mainly to its short life active deposit of radon, while the 4½ hour delayed count is due mainly to its longer life active deposit of thoron. Calibrating the instrument by measuring the radon content of air samples directly and comparing the result with the filter count indicated that  $530 \pm 20$  counts per minute from the filter was equivalent to a concentration of  $10^{-9}$  microcuries of radon per cc of air.

The records for the past two months show that a typical condition is represented by a concentration of  $0.15 \times 10^{-9}$   $\mu\text{c}/\text{cc}$  of radon during the day and a building up of radon concentration over night during the normal temperature inversion period to a maximum of  $0.7 \times 10^{-9}$   $\mu\text{c}/\text{cc}$  in the morning when the inversion breaks. Values as low as  $0.07 \times 10^{-9}$   $\mu\text{c}/\text{cc}$  during the day and  $1.0 \times 10^{-9}$   $\mu\text{c}/\text{cc}$  in the morning are not unusual. An example involving an inversion is shown in the following figure. In cases when we have no temperature inversion during the night, the radon does not build up and remains more or less the same as the concentration during the day.

The thoron concentration is expected to follow the same typical variation; however, the records do not show as marked a variation due to long half life of ThB (10.5 hrs) which does not have time to come to equilibrium with the changing thoron content but lags behind with dampened magnitude of variation. The thoron radon ratio assuming the same efficiency of active deposit collection appears to be about 3 percent.

*Distribution of Gaseous Activity from X-10 Stacks.* A project to study the attenuation of stack gases from X-10 to K-25 was described briefly in the last

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# 1 - 20 MIN. AFTER DEPOSIT ( PRINCIPAL ACTIVITY  
 DUE TO PRODUCTS OF RADON )

# 2 - 4 1/2 HRS. AFTER DEPOSIT ( PRINCIPAL  
 ACTIVITY DUE TO PRODUCTS OF THORON )

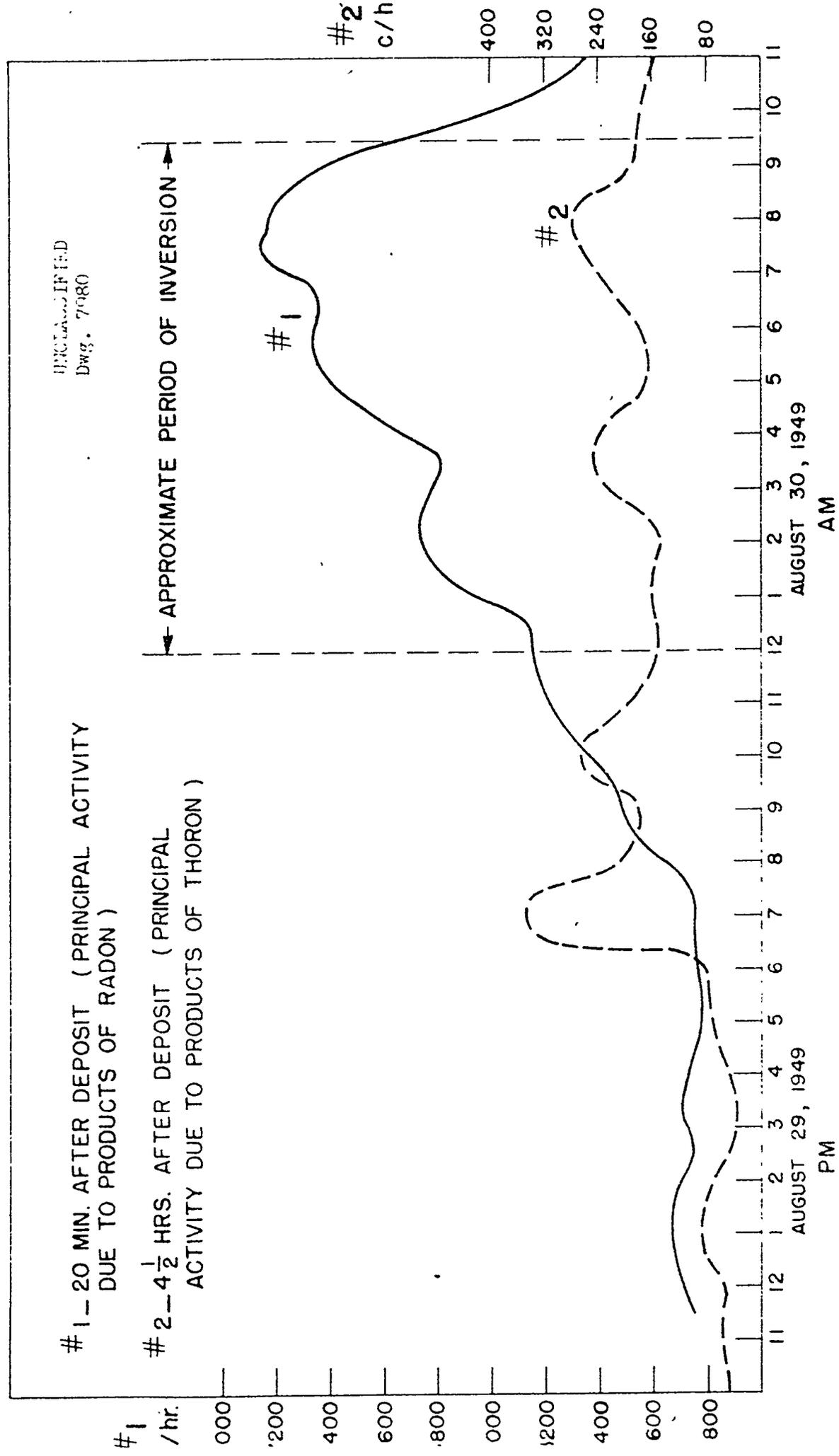


ILLUSTRATION OF VARIATION OF NATURAL RADIOACTIVE CONTENT OF ATMOSPHERE  
 DURING 24 hr. PERIOD

quarterly report. One unit of the experimental apparatus was located in the vicinity of K-25, but due to unfavorable location and experimental difficulties, little progress has been made. It is now planned to accelerate and improve the studies by use of three movable units, each of which will be independent with its power supplied by a gasoline generator. Apparatus to operate these units is being assembled. Continuous records will be obtained from (1) moving filter monitors giving the alpha and beta activity of particulate matter, (2) air conductivity apparatus giving the ionization of the air, and (3) G-M counters in anticoincidence registering the gamma activity. These units will permit observations not only in the direction of K-25 but in other directions of interest. Data obtained from these observations will be correlated with the data obtained by the AEC Weather Bureau Meteorological Project in which data on atmospheric activity is being studied in connection with meteorological conditions by use of balloon borne G-M counters.

*Consultant Service to the Geological Survey.* Approximately one month's time of two people in the section was devoted to the Geological Survey as consultant service for the purpose of design and operation of instruments aboard an aircraft (DC-3) for aerial prospecting for uranium. A test strip in the red desert of Wyoming was run and the activity record from flights at 500 feet above ground correlate well with ore deposits containing 0.01 percent  $U_3O_8$ . At 1000 feet some correlation but weak response was obtained. Flight at 250 feet gave marked responses over twice background level. These records were obtained from air conductivity apparatus and G-M counters connected in anti-coincidence. No shielding was used with the counters. Tests made in the laboratory show that 1 inch lead shields weighing 180 pounds covering the G-M counters will reduce background by a factor of six so that improved response is expected with use of the shield on the next test run which is scheduled the last week in October.

## SPECIAL PROBLEMS

Changes of personnel of this group include the addition of Dr. H. K. Richards in the capacity of Section Leader. One associate physicist formerly assigned to this group but primarily concerned with instrumentation for the Waste Disposal Research Section has been transferred to the Instrument Development Section. An associate physicist recently employed by the Division has been assigned to this section.

*Neutron Monitoring.* Work on the problem of neutron monitoring by means of films supplementary to that in MDDC-890 is in progress. The experimental data for fast fission neutrons show a track density of recoil protons about 15% above the calculated values, possibly due to instability of the Victoreen meters. Exposure to a Po-Be neutron source gave experimental values 3.5 times those expected. The discrepancy was apparently due to the fact that the high energy neutrons from this source produced recoil protons in a paper wrapping with sufficiently large ranges to give tracks in the film. Evidence for this hypothesis was obtained by experiments in which a bare film, exposed with the emulsion toward the source gave the calculated value as did a film shielded by 1 mm Cd from protons formed in the wrapper, while a film exposed, emulsion to source, fully wrapped, and another one exposed bare, emulsion away from source, showed 3.8 respectively, 4.3 times the calculated values. Studies to determine the possibility of using calibrated Po-Be sources to calibrate NTA films for exposure to fission neutrons indicated that, for NTA films of emulsion #42243475666 (30  $\mu$ ) and #42301014406 (40  $\mu$ ), one week's tolerance of fission neutrons ( $2.9 \times 10^7$  nf/cm<sup>2</sup>) as determined by Victoreen measurements were obtained by exposure of  $1.52 \times 10^7$  and  $1.53 \times 10^7$  Po-Be neutrons, respectively.

Studies on the blackening of commercial films of various types by fast neutrons are underway. Evaluation of results have been made difficult by irregular dark areas in the irradiated film.

*Atmospheric Contamination.* In cooperation with another laboratory an investigation of a method of estimating contamination of the atmosphere by non-gaseous radioactive materials is in progress. The method consists essentially of collecting large quantities of rain water, concentrating the radioactive materials in the water by addition of aluminum sulphate and analysing the concentrated material for radioisotopes of interest. For this purpose rain water

is being collected from the middle western section of the Health Physics Building. A preliminary scrub of the roof and intermediate trough with stiff brushes and water has been made and collected in a 300 gal tank. Surveys of the roof prior to the scrub revealed many high spots of radiation particularly in the trough. The maximum reading obtained was  $5\frac{1}{2}$  mr/hr. After scrubbing most spots had been decreased in radiation intensity by at least a factor of 10. Analytical procedure on the scrub sample has been rather difficult because of the large amounts of solids present. Three collections of rain water of volumes ranging from 250 gal to 300 gal have been made. Analyses on the three runs have not been completed.

*Studies on  $\beta$  Radiation.* The construction of an improved extrapolation chamber combined with a vibrating reed electrometer was completed during this quarter. This instrument is now being used for beta absorption, beta scattering and determination of the surface dosage of uranium.

Studies on  $\beta$  absorption and angular distribution of scattered  $\beta$ 's are being made with the use of a G-M counter.

## URINALYSIS

An exploratory sampling of  $\beta$ - $\gamma$  activities in urine from laboratory employees handling large quantities of  $\beta$ - $\gamma$  emitting materials has been started. Seven persons who are believed not to be exposed to significant radioactive hazards have been used as controls. The average activity above background found in 24 hr samples for the seven persons was 1.1 c/m with a maximum activity of 2.2 c/m. Among samples from personnel working with  $\beta$ - $\gamma$  materials occasional activities of the order of magnitude of 50 c/m for a 24 hr sample have been found. Decay studies indicate that a large fraction of such activities may be due to  $\text{Sr}^{89}$ .

Although the procedure for analysis of body fluids for low tolerance concentrations of some of the beta-gamma emitting radioisotopes have been developed to provide quantitative recovery of Sr, Ba, Y and La, some additional changes were found desirable before routine analyses could be carried out. Since a large fraction of the samples studied contained beta-gamma activities only slightly above the background of the counter, it was desirable to eliminate all activity introduced by carriers and chemical reagents used in the analysis.

Lanthanum and yttrium carriers were found to give some beta-gamma activity. It was possible to remove the impurities in these carriers such that the activity remaining was less than the statistical error of counting. Impurities can be removed from yttrium by precipitation procedures and from lanthanum by use of a cation exchange resin column. Use of  $\text{Na}_2\text{CrO}_4$  as a reagent in the final precipitation instead of  $\text{K}_2\text{CrO}_4$  was found necessary. Activity from  $\text{K}^{40}$  which was not removed by the limited wash of the final precipitate was sufficiently high to warrant the change.

## CONSULTATION AND RADIATION PROTECTION ENGINEERING

During the past quarter the senior member of this group has spent one month on loan to Los Alamos Scientific Laboratory and has spent two days as consultant to Y-12 and one day to K-25. It is estimated that during the quarter members of this group have considered an average of three problems per day in consultation and liason with persons within the Division, within the Laboratory and outside the Laboratory.

The group has undertaken long range critical studies of Health Physics functions at ORNL for the purpose of recommending changes or improvements to increase the efficiency and effectiveness of the functions. A report on the progress of this study during the past six weeks has been presented to the Director of the Division.

Closer liason between Health Physics and persons responsible for the design and construction of new laboratory facilities will be effected by membership of one of this group on the ORNL Building Committee. Members of the group operating as individuals through the past quarter have for various reasons failed to keep abreast of the rapid progress of the building program. It is anticipated that with all three members of the group participating as a team in an organized effort these difficulties will be remedied. Inspection of the 900 Area reveals that advice recommending designs which would eliminate the possibility of splatter from "hot" sinks and positive pressures in the "hot" waste system has not been heeded. Although much good design has been incorporated, this group feels that it has failed because of the persistence of these two items.

An inspection by this group of the lead shielding installed in the 900 Area discloses cracks where the lead panels butted against steel supports. These cracks result from inability to fill channels with molten lead. Collimated leaks at these points were of the order of those which would be produced by 2 in. of lead missing in a 6 in. shield.

A problem receiving consideration by this Division and other laboratory groups is that of formulation and administration of a reasonable policy covering the issue and handling of clothing for radiation protection. One phase of this problem involves such items as the choice of materials, the possible use of dyes for identification and procedures in decontamination or disposal procedures. Pilot studies of decontamination have been made in beakers using

coverall cloth dyed with yellow Rit. Such studies show that the presence of dyes does not make decontamination more difficult. In these studies it was found that commercial detergents were considerably inferior to the presently used laundry solution employing citric acid followed by igapl. A commercial soap was found to be considerably better than the detergents but inferior to the citric acid procedure.

A course in basic physics and health physics (totalling 20 hrs) has been conducted for the benefit of ORNL personnel engaged in shipping radioisotopes. The objective is an explanation of the shipping regulations to enable these persons to better perform their work.

## PERMISSIBLE INTERNAL DOSE

During this period calculations were made and the Subcommittee of National Radiation Protection Committee has agreed upon a tentative maximum permissible concentration of  $C^{14}O_2$  in controlled areas (plant atmospheres). The tentative level is  $10^{-7} \mu c C^{14}O_2/cc$  air.

Approximately 225 key persons in the United States were notified of the committee's recommendation concerning the  $C^{14}O_2$  level.

A table of 24 radioisotopes has been prepared and sent to the committee members. This table consists of all pertinent information to enable the members to arrive at a recommended level for each of the isotopes. The particular isotopes are those which are common to the normal body metabolism and only those which have half-lives  $>11$  hr. The isotopes are:

$H^3$ ,  $C^{14}$ ,  $Na^{22}$ ,  $Na^{24}$ ,  $P^{32}$ ,  $S^{35}$ ,  $Cl^{36}$ ,  $K^{40}$ ,  $K^{42}$ ,  $Ca^{45}$ ,  $Ca^{47}$ ,  $Ca^{49}$ ,  
 $Mn^{52}$ ,  $Mn^{54}$ ,  $Mn^{56}$ ,  $Fe^{52}$ ,  $Fe^{59}$ ,  $Fe^{55}$ ,  $Cu^{67}$ ,  $I^{125}$ ,  $I^{126}$ ,  $I^{130}$ ,  
 $I^{131}$ ,  $I^{133}$ .

## EDUCATION AND TRAINING

The education and training in Health Physics during this period included programs for the following groups or persons:

1. The nine NRC Fellows who have been here for a period of one year beginning November 1, 1948, and who completed their training October 8, 1949.
2. Eight medical officers for a six months period, beginning April 11, 1949.
3. Fourteen officers from the Armed Forces engaged in a three year program in radiation and assigned to this Laboratory for eight weeks of field training from July 7, to September 1, 1949.
4. One person from the AEC Installation at Rochester, New York, for special training for one month.
5. One Naval Officer who completed a more or less formal training period of approximately one year working with the Special Problems group.
6. Six personnel from the Brookhaven Laboratory for a period of ten days for field training.
7. Nine NRC Fellows (the number will be increased at least to ten and perhaps more) who began, on October 5, 1949, a training period of one year.

Substantial contributions to the training program have been made by other laboratory groups and personnel—field work training by the Operations and Production groups, lectures on special subjects by members of other divisions and the AEC.

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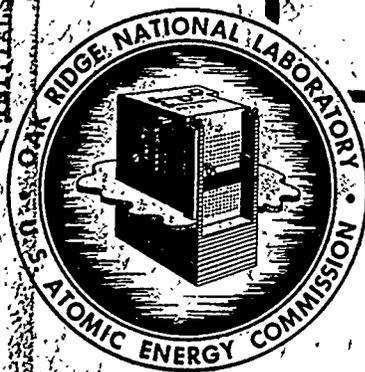
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HEALTH PHYSICS DIVISION  
QUARTERLY PROGRESS REPORT  
FOR PERIOD ENDING JANUARY 15, 1950

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## TABLE OF CONTENTS

INSTRUMENT DEVELOPMENT	5
Fast Neutron Instrumentation	5
Continuous Water Monitoring Instrumentation	5
Low Level Alpha Scintillation Counter	6
WASTE DISPOSAL STUDIES	7
Water and Sewage Treatment Process	7
Survey Studies of White Oak Lake and Clinch River	8
Instrumentation	8
Miscellaneous Activities	9
THEORETICAL PHYSICS	10
Projects Completed	10
Active Projects	10
EXPERIMENTAL PHYSICS	11
SPECIAL PROBLEMS GROUP	12
Surface Dose of Uranium and Thorium	12
Backscattering.	12
Absorption of Beta Radiation	13
Fast Neutron Monitoring with Commercial Films	13
Neutron Monitoring by NTA Films	14
Neutron Monitoring with Palladium	14
URINALYSIS	15
PERMISSIBLE INTERNAL DOSE	17
EDUCATION AND TRAINING	17

## INSTRUMENT DEVELOPMENT

**Fast Neutron Instrumentation.** A. The portable battery operated fast neutron survey meter, described by G. S. Hurst in report ORNL 485, has proven to be reliable and a desirable instrument in the past six months of usage in the pile building. The Health Physics Survey-Monitoring Section is procuring three instruments to increase its fast neutron surveying capacity. Large numbers of this instrument will not be built as it is regarded as an interim model (see following paragraph).

B. G. S. Hurst has completed in rough draft a report in which the critical specifications of a special type of fast neutron dosimeter are calculated. This instrument would be designed for measurements in unidirectional beams, and would be unique in that a good approximation to the dosage (or energy lost in tissue) would be given by considering count rate only. A result is the simplification of associated electronics such as to require only a one or two tube amplifier. The report is now being criticized and is to be issued shortly. Components and apparatus are being procured and arrangements are being made to experimentally test this design with monoenergetic neutron beams.

C. An a-c operated, portable, fast neutron monitor with alarm has been constructed and tested. A report is now being written by R. J. Farber, and drawings are to be made. The Survey-Monitoring Section is expected to have three models constructed.

D. A fast neutron meter, integrating version considering both flux density and pulse heights, has been constructed (and is now being "debugged") by F. M. Glass of the Radiation Detection Section of the Instrument Department. This activity is in the interests of the Technical Division Shielding Program as well as the Health Physics Division.

E. The proportional counter development is continuing with application to all of the above instruments.

F. Film calibration for fast neutrons related to personnel monitoring was thought to have need of a special design of the instrument noted in paragraph A above. Work was started, then stopped due to pressure of other problems, and the job is now inactive.

**Continuous Water Monitoring Instrumentation.** This work, mentioned in the preceding quarterly report, is presently inactive. Work may be started in about one month.

**Low Level Alpha Scintillation Counter.** One laboratory model is being made for testing by the Health Physics Counting Room and the Chemistry Section.

## WASTE DISPOSAL STUDIES

During this period there has been no change in the permanent research staff of the Section nor in the personnel assigned from other agencies and groups as mentioned in previous quarterly reports.

**Water and Sewage Treatment Process.** A major part of the program is continued study of the well-known and widely used methods of water, sewage, and industrial waste treatment. The general purpose is to determine the efficacy of such sanitary plants and processes in the removal of various radioactive materials from water or waste liquids, and to evaluate and adapt these methods as a means for economical treatment of relatively large volumes of slightly or moderately contaminated radioactive wastes.

The small model water treatment plant had to be removed from Building 813 which was torn down beginning October 17. Duplicate stainless steel units have been completed and the two plants set up ready to resume operation in a laboratory of the Health Physics building. Laboratory work has been continued on the removal of  $P^{32}$  and also  $I^{131}$  by modified water treatment methods and a report on the  $P^{32}$  work has been compiled for limited distribution. It was found that the removal of  $P^{32}$  by these processes is very efficient, but the removal of  $I^{131}$  by the methods tried thus far is relatively poor. It is planned to continue both laboratory and semi-works experiments on a number of other radioisotopes and to try various modifications of treatment before decontamination of mixed wastes is studied.

Studies of sewage treatment processes have included operation of sewage sludge digestion flasks for extended periods with daily additions of raw sludge, analyses of the sewage, and collection and analysis of the gas evolved. The purpose is to determine the digestion and other characteristics of the local sewage as a preliminary to experiments on the absorption and removal of various radioisotopes by sewage constituents. Also a six-foot sewage filter column has been dosed with a dilution of  $I^{131}$  in sewage at filtration rates from 5.6 to 18.3 million gallons per acre daily. Preliminary findings indicate a reduction in activity ranging from 40 to 24 per cent in this range of dosage.

Two small series of experiments on the extrusion of radioisotopes from water during freezing have been completed and a memorandum suggesting the course and value of further work on these phenomena has been prepared.

Apparently progress has been made and tentative approval has been given toward the provision of more adequate facilities for waste disposal research which was proposed several months ago. These would include a building for laboratories and for semi-works and pilot plant space to be devoted to water and waste decontamination and related study projects which are of particular interest to a number of agencies.

**Survey Studies of White Oak Lake and Clinch River.** Much of the work on survey studies has been in cooperation with the TVA ecological reconnaissance and the comprehensive biological study project which is authorized and scheduled to become active early in 1950. This has included the study and improvement of techniques for the assay of biological specimens and mud, and for mud and water surveys in order to measure more accurately the exposure and radioisotope concentration levels of the biological organisms to be studied. A large wood stave tank previously made available for instrument testing was prepared for the storage of uncontaminated fish to be collected and used by TVA personnel in connection with this project. A special study has been made in an effort to evaluate the magnitude of common errors in beta counting of biological and other bulky materials and to indicate correction factors for errors due to variations in the spread of samples, scattering from sides of counting dishes, self absorption losses, and other factors.

Hydraulic and hydrologic data concerning variations of flow and time of water and wave travel in Clinch River in relation to discharges from White Oak Creek have been analyzed and the first in a series of reports on these studies has been issued as ORNL 562.

Some work has been done in cooperation with the AEC geological study project in its program of core drilling in and around the Laboratory area for the exploration of ground water movement and evidences of contamination.

**Instrumentation.** Further work on the development and calibration of probe instruments for mud and stream water surveys has been done. For continuous measurements of radioactivity and water discharges at White Oak Dam a pilot model gamma ray monitor has been operated more or less continuously at the dam for testing and calibration. A project has been approved for installation of continuous monitoring, water level recording, and telemetering at White Oak Dam in order to provide information for the special survey studies and also routine operating data.

Instruments have been adapted for continuous indication and recording of levels of radioactivity in different parts of the continuous waste treatment

experimental units in connection with water and sewage decontamination studies.

**Miscellaneous Activities.** Three papers were prepared and presented by members of the staff at meetings during this period: O. R. Placak on "Investigations on Radioactive Waste Disposal in Relation to Water and Sewage Treatment" at the Twenty-first Annual Meeting of the Kentucky-Tennessee Section of the A.W.W.A. and the Third Annual Meeting of the Kentucky-Tennessee I. W. & S. W. A., Lexington, Kentucky, October 31 and November 1, 1949; R. J. Morton on "Public Health Aspects of Atomic Energy" at the General Session of Thirteenth Annual Meeting, Mississippi Public Health Association, Jackson, Mississippi, December 13, 1949; and C. P. Straub on "The Sanitary Engineering Aspects of Radioactive Waste Disposal" at the 116th Meeting of the American Association for the Advancement of Science, New York, New York, December 26 to 31, 1949.

O. R. Placak has served and done considerable work on the Subcommittee on Waste Disposal, National Committee on Radiation Protection. This has included attendance at a Subcommittee meeting, completion of a draft of recommendations for exhaust air criteria applicable to laboratory hoods, and review and comment upon several drafts on other subjects by Subcommittee members.

Detailed activities of the Waste Disposal Research Section are covered by monthly reports prepared for limited distribution by R. J. Morton.

## THEORETICAL PHYSICS

**Projects Completed.** The calculation of collision density for a beam of thermal neutrons on a tissue slab was completed, and a paper giving the solution and some discussion of its significance in determining maximum permissible exposures is to appear in the February issue of *Nucleonics*.

The gamma ray mass absorption coefficient project completed jointly by W. S. Snyder and J. L. Powell was issued jointly by the Health Physics Division and the Summer Shielding Session. This report is now in process of declassification and is to be issued as ORNL 421.

A paper, "An Alignment Chart for Monte Carlo Solution of the Transport Problem," jointly authored by Snyder, Goertzel and Spinrad, was prepared for publication in a forthcoming volume of the Proceedings of the Conference on Monte Carlo Methods at Los Angeles.

**Active Projects.** The thermal neutron problem, mentioned above for the case of an incident normal beam, is being considered for the case of a general distribution of the angle of incidence of the neutrons.

A method has been outlined for determining energy losses of charged particles of intermediate energies; *i. e.*, which do not carry bound electrons and have velocities lower than the K shell velocity of the stopping atom. The results obtained are also of interest in evaluating energy losses for low energies.

## EXPERIMENTAL PHYSICS

The project to study the distribution of reactor stack gases, discussed in the two preceding quarterly reports,<sup>(1)</sup> is in the midst of instrument construction and is about two thirds completed. The usual "de-bugging" of apparatus consumes most of the time of two people in the section.

A trip was taken to the Los Alamos Laboratory to obtain data on particulate fall out from atmospheric contamination. The data will be useful in evaluation hazards due to radioiodine or other volatile isotopes. Some data have been received and more recent data will arrive shortly.

Two members of the section were on loan to the Geological Survey during the month of November. A test flight of the instruments aboard the survey aircraft for uranium prospecting purposes indicated that connection of the conductivity apparatus to the ventilating system was not feasible and it is intended to mount the conductivity tube on the outside of the aircraft. A test of the mounting and operation of the instrument is planned in February.

(1a) Morgan, K. A. and Western, F., *Health Physics Division Quarterly Progress Report for Period Ending July 15, 1949*, ORNL 375 (August 23, 1949)

(1b) Morgan, K. Z. and Western, F., *Health Physics Division Quarterly Progress Report for Period Ending October 15, 1949*, ORNL 495 (November 29, 1949)

## SPECIAL PROBLEMS GROUP

**Surface Dose of Uranium and Thorium.** The beta surface dose of uranium was measured with an extrapolation chamber. The gamma radiation is included in this experiment. The result was 239.86 mrep/hour, corrected for 760 mm Hg and 0°C. The determination of the total dose for uranium and thorium is in progress and will probably be finished in the near future. A considerable part of the time was spent in calibration and readjustment of the extrapolation chamber.

**Backscattering.** Backscattering experiments were conducted with several sources such as  $P^{32}$ ,  $S^{35}$ , and  $Sr^{90}$ . The backscattering was measured with an extrapolation chamber, and the experiments will be repeated with a beta proportional counter. The backscattering was measured in percents of the ionization produced by the source only. The source was deposited on rubber hydrochloride having negligible backscattering itself. Eleven elements were tested, ranging from Be to uranium. The backscattering material was placed directly behind the rubber hydrochloride. The effective thickness of the scatterer was practically infinite (multiple backscattering). The distance between the rubber hydrochloride and the chamber was variable from 1 to 25 mm. The detailed description of the measurement will follow in a later report.

The primary radiation of each source has a wide spectral range from very low values to a maximum energy about 1.72 Mev for  $P^{32}$  and 0.168 Mev for  $S^{35}$ . Since exact experiments would require a defined single energy, the observations cannot yet be evaluated with certainty. The following preliminary results were obtained:

1. The amount of backscattering increases with increasing atom number  $Z$ , rapidly for lower  $Z$  and medium  $Z$ , and to a lesser degree for high  $Z$ .
2. The relative intensity of backscattering is higher from a high energy source ( $P^{32}$ ) than that from one of low energy ( $S^{35}$ ).
3. Interposing absorbers between source and chamber (air distance or preferably Al) reduced the backscattering from lower atom numbers by a much larger percentage than that from high atom numbers. For instance, 6.6 mg/cm<sup>2</sup> Al as an absorber reduced the backscattering from Be by 45% and that from Pb by 8.6%.

The result was considered as a possible indication that the backscattered electrons from Be have a lower average energy than those of Pb. These experi-

ments had to be discontinued temporarily.

**Absorption of Beta Radiation.** Absorption experiments of beta rays with several materials are in progress.

**Fast Neutron Monitoring with Commercial Films.** The films were investigated for blackening rather than for tracks. A Po-Be source was used for exposures from one week to more than 35 weeks tolerance ( $2.5 \times 10^7$  to  $1 \times 10^9$   $N_f/cm^2$ ). One part of the film was exposed to the direct radiation (open window), while the other part was shielded by 0.07 in. lead. While relatively "fast films" failed to show a linear relation between flux and log of blackening with a densitometer, the relationship for slow films (AnSCO process film) could be graphed as a straight line on log paper.

The shielded portion of the film showed an increased blackening over the open window portion. This suggested that secondary X-ray or beta radiation is produced in the lead either by the primary neutrons or by some gamma radiation or by both. A number of investigations have been conducted to decide the origin or nature of the blackening, as follows:

1. The distance of the source excluded heavy particles such as alpha and primary protons.
2. Since aluminum between the source and lead shield did not reduce the blackening, primary beta rays are excluded.
3. As to the question of primary gamma radiation, one cobalt and one radium source showed less blackening behind the lead shield than behind the open window, *i. e.*, the opposite behaviour of Po-Be. Apparently the lead reduces the blackening from the gamma radiation of cobalt and radium but not the radiation from Po-Be.
4. Additional aluminum shielding between the lead shield and the film, using Po-Be, eliminated or reduced this blackening. It is, therefore, possible that this type of radiation consists either of very soft X-rays, beta radiation, or both probably produced by the primary neutrons of Po-Be by inelastic scattering lead.
5. By exposing the film to the Po-Be source in such a way that the film is parallel to the direction of the neutron beam (striking incidence) actual recoil proton tracks could be observed.

The final evaluation of these results, however, will require more investigation.

**Neutron Monitoring by NTA Films.** The supplementary report on neutron monitoring by means of NTA emulsion was finished, and is in the process of publication as ORNL 547 (unclassified).

The track expectancy in NTA emulsion previously reported in MDDC-890 was recalculated on the basis of Eastman's analysis of composition of their present NTA emulsion, and B. E. Watt's determination of the fission energy spectrum (LA-718). The new values were somewhat higher than those reported previously.

Track densities found were greater than those expected from the emulsion alone, and it was determined that this was the effect of the protons formed in the film wrappers. The excess, with fission neutrons was on the order of 25%, and with Po-Be neutrons on the order of 200%, i. e., the number of externally formed protons which were being recorded was a function of incident neutron energy.

The fading of the latent images of proton tracks was investigated. The rate of loss was found to vary with different batches of film, but could be diminished by using a longer development time. With the one week cycle of film change now used, probable track loss is approximately 12% in most of the batches tested. It was also noted that when the emulsion was mounted on glass plates, the latent images tended to greater stability.

Calibration and monitoring procedures were reviewed as to statistical reliability. It was found that with the more sensitive batches of film, and using the current tolerance values (*K.Z.M. Jour. Ind. Hyg. & Tox.*, September 1948) exposure in the range of tolerance doses could only be determined to within a factor of two.

A more sensitive and reliable method of monitoring personnel for neutron exposure is still being sought.

**Neutron Monitoring with Palladium.** Investigation was begun on the possible use of palladium as a fast neutron detector. This was suggested by resistance changes noted by B. R. Gossick, working in the Physics Division, when irradiating Pd coils with fast neutrons. If this effect can be determined to be due to fast neutrons, it may be used for monitoring.

## URINALYSIS

The exploratory survey for determining beta-gamma activity in urine specimens of Laboratory employees handling large quantities of beta-gamma emitting materials has been continued during the period. Urinalyses for alkaline earth and rare earth beta-gamma emitting elements have been made on 38 individuals.

A tabulation of the results of the activity found in the samples is listed below. The beta-gamma activity was determined by counting the sample in a G-M counter with a thin mica window. The geometry was 27.5%.

Net cts/min excreted per day	Number of individuals
<5.0 c/m	15
5.0 to 10 c/m	9
10.0 to 20 c/m	5
20.0 to 50 c/m	2
>50.0 c/m	7

Detailed studies of the nine cases which showed excretion >20 c/m per day have been made. Seven of the nine samples showed a decay with a half-life of approximately 60 days. This beta activity is believed to be strontium<sup>90</sup>. Absorption curve studies substantiate this fact. The activity of the samples from the other two individuals was shown to be strontium<sup>90</sup>--yttrium<sup>90</sup>. This was proven both by absorption curve studies and by radiochemical separation with a subsequent study of the decay and/or growth of the component parts.

Of particular interest was the case which showed the highest activity. This case was studied in detail by the analysis of weekend samples for seven consecutive weeks. The following table shows the total beta-gamma activity found during the period checked:

	Cts/min excreted per day*
1st week	830
2nd week	214
3rd week	201
4th week	82
5th week	59
6th week	56
7th week	54

\*Activity due to Sr<sup>90</sup>--Y<sup>90</sup> in equilibrium

## PERMISSIBLE INTERNAL DOSE

Calculations for permissible concentrations for some 27 radioisotopes completed during this quarter are recapitulated in Report No. ORNL 591.

## EDUCATION AND TRAINING

The Education and Training in Health Physics during this period included programs for the following groups and persons:

1. The eleven NRC Fellows who began their training here on October 5, 1949, have during this quarter been occupied with the following courses:

Atomic Physics	4 hrs. per week
Electronics and Instrumentation	4 hrs. of lecture per week and 3 hrs. of laboratory per week.

Two of the Fellows, who have had considerable work in electronics were excused from participation in that course to do lab work with Health Physics Research groups. One has been assigned to the Experimental Physics group and the other to the Special Problems group.

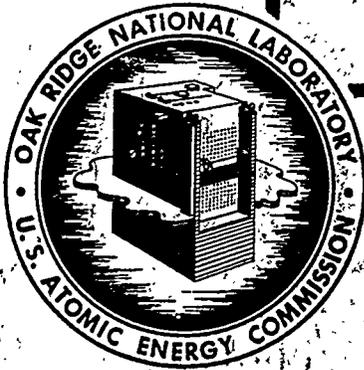
2. An employee of the U. S. Department of Agriculture, Agricultural Research Administration, Beltsville, Maryland, spent two weeks at the Laboratory with the various Health Physics survey groups on a schedule worked out jointly by this section and the survey monitoring section.

In addition to the above training program, the section has been working in two major problems: (1) The organization and credit for the AEC Technical Fellowship program for next year, 1950-51, and (2) the writing of a manual and the preparation of a curriculum for the Civil Defense program.

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1951

HEALTH PHYSICS DIVISION  
QUARTERLY PROGRESS REPORT FOR PERIOD  
ENDING APRIL 15, 1950



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**HEALTH PHYSICS DIVISION**

**K. Z. Morgan, Director**

**F. Western, Associate Director**

**QUARTERLY PROGRESS REPORT  
for Period Ending April 15, 1950**

DATE ISSUED: MAY 26 1950

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## TABLE OF CONTENTS.

<b>INSTRUMENT DEVELOPMENT</b>	5
Fast Neutron Program	5
Portable Alpha Survey Meter	5
Constant Water Monitoring	6
Beta Dosimeter	6
<b>WASTE DISPOSAL STUDIES</b>	7
Water and Liquid Waste Decontamination Processes	7
Survey Studies of White Oak Drainage System and Clinch River	8
Instrumentation	9
Miscellaneous Activities	10
<b>THEORETICAL PHYSICS</b>	11
Ionization and Excitation Losses of Charged Particles	
Traversing Matter	11
Interpretation of Cross Section Data	11
Fast Neutron Problem in Tissue	11
<b>EXPERIMENTAL PHYSICS</b>	13
<b>SPECIAL PROBLEMS</b>	14
Surface Dose of Uranium	14
Backscattering of Beta Particles with an Extrapolation	
Chamber	14
Backscatter Measured with Beta Counter Filled with A and CH <sub>4</sub>	15
Absorption of Beta Particles	16
Neutron Monitoring	16
<b>URINALYSIS</b>	19
Analysis of Urine for Radioactive Strontium	19
Method for Removing Impurities from Lanthanum	19
<b>EDUCATION AND TRAINING</b>	21

This report covers the activities of those groups in the Health Physics Division primarily engaged in Applied Research or Development. More or less routine activities of the Survey-Monitoring Section are covered in the Laboratory Weekly Progress Report.

## INSTRUMENT DEVELOPMENT

**Fast Neutron Program.** A. The calculations describing a proportional counter applicable to a portable fast neutron dosimeter, where the neutron dosage is indicated directly by a counting rate, are included in a report ORNL 589<sup>(1)</sup> issued February 17, 1950. Since that date, refinement of some of the assumptions have been made, and experimental counters to test the theories involved have been constructed. Test measurements using various monoenergetic neutron beams provided by equipment at Los Alamos are scheduled to take place about April 10-14, 1950.

B. A report, ORNL 590<sup>(2)</sup> issued March 21, 1950, describes a Fast Neutron Continuous Monitor and Survey Meter. The survey meter has a count rate meter with full scale values of 50, 1,000, and 10,000 neutrons/cm<sup>2</sup>/second. The instrument will discriminate against gamma radiation up to about 10 r/hr. The probe is connected by a 12 foot cable to a power supply permitting the use of the probe as a survey instrument. An alarm circuit is provided. The instrument is powered by the 110 volt 60 cycle line. One model of this instrument is in operation and will be observed for reliability and general performance.

C. Work is proceeding on the design and construction of a proportional counter to have a uniform response or count rate sensitivity related to neutron energy, where the neutron beam may have energies between 0.5 Mev and 15 Mev. The application of this counter is to measure total emission of such sources as Po-Be, Ra-Be, etc., and an objective is increased accuracy over present methods of such source measurements.

D. A proportional counter to have equal sensitivity in all directions is being developed. The application of this counter will be largely for shielding measurements and monitoring.

**Portable Alpha Survey Meter.** A. Report ORNL 602<sup>(3)</sup> issued March 14, 1950, describes the subject instrument which, briefly, is a proportional counter, gamma discriminating, battery operated, survey meter of four pounds total

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(1) Hurst, G. S., *Fast Neutron Count-Rate Dosimetry*, ORNL 589 (February 17, 1950).

(2) Farber, R. J., *Fast Neutron Continuous Monitor and Survey Meter*, ORNL 590 (March 21, 1950).

(3) Hurst, W. M., Hurst, G. S., and McDonald, W. B., *A Portable Alpha Survey Meter*, ORNL 602 (March 14, 1950).

weight. Operation in a high humidity is achieved by the use of silica gel in the probe and some effort is now being made to eliminate the silica gel by the use of guard rings. Twelve instruments are ordered for further field testing. Some consideration is being given to the possibility of a commercial production contract.

**Constant Water Monitoring.** A. This problem has been worked on for one month. Exploratory work is contemplated for a period of about six more months at which time we will want to freeze on the type of detector to be used and construct a laboratory model.

**Beta Dosimeter.** A. This problem is to be attacked starting April, 1950, and the objective is a survey instrument, possibly operated from 110 volt line, for use in scanning laboratory tables, equipment, and machinery.

## WASTE DISPOSAL STUDIES

During this period there have been no major changes in the research staff and facilities of the Waste Disposal Research Section. There have been some important changes in the work program, particularly increased emphasis on laboratory studies of processes for water decontamination, and extensions of cooperation with other groups and agencies and the development of joint research projects.

**Water and Liquid Waste Decontamination Processes.** The small model water treatment plant set-up has been completed in a laboratory of the Health Physics Building. Numerous items of experimental and control equipment have been procured and installed making the plant practically automatic in operation. These include a weir type effluent collecting and sampling container, a constant head multiple orifice feedbox, lucite tubing rapid sand filters, Flow-rator control devices, a supporting stand for the feedbox, and other necessary accessories. A preliminary run with the Spaulding precipitator has been carried out without radioactive materials and with comparative use of alum and ferric chloride as a coagulant.

Extensive series of experiments on coagulation and precipitation processes for the decontamination of liquids have been continued. The purpose is twofold: (1) to evaluate the action of usual water coagulation processes in the removal of typical radioisotopes and mixed fission products; (2) to find and evaluate the coagulant aids that can be used effectively and without too much modification in conjunction with conventional water and waste treatment procedures. The study is planned to include a wide range of operating conditions as found in typical water plants. Experiments thus far have included tests upon the removal of cerium 144, zinc 65, yttrium 91, and tungsten 185, and a number of other isotopes have been obtained for use in future series of experiments. Preliminary results indicate very good efficiencies in the removal of the isotopes tested from very low as well as from moderate concentrations in water.

Further laboratory tests of a sample of East Pond water have been made in the study of adsorption of activity on particles of kaolinitic clay, and radiochemical analyses are being made to determine the sources of activity in this

sample. Previous results were confirmed and a report on this project is being prepared.

Studies of sewage treatment processes have included an additional series of sewage digestion experiments begun on January 28 and completed near the end of March. For further study of the action of sewage filters in the concentration of radioactive materials, a number of the six foot sewage filter columns arranged for sampling at intervals of one foot depths have been completed by the Research Instrument Shop.

The proposal for construction of a laboratory and pilot plant building for research in water and liquid waste decontamination has been approved and the Division is authorized to proceed with this project. With cooperation from the Engineering and Maintenance Division the change recommendation (CR-75 Revised) "Facilities for research in water and liquid waste decontamination" and preliminary plans for the building have been completed and design criteria for the building and equipment to be procured under contract are being prepared. In addition to the Health Physics Waste Disposal Studies, these facilities will provide for research projects of particular interest to the Public Health Service and to military agencies, and a plan for cooperative work by which these agencies will participate in water and waste decontamination studies at ORNL has been developed. At a conference on April 12 in the Health Physics Division, representatives of the Public Health Service, the Armed Forces, the AEC and ORNL were present and a framework of general policy and plans for this program of cooperative research was adopted.

**Survey studies of White Oak Drainage System and Clinch River.** The contract between AEC and TVA covering an Ecological Study of White Oak Drainage System was drawn up and approved in January and general plans for the study have been completed. The stated general purpose is (1) to determine what radioactive elements have accumulated in living things in the stream, (2) where they have accumulated, and (3) what has been the effect on survival rates, population balances, and types of organisms. This is a comprehensive long range program with which ORNL will cooperate and work jointly since the study includes many questions with which the Health Physics research program is concerned. Major sections of the work plan include a physical survey of the White Oak Creek Drainage area, a limnological study, fish population biology,

and a radiological study of the drainage area possibly as far down stream as Watts Bar Dam. An advisory committee was formed and has held two meetings. General direction of the study and the physical survey is a function of the Health and Safety Division of TVA. Detailed studies of fish and fish food biology are to be conducted by the TVA Fish and Game Branch. Much of the radiological study will be performed by the Health Physics Division as a part of the program of waste disposal studies or through analytical and assay services rendered to TVA. Use of the data obtained and supplementary studies are to be made by the Waste Disposal Research Group in order to interpret the results of the Ecological Study from the viewpoints of Health Physics.

Work in connection with the White Oak Drainage System has been continued both as a part of Waste Disposal studies and in preparation for the Ecological Study mentioned above. This has included (1) field measurements of the volume of flow through White Oak Dam at various water elevations to provide a more accurate rating curve, (2) review of data and preparation of drafts of reports on all previous fish studies in White Oak Lake and Clinch River, (3) progress toward the completion of the continuous monitoring installation at White Oak Dam, and (4) plans for a re-survey of radioactivity in mud deposits above White Oak Dam.

The AEC Geological Survey project has completed the core drilling of 51 test wells totaling 4500 feet of holes for the study of ground water contamination. The Health Physics Division is cooperating in probing and analyses for radioactive measurements in these wells. A special probing detector with about 200 feet of cable and indicating-recording instruments has been assembled to permit logging of the test wells after they are completed and several wells have been measured and reported. It was agreed that all wells should be probed for evidences of radioactivity above natural background, that pulverized rock samples of the cores from representative strata should be counted and analyzed, and that radiochemical analyses of water samples from selected wells should be made by the Waste Disposal Research Group.

**Instrumentation.** For the probing of test wells mentioned above a probing detector has been constructed and tested in manual operation. An automatic reel and recorder assembly for the well probe has been designed and assigned to the shop for construction. Other work has included preliminary design and

testing of a small probe for scanning fish specimens for radioactivity, further design and testing of a detector for continuous monitoring of water at White Oak Dam, and preliminary work on a special probing instrument for mud surveys.

A small radiochemical laboratory has been equipped for analyses in connection with the TVA-AEC Ecological Study and in the regular program of waste disposal studies; active work has been done in the adaptation of radiochemical techniques for use with organic specimens and the other types of materials involved in these programs.

**Miscellaneous Activities.** Liaison has been maintained and several conferences have been held with members of the Chemical Technology Division for exchange of information, coordination of Waste Disposal Research activities, and preparation of material to represent ORNL in the new AEC working group on waste disposal problems.

As a result of a flood in White Oak Creek in January, temporary measures were taken to provide emergency protection against overflow of the roadway and possible destruction of the dam. Members of the Waste Disposal Research Group have collaborated with design engineers and others in the development of plans for permanent changes in the dam to eliminate flood hazards.

## THEORETICAL PHYSICS

**Ionization and Excitation Losses of Charged Particles Traversing Matter.** Efforts are being made to fit the available data into the formulas previously derived in order to determine the oscillator strengths of a Fermi-Thomas atom. These oscillator strengths are the only empirical constants which are necessary in order to evaluate the energy losses of heavy particles of intermediate energies.

The only available data are from the stopping power measurements of protons in the various substances performed by S. D. Warshaw.<sup>(1)</sup> Unfortunately, these measurements cover a low energy range (below 600 Kev) and, therefore, the data do not appear to be very useful.

Consideration was given to the stopping power calculations made by Hirschfelder and Magee<sup>(2)</sup> using the Bethe theory. These calculations cover the intermediate energy range and, therefore, could be used for determination of oscillator strength. However, it was found that the calculations are quite unreliable since in the low energy range they differ from the measurements of Warshaw by 35 to 40 percent.

**Interpretation of Cross Section Data.** During the recent few months, the Mathematics Panel was engaged in interpretation of cross-section measurements performed by Dr. S. Bernstein and his associates. In that connection a certain amount of theoretical and experimental material has been compiled justifying the assumption that the neutron width of the element under consideration is as follows:

$$2.3 \times 10^{-3} \sqrt{E_0} > \Gamma_n > 0.3 \times 10^{-3} \sqrt{E_0}$$

where  $E_0$  is the resonance energy in ev.

**Fast Neutron Problem in Tissue.** The problem is now on the calculating machines and the fifth collision calculations are completed. There has been

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(1) Warshaw, S. D., "The Stopping Power for Protons in Several Metals," *Phys. Rev.* 76, 1759 (1949).

(2) Hirschfelder, J. O. and Magee, J. L., "Range-Energy Relations for Protons in Substances Containing C, H, O, A, and Xe," *Phys. Rev.* 73, 211 (1948).

considerable delay due to machine trouble, but the neutron histories should be available in a matter of weeks. Preliminary studies are in progress to determine the most effective method of handling this data for tolerance calculations.

## EXPERIMENTAL PHYSICS

Apparatus previously used for determination of radon content of air samples and radium content of water samples is being overhauled. When reconditioned, this apparatus will be used for radium analyses of core samples from bore holes in an effort to correlate radium content with natural background variations observed in the logging of these holes with a Geiger counter probe (See discussions of core drilling project under "Water Disposal Studies.")

As a part of the program of studies of dispersal of stack gases in the atmosphere two of four high pressure ionization chambers containing 100 cubic feet of argon each have been installed at distances of approximately one and three miles east of the stack. The other two will be placed as soon as lines are available at corresponding distances to the west of the stack. All four chambers will feed into recording apparatus in Building 104-B. Since the winds are usually up and down the valley, the two chambers upwind will act as background measurements to subtract from the activity measured downwind from the stack. Three trailers containing apparatus for measuring air contamination are near completion. It is intended to place at least two of the trailers at positions occupied by the high pressure chambers.

Approximately one month's time of two people in the section was devoted to the US Geological Survey for the purpose of instrument design and use in aerial prospecting for uranium. The present sensitivity of the apparatus is the detection of small outcrops of 0.1% ore while flying at 500 feet above ground. It is desirable to have a sensitivity of about ten times this which means counting rates of the order of 100 times the present. Attempts to approach this sensitivity are being made by using bundles of large Geiger counters and also by use of large crystals of sodium iodide as scintillation counters.

## SPECIAL PROBLEMS

**Surface Dose of Uranium.** Enriched uranium was investigated to determine the alpha and beta dose. The details and results will be given in a later report, ORNL 697.

**Backscattering of Beta Particles with an Extrapolation Chamber.** The previous experiments with  $P^{32}$  were continued. The source was deposited on the inside of the upper electrode, consisting of rubber hydrochloride made conductive with aquadag. The mass was less than one mg per  $cm^2$ .

The primary beta radiation, the backscattered electrons, and the ions produced a current through a resistance from the collector to ground. The voltage across this resistor was measured. The rubber hydrochloride was usually the negative electrode and the collector was the positive one. The distance between the upper electrode and the collector was varied from about 1 mm to 0.5 mm to obtain a correct extrapolated value.

The contribution of several collector materials to the backscattering was investigated. The current increases considerably with increasing atom number  $Z$  of the collector. A correction of about 1.75 percent for beryllium collector should be made to account for backscattering from the rubber hydrochloride. Theoretically the following observations should be expected:

Setting:

- $I_{\beta}$  = primary beta current
- $m$  = average number of ion pairs per primary beta
- $l$  = average distance between collector and source
- $s$  = number of backscattered electrons per primary beta
- $n$  = number of ion pairs per cm produced by backscattered electrons
- $I$  = total current through collector

It shall be assumed that all the backscattered electrons are reaching the negative electrode.

It follows then:

$$(1) \quad I = I_{\beta} [ l + ml - s + snl ], \quad s = f(Z)$$

$$(2) \quad dI/dl = I_{\beta} [ M + sn ], \quad n > m,$$

since the backscattered electrons have a lower velocity than the betas, and are producing more ions/cm. Since  $s$  increases considerably with  $Z$ , the intercept for  $l = 0$  on the  $I - l$  coordinates should decrease with increasing  $Z$ , while according to (2), the slope  $dI/dl$  should increase. While the second conclusion was confirmed qualitatively, the first one is not yet proved. The investigations are still in progress.

**Backscatter Measured with Beta Counter Filled with A and  $\text{CH}_4$ .** A special construction of the ionization chamber makes it possible to limit the backscattering to that of the source carrier, that is, rubber hydrochloride. The backscattering material can be supported in such a way that it contacts the outside of the rubber hydrochloride very closely. The source itself is on the inside of the rubber hydrochloride and has a geometry of nearly 50 percent. The construction permits a rapid exchange of backscattering material without opening the ionization chamber.

**A. Backscattering from the thick materials:** The intensity of the backscattered electrons has been plotted in percents of the beta radiation without scatterer. The following results were obtained:

	$z$	INTENSITY IN PERCENT OF RADIATION WITHOUT BACKSCATTERER
Polystyrene	6	23%
Al	13	31%
Cu	29	43.5%
Cd	48	49.5%
Pb	82	58.5%

**B. Backscattering with materials of varying thickness.** Al, Zn, Sn, Pb, were investigated from about 5 mg/cm<sup>2</sup> for Al; 15 mg/cm<sup>2</sup> for Pb; 40 mg/cm<sup>2</sup> for Sn and Zn up to saturation backscattering for each element. The increase of intensity with weight is larger for higher atom numbers and approached saturation for about 100-150 mg/cm<sup>2</sup>. The details are still under investigation (Figs. 1 and 2).

For 30 mg/cm<sup>2</sup> backscatter of Al, Zn, Sn, Pb, the experimental values were reduced to the relative backscattering for the same number of atoms. It appears that the backscattering increases like constant  $\times Z^n$ .  $1 < n < 2$ . Further investigations with very thin foils are required to give dependable results.

**Absorption of Beta Particles.** A number of experiments have been started with the beta counter using collimation.

**Neutron Monitoring. A.** Resistance changes of Pd resistors as observed and reported by B. R. Gossick<sup>(1)</sup> when covered with hydrogenous materials under neutron bombardment were investigated. Most tests were made without enamel coating. The resistances ranged from 50 K to about 1,000 K. Preliminary tests with  $6 \times 10^6$  roentgens from cobalt did not show any measurable response.

The changes by temperature were very troublesome. The resistances were, therefore, divided in groups, kept above and below room temperature for awhile, and their return to the original values were measured. It seems that the thermal history is an important factor in the resistance value. These superimposed thermo-effects are somewhat unpredictable and make it very difficult to observe small resistance changes due to fast neutrons. Exposure to  $\sim 6.8 \times 10^4$  weeks tolerance doses of fast neutrons produce drops in resistance from 0.5% to 3%, the higher resistances giving the higher percentage. These changes are showing healing effects with half-life times of 4 - 5 days. B. R. Gossick obtained the large and permanent changes with radiations of several magnitudes higher.

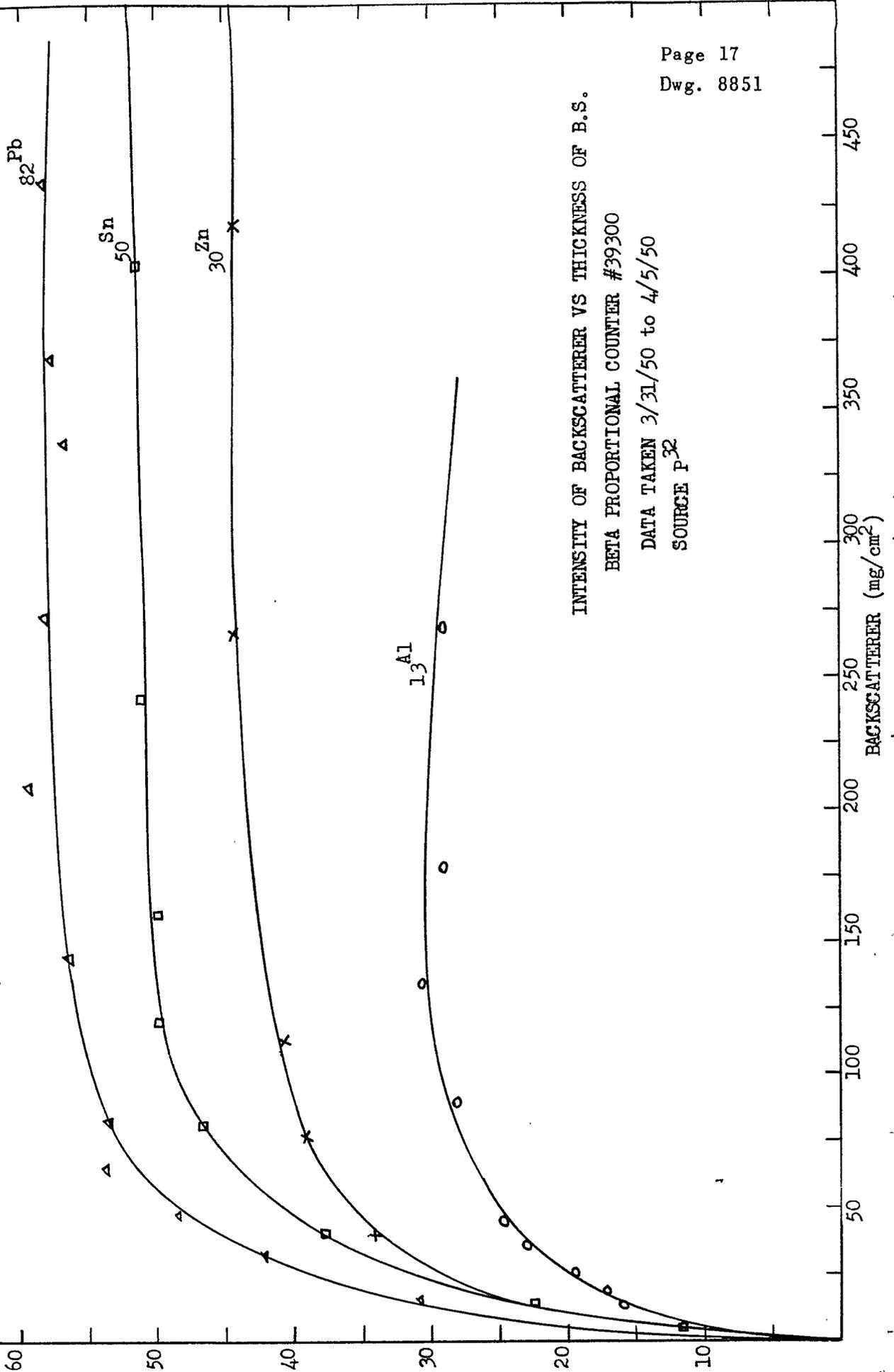
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(1) Gossick, B. R., "Pd Film Fast Neutron Detector," *Phys. Rev.* 77, 297 (1950).

Unclassified

Figure 1

Relative Intensity



INTENSITY OF BACKSCATTERER VS THICKNESS OF B.S.

BETA PROPORTIONAL COUNTER #39300

DATA TAKEN 3/31/50 to 4/5/50

SOURCE P<sup>32</sup>

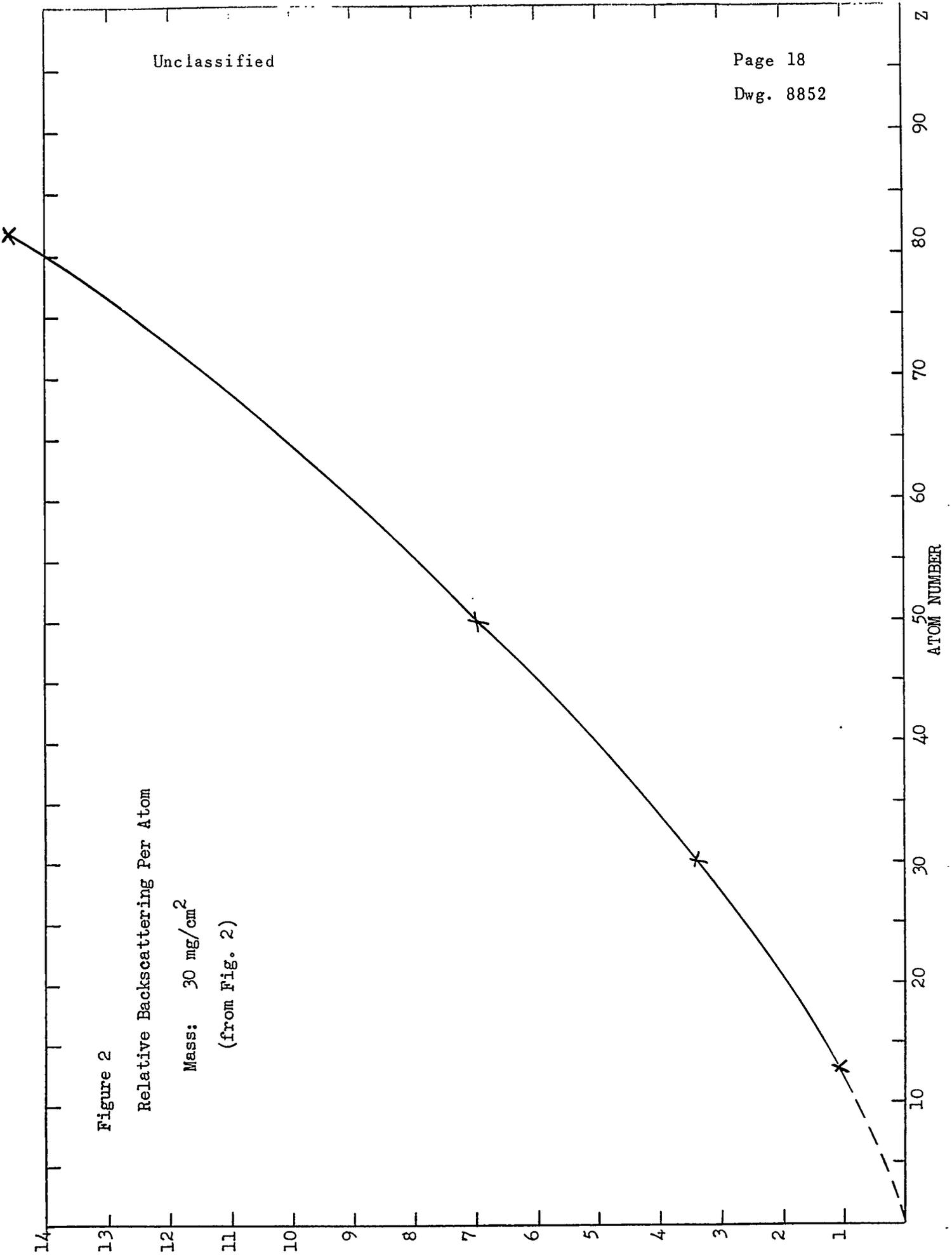


Figure 2

Relative Backscattering Per Atom

Mass: 30 mg/cm<sup>2</sup>

(from Fig. 2)

## URINALYSIS

**Analysis of Urine for Radioactive Strontium.** The results of an exploratory survey of excreted beta-gamma emitting fission products in urine have emphasized the need for an analysis procedure which is specific for strontium. The procedure used in the survey isolated a group of elements including strontium, barium, yttrium, lanthanum and associated rare earths in one operation. Due to the low level of activity which was found in most of the urine samples, it was difficult to determine the radioactive element or elements present by conventional absorption curve and/or decay studies. A change in the procedure is recommended in the event an analysis for strontium alone in urine is needed.

The analysis procedure described in report ORNL 368<sup>(1)</sup> provides separation of Sr, Ba and the rare earths from Ca and Mg by precipitating  $\text{SrCrO}_4$  and  $\text{BaCrO}_4$  from a chromate solution at pH 8 in the presence of alcohol. The suggested change would separate Sr from Ca and Mg by a  $\text{Sr}(\text{NO}_3)_2$  precipitation from a 70% nitric acid solution. The Sr can then be recovered as  $\text{SrC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ . The percentage recovery can be determined gravimetrically by comparison of the recovered Sr with the Sr tracer originally added to the urine sample. The beta-gamma activity can be determined by conventional counting procedures.

Eighteen urine samples have been assayed for strontium by this procedure. An average recovery of  $90.3\% \pm 5.6\%$  has been achieved.

**Method for Removing Impurities from Lanthanum.** When water or urine samples with plutonium activity of approximately 5 d/min are assayed using lanthanum as a carrier, it is desirable to eliminate the radioactive impurities normally present in lanthanum. Impurities may be found in commercial lanthanum compounds which will contribute extraneous alpha from 1 to 2 d/min/mg. Some beta-gamma activity will also be present. Lanthanum can be separated from these impurities satisfactorily by use of synthetic cation exchange resins.

Essentially the separation can be made as follows:

1. Use of Dowex - 50 resin (40 to 60 mesh) in a cylindrical glass column approximately 3 ft in height.
2. Put onto resin column the lanthanum in 0.1 N HCl (1 gm La per  $\text{cm}^2$  of resin bed).

---

(1) Tompkins, P. C., Farabee, L. B., and Ehm, J. X., *Procedure for the Radiochemical Analysis of Barium, Strontium and the Rare Earths in Human Urine*, ORNL 368 (October, 1949).

3. Elution of lanthanum from the resin with 5% citric acid at a pH of 3.4 at a flow rate of 0.1 cc/min/cm<sup>2</sup> resin.
4. Recovery of lanthanum as lanthanum oxalate.
5. Two re-precipitations of lanthanum oxalate.
6. Ignition of the oxalate to La<sub>2</sub>O<sub>3</sub>.

By this procedure lanthanum has been prepared with alpha activity less than 0.02 disintegrations/minute/mg. This represented removal of more than 99% of the alpha impurities essentially present. The removal of beta-gamma emitting impurities was also good.

## EDUCATION AND TRAINING

1. During this quarter, the eleven NRC Fellows who began their year's training here October 5, 1949, have been occupied with basic courses in Nuclear Physics, Mathematics, and Elementary Biology. In addition most of the fellows have been working on regular Research projects in the Health Physics Division, the Biology Division or the Chemistry Division.

2. Five medical officers from Duke University (the sixth is still waiting for clearance) came to the Laboratory April 3, for an eight week training period.

The training program for these men consist of field training supplemented by lectures in Health Physics and related subjects.

3. Considerable time has been devoted to planning for the Civilian Teachers Training Course in Radiological Defense, jointly sponsored by the Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies.

The course now in progress began April 3, and will continue for a period of five weeks. The Laboratory has taken full responsibility for the field test. This section has drawn heavily on other members of the Health Physics Division for teaching and planning this course.

4. On March 6, the first draft of the Manual of Radiological Protection for Civilian Defense was completed and sent to Washington for a classification check and distribution to the training centers. Since that time, the section has been busy correcting, revising, and editing the manual, which should be ready for final distribution in the near future.

5. The reorganization of the AEC Fellowship Program for next year has been completed. The ORINS has the administration details of the program of the training being given at Vanderbilt University and the Oak Ridge National Laboratory. Vanderbilt University will grant graduate credit for this program. Present plans are that the student will spend the first quarter at Vanderbilt, and the next nine months at the Laboratory. Those students, to whom a six months extension in their fellowship is granted, will spend an additional two

quarters at Vanderbilt earning master's degrees in science. It is expected that the research problems will be done at the Laboratory.

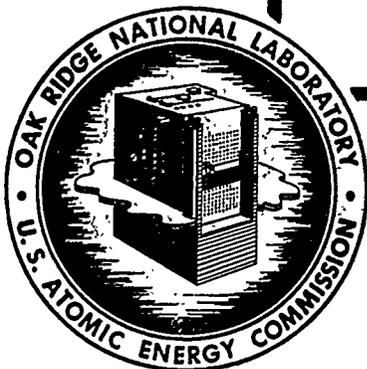
The preliminary selection of candidates has been completed for next year. There were 200 applications for the Fellowship. The number to be trained at ORNL has been increased to 20 for next year.

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FOR PERIOD ENDING JULY 15, 1950



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K. Z. Morgan, Director  
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**QUARTERLY PROGRESS REPORT**  
for Period Ending July 15, 1950

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## TABLE OF CONTENTS

INSTRUMENT DEVELOPMENT	6
Portable Fast Neutron Dosimeter	6
Fast Neutron Fluxmeter	6
Non-Directional Proportional Counter	6
Portable Alpha Survey Meter	6
Continuous Water Monitoring	6
WASTE DISPOSAL STUDIES	10
Water and Liquid Waste Decontamination Processes	10
Survey Studies of White Oak Drainage System and Clinch River	11
Instrumentation	12
Miscellaneous Activities	12
THEORETICAL PHYSICS	14
Fast Neutron Tolerance Calculations	14
An Empirical Evaluation of Effective Atomic Number	14
Calculation of Stopping Power at Intermediate Energies	14
EXPERIMENTAL RADIATION MEASUREMENTS	15
Dispersal of Stack Gases	15
Geological Surveys	15
PHYSICS OF NUCLEAR RADIATION	18
Backscattering and Absorption of Beta Particles	18
Absorption	18
Backscattering	18
Absorption of backscattered radiation	19
Detection of Fast Neutrons	19
RADIOCHEMICAL ANALYSIS	20
EDUCATION AND TRAINING	21
AEC Fellowship Program	21
Training Programs for Military Personnel	21
Civilian Defense	21

This report covers the activities of those groups in the Health Physics Division primarily engaged in Applied Research or Development. More or less routine activities of the Survey-Monitoring Section are covered in the Laboratory Weekly Progress Report.

## INSTRUMENT DEVELOPMENT

**portable Fast Neutron Dosimeter.** The special design of a recoil proton proportional counter, applicable to a fast neutron dosimeter<sup>(1)</sup> where the neutron dosage is indicated directly by a counting rate, is confirmed in the neutron energy range of 0.3 to 2.5 Mev by experiments with monoenergetic neutron beams at Los Alamos. Measurements in the energy range of 2.5 to 6 Mev are scheduled for about July 12-16, 1950 at Carnegie Institute, Department of Terrestrial Magnetism.

**Fast Neutron Fluxmeter.** Two experimental proportional counters have been constructed, designed to have uniform count rate response to fast neutrons in the energy range of 0.5 to 15 Mev. These counters will be tested in the energy range of 2.5 to 6 Mev at the Carnegie Institute, Department of Terrestrial Magnetism.

**Non-Directional Proportional Counter.** One experimental non-directional proportional counter is ready for testing and another is now being processed. These counters will in the near future be tested for non-directional characteristics relative to neutron energy absorption. These counters are for general monitoring and special applications.

**Portable Alpha Survey Meter.** Modifications, largely in the probe, have been made in the alpha survey meter described in ORNL-602,<sup>(2)</sup> resulting in an instrument operable in 98% relative humidity without the usage of a desiccant. Briefly, the probe insulator holding one end of the collector wire is removed from ground and is now supported by a beam attached to the capacitor H. V supply. A supplement to ORNL-602 is being prepared, describing the modifications in detail and listing all drawings required to manufacture the complete instrument.

**Continuous Water Monitoring.** In general, the water supply of a community is provided by a filtration and processing plant which receives its water from a source such as a river, mountain stream, spring, or water table. All types

(1) Hurst, G. S., *Fast Neutron Count-Rate Dosimetry*, ORNL 589 (Feb. 17, 1950).

(2) Hurst, W. M., Hurst, G. S., and McDonald, W. B., *A Portable Alpha Survey Meter*, ORNL 602 (Mar. 14, 1950).

of sources are subject to the possibility, usually remote, of contamination significantly above natural background by radioactive isotopes. We are concerned with the instrumentation problems of monitoring a municipal water supply so as to protect the community against exposure to a possibly dangerous concentration of radioactive materials in drinking water.

Preliminary specifications considered for the monitoring instrumentation include the following:

1. The instrument is to detect beta and gamma radiation.
2. The instrument will not be required to detect alpha radiation.
3. The instrument is to alarm at the maximum permissible level of activity.
4. A continuous record is to be made showing the water quality to be "safe" or "dangerous."
5. Radiation energy measurements will not be required.

It is desirable that the instrument should be sufficiently sensitive to provide a continuous record showing the level of radioactive content of the water to be "safe" or "dangerous," and to alarm when the level becomes dangerous. Consideration of these features discloses two difficulties (1) The level of activity at which the water shall be considered dangerous is somewhat arbitrary, and (2) the level of activity at which one desires an alarm may be below the sensitivity of present day radiation detectors.

Recommended maximum permissible concentrations of radioisotopes in drinking water are customarily based on the assumption that the water is to be used at these concentrations over a period of many years. For some of the radioisotopes for which the permissible levels for continuous use of the water are particularly low, the effective contribution to the radiation dosage of the body due to an unusual period of high activity is approximately proportional both to the level of activity and to the length of period through which this level persists. In other words, in describing the hazard involved in drinking water with a radioactive content above the maximum permissible level, it should be understood that it is generally not dangerous to drink the water but that it may be dangerous to use the water for drinking over a period of time, the length of which depends on the level of activity and the characteristics of the radioactive materials involved.

The maximum permissible concentrations of radioisotopes in drinking water for continuous usage range from the order of  $10^{-7}$  microcuries/cc up to about  $10^{-2}$  microcuries/cc. and these levels are for long ingestion terms of many years. To alarm at the low level of  $10^{-7}$  microcuries/cc the instrument would have to reliably detect activity of the order of  $10^{-8}$  microcuries/cc, and that is considerably beyond the sensitivity of present day radiation detectors. For instance, activity of  $10^{-8}$  microcuries/cc is about 0.02 dis/min/cc, and the background count of various beta detectors is of the order of 20 or 30 counts/min. To detect a low-level dose rate in water concentration of the activity found in a gross quantity of water is mandatory

A compromise is effected if we stipulate that the constant water monitoring is to detect a short-term high dose rate level or "surge" and the low-level activity is to be monitored by concentration of the activity. Continuous monitoring for the detection of short term high level activity should be performed on the intake or raw water both to permit the plant operator more time to handle an unexpected surge of activity and to provide higher sensitivity of detection than would be afforded by the processed water from which some of the activity would have been removed. However concentration for measurement of routine low level activity should be from the processed water

A rough set of numbers supporting such a design philosophy may be prepared by using the following assumptions

1. The transit time of water through the process plant and on to the consumer is longer than 30 minutes
2. Direct measurement of the surge (high dose rate) may be a 15 minute integration
3. The surge activity is to be approximately  $5 \times 10^5$  microcuries/cc (or about 100 disintegrations/minute/cc)

Such an operating condition gives us two maximum permissible values (related to a short and a long term level) to monitor, and a single instrument may suffice for both measurements if the long term activity level is concentrated from an appropriately large volume of water.

The design of a continuous water monitor is now thought of as consisting of the following components:

1. The radiation detector is to be an anthracene crystal followed by a "light piper" and the RCA 5819 photomultiplier tube. A light-tight housing for the detector is also to house a tray filled with running water to be monitored and possibly a pre-amplifier or cathode follower.
2. A differential pulse height selector is used to eliminate tube noise and to reduce the response to cosmic ray pulses.
3. An amplifier of extremely stable and reliable operation is essential. To start with, an A-1 linear amplifier would be used. A small amplifier is feasible, but will require engineering.
4. A recording counter is required with automatic reset to record a 15 minute integration of counts and then repeat.

The long-term tolerance activity is to be concentrated from a large volume of water by the use of a coagulant, collection of the floc and drying. Preliminary work by the Waste Disposal Research Section of the ORNL-Health Physics Division has disclosed attractive results relative to a single stage coagulation and the percentage of activity removed from a gross quantity of water. A desirable feature of this method of activity concentration is that the materials and process used are already present as a normal phase of water processing.

## WASTE DISPOSAL STUDIES

The present program of the Waste Disposal Research Section is concerned principally with methods for the decontamination of water supplies and liquid radioactive wastes, studies of the effects of radioactive contaminants upon streams, instrument development and adaptation for waste disposal research, and related cooperative or miscellaneous activities. The established projects in these categories have been continued. In addition, active progress has been made with the TVA-AEC Ecological Study and the cooperative project for liquid waste research.

**Water and Liquid Waste Decontamination Processes.** A series of laboratory jar-test experiments on coagulations and precipitation processes to study the removal of individual isotopes has been completed. Data from these studies have been assembled into a draft of a report which is in process of review and final revision. Similar experiments have been begun on the removal of mixed fission products using iodine dissolver solution as the source of radioactive materials. Tune-up operation of the small model water treatment plant without radioactive materials has been completed and one experimental run has been made using conventional water treatment processes on a raw water to which radioiodine has been added. With the laboratory jar-test studies as a guide, it is planned that the next run of the water treatment plant will be on a raw water solution of mixed fission products.

In another series of laboratory studies now in progress, precipitation and coagulation will be applied to determine the feasibility of concentrating and measuring radioisotopes in river water as a possible method of monitoring raw water supplies that are near tolerance levels of radioactivity.

A graduate student assigned to this group has selected as a thesis problem the efficiency of trickling filters in the removal of selected radioisotopes from sewage. He has operated for seeding and will use in his problem the six foot sewage filter columns mentioned in the preceding quarterly report.

A cooperative program with the U. S. Public Health Service for liquid waste research will include the construction of a laboratory and pilot plant building for research in water and liquid waste decontamination and studies on civilian and military water supply decontamination. Through efforts of

the Health Physics and the Engineering and Maintenance Divisions of ORNL and of the Austin Company, design criteria and preliminary plans for the research building and equipment have been expedited. Complete preliminary plans and specifications have been reviewed and contract drawings are expected to be complete about August 1.

Representatives of this Division conferred with Public Health Service officers in Cincinnati May 23 and 24 regarding design details of the building and basic equipment and also regarding general work plans and assignment of personnel for intensifying the studies of water and liquid waste decontamination methods. Early in July correspondence was completed which authorizes the Laboratory to accept equipment and personnel from the Army Corps of Engineers and to initiate immediately a program to evaluate the efficacy of military field water supply equipment in the removal of radioactive materials from water.

**Survey Studies of White Oak Drainage System and Clinch River.** Organization and planning of the Ecological Study to be conducted by the Tennessee Valley Authority under contract to the AEC has proceeded actively and is essentially complete. The present full-time staff employed by TVA for this purpose includes two aquatic biologists, a botanist, and a biological aide. One or two additional workers are to be employed and further assistance will be afforded by the part-time and cooperative efforts of personnel of TVA and ORNL. General plans for the study were reviewed at a full staff meeting of the Ecological Study in the offices of AEC on June 27. The technical staff meets each Monday morning to work out the details of the program. New members of the staff have acquainted themselves with the White Oak Creek area, sampling equipment has been procured and assigned to the Laboratory for this Study, orientation and lectures are conducted weekly for this group and arrangements are complete for personnel monitoring service and storage of equipment.

During the past three months much work has been done in preparation for the Ecological Study. Two stream gaging stations have been installed on White Oak Creek, permanent reference markers have been placed along the banks of White Oak Lake, a silt survey to define the topography and depth of bottom deposits in the Lake is in progress, and an additional weather bureau station has been located near the area of study.

To supplement the Ecological Study and to assist in the interpretation of field survey data, additional studies are being developed in the Health

Physics Division. Laboratory collections of small fish, snails, aquatic plants and other organisms have been established in preparation for controlled exposure of living organisms to radioactive materials. For these experiments natural specimens are collected from uncontaminated parts of the White Oak Creek area.

**Instrumentation.** Work on instrumentation has been largely in preparation for the Ecological Study. Two models of a probe, one for gamma and the other for beta-gamma radiation, have been developed and are being tested for the indication of radioactivity in live fish. A portable battery operated scaler will be used with these probes.

In an effort to improve the measurement of radioactivity in mud, a mud probe assembled with a Tracerlab survey meter, modified for this use, has been completed and calibrated. Also an experimental model of an auger-type mud sampler designed to obtain undisturbed sediment samples under water has been constructed. This sampler is being tested and is to be constructed in final form as soon as possible.

For further observation of the test wells drilled under the AEC Geological Survey project, an automatic cable reel for periodic probing of the wells for radioactivity has been designed and is under construction by the shop. Radiochemical analyses were made on two samples of water from test well #1. Ruthenium 106 was isolated and identified in very low concentrations from a 45 gallon sample but another 15 gallon sample failed to show identifiable radioactive contamination.

With assistance from hydraulic engineers from TVA, work is continuing to develop a continuous proportional sampler to provide a representative sample of the discharge of settling basin effluent into the creek. At present it appears that a design known as the "Trebler" sampler offers the best promise of successful adaptation.

A major portion of the work necessary to install continuous monitoring, water level measurements and telemetering at White Oak Dam has been completed during the period. The stilling well and water level are in place, instruments have been received, and an instrument house has been moved and installed at the dam.

**Miscellaneous Activities.** Members of this section have cooperated in education and training and related activities. Through arrangements by the

Education and Training Section, a group of Army and Navy Medical Officer trainees reviewed waste disposal research activities during the period May 3 to May 9.

A research participant from the University of Texas Sanitary Engineering Staff joined the Group for a three months period about June 1; and a graduate student from Georgia Institute of Technology was assigned to the Group early in May for a research problem which will require approximately six months.

Detailed activities of the Waste Disposal Research Section are covered by monthly reports prepared for limited distribution by R. J. Morton.

## THEORETICAL PHYSICS

**Fast Neutron Tolerance Calculations.** The life histories of 2,000 neutrons of 10 Mev initial energy have been computed by the Monte Carlo method to show the energy losses due to scattering in tissue. Each neutron was followed until thermal energy was obtained. At present the energy losses are being tabulated to obtain their distribution as a function of energy and distance.

**An Empirical Evaluation of Effective Atomic Number.** Using experimental data from the literature, we are attempting to derive an analytic formula for the effective atomic number of a substance to be used in the calculation of a mass absorption coefficient for gamma rays. The attempt is to establish definite ranges of atomic number and energy and the maximum energies for which the formula is valid.

**Calculation of Stopping Power at Intermediate Energies.** An attempt is made to verify the formulas derived previously with some experimental data of S. D. Warshaw.<sup>(1)</sup> Because of the low energy of particles measured, the verification will be limited in scope. The problem has been temporarily superseded by others.

(1) Warshaw, S. D., "The Stopping Power for Protons in Several Metals," *Phys. Rev.* 76, 1759 (Aug. 15, 1949).

## EXPERIMENTAL RADIATION MEASUREMENTS

(formerly Experimental Physics)

**Dispersal of Stack Gases.** Work on this program has continued through the quarter. To provide a controlled source of radioactive material for discharge through the pile stack, an aluminum pressure tank containing argon has been placed in the pile. The tank is placed in hole #18 and runs the full length of the pile. The volume is roughly one cubic foot and when up to design pressure of 500 lbs/in.<sup>2</sup> will contain approximately 27 cu ft. The equilibrium argon activity with full pile power will be of the order of 200 curies. A manifold is incorporated with pre-set flow rates which will empty the tank in the following times: 10 minutes, 30 minutes, 1 hour, and 2 hours. It is intended to operate intermittently so as to put out puffs of activity such as releasing the activity for one hour every other hour. In this case the argon would be at roughly one-half equilibrium activity and of the order of 100 curies/hour would be released every second hour. It is intended to release the activity under various meteorological conditions to be studied and the activity at the trailer stations will be compared so as to get attenuation factors.

Each of the three trailer stations contains its own gas electric generator and equipment to measure (1) gamma ray activity indicated by a bundle of 19 Geiger counters connected in anti-coincidence, (2) beta activity by four 10-inch beta tubes in parallel mounted above the trailer, (3) total ionization of the air conductivity measuring apparatus, and (4) alpha activity which is essentially radon active deposit by counting alpha emissions from a moving filter. Besides the trailers, four fixed pressure ionization chambers have been placed at distances of one and three miles from the stacks up and down the valley.

**Geological Surveys.** A large sodium iodide crystal, four inches in diameter and two inches thick, has been received for use in a high sensitivity scintillation counter. It is expected that the scintillation counter will replace present Geiger counter equipment in the Geological Survey DC-3 airplane for aerial uranium prospecting. The Survey is ordering six more which will be connected in parallel with the one just received to push the sensitivity still

further. It is planned to include a gating circuit so that the response is to the energy regions of radium gamma rays, thereby cutting out high energy background radiation.

In order to get measurements on the attenuation of the gamma radiation from radium with height above ground, flights were made over two sources, (1) a two gram radium source, and (2) a stockpile of pitchblende. In a paper by Gladys R. White,<sup>(1)</sup> it is shown that the build-up factor of scattered radiation over primary radiation is proportional to the height  $h$  in the region we are interested in, and at very large distances approaches a value  $h^{1.5}$ . Assuming a build-up factor proportional to height  $h$ , the attenuation with height should follow the law  $e^{-\mu h}/h$ . The signal was multiplied by the height and plotted on semi-log paper versus height to obtain the air absorption coefficient  $\mu$  from the slope of the curve. At heights in the neighborhood of 500 feet above the 2 gram Ra source the mass absorption coefficient  $\mu/\rho$  where  $\rho$  is the density of the air was 0.071 cm<sup>2</sup>/gm which agrees with the theoretical value for a gamma ray energy of 0.8 Mev which is also the average energy of the gamma rays from radium and its decay products. Above 1000 feet the mass absorption coefficient was 0.049 cm<sup>2</sup>/gm which corresponds to a theoretical value for a gamma ray energy of 1.6 Mev indicating a considerable hardening of the radiation or a change in the build-up factor. From the data obtained from flights above the pitchblende source the mass absorption coefficient in the region 500 feet to 1800 feet was 0.056 cm<sup>2</sup>/gm corresponding to a theoretical value for a gamma ray energy of 1.2 Mev, showing considerable hardening had taken place by self-absorption in the pitchblende.

If we assume a uniformly distributed source in the ground with an absorption coefficient  $\mu_2$  and integrate assuming a build-up factor proportional to the distance traveled in the two media, ground and air, multiplied by their respective absorption coefficients, we obtain the simple relation for the response:

$$R = \frac{\rho_2 K S e^{-\mu h}}{\mu_2}$$

where  $S$  is the source concentration to be measured in gms of Ra/gm,  $\rho_2$  the density of the ground, and

$$K = \frac{2\pi R_0 h_0}{S_0 \mu e^{-\mu h_0}}$$

(1) White, Gladys R., "Penetration and Diffusion of Hard X Rays Through Thick Barriers VI," to be published in the *Physical Review*.

where  $R_0$  is the response to a calibration source of strength  $S_0$  in gms of Ra measured at height  $h_0$ . A calibration of the present Geiger counter equipment for flights at 500 feet is  $2 \times 10^{-13}$  gms Ra/gm/div. Since the standard deviation is about five divisions a change of  $10^{-12}$  gms Ra/gm is the minimum detectable amount. With the high sensitivity scintillation counter we should expect to detect changes smaller by a factor of 5 to 10.

The design of apparatus coupled to the radio-altimeter in the airplane to automatically correct for the variation in altitude above the terrain according to this function is in progress.

Data obtained from flights over areas in the northern Michigan peninsula indicate that geological formations can be mapped from correlation with their natural radioactive content. Areas of shale for instance show a marked differentiation from granite and both show marked radioactivity above that of Lake Superior. This will be investigated further when the more sensitive scintillation counters are completed. A circular published by the Department of Interior "Airborne Radioactivity Survey of Parts of Marquette, Dickinson and Baraga Counties, Michigan" will appear in a few weeks.

# PHYSICS OF NUCLEAR RADIATION

(formerly Special Problems)

## Backscattering and Absorption of Beta Particles.

A. *Absorption.* Comparisons were made between absorption of beta radiation as measured with an end-window beta counter and as measured in an extrapolation chamber.  $P^{32}$ ,  $Sr^{90}$ ,  $UX_2$ , and  $S^{35}$  were used as sources of beta radiation, and aluminum, copper, tin, lead, cellulose acetate, and polystyrene were used as absorbers. (Measurements with  $S^{35}$  were limited to absorbers of low atomic number.) It was found that the absorption was larger for the ionization chamber in every case.

B. *Backscattering.* The relative radiation measured from sources oriented with the mounting between the radioactive material and the sensitive volume of the instrument was compared with that measured with the radioactive material between the mounting and the sensitive volume of the instrument. Measurements were made with a number of radioisotopes, all mounted on rubber hydrochloride, using both the extrapolation chamber and an argon-methane filled proportional counter. In the first orientation, both the direct and the backscattered radiation must pass through the rubber hydrochloride; while, in the second orientation, the direct radiation does not pass through the rubber hydrochloride but both the backscattered radiation and the primary radiation which produces it must pass through the rubber hydrochloride.

Expressed as percentages of the direct radiation, the backscattering of radiation from  $P^{32}$  and  $Sr^{90}$  with the source between the mounting and the sensitive volume of the extrapolation chamber was 50% of that for the reverse orientation; while with the  $S^{35}$  of relatively low energy, the corresponding ratio was only about 25%. Measurements with  $P^{32}$ , using the proportional counter showed the same type of result, although the ratio was reduced only to about 75%. The difference between ionization and counter methods is apparently the fact that the slow electrons are producing more ions/cm and their elimination from the ionization chamber has a larger effect than in the beta counter, since this is operated at the plateau, where only the number of particles is counted.

C. *Absorption of backscattered radiation.* The investigation is in progress and confirms an increase in energy of the backscattered radiation with the atom number.

**Detection of Fast Neutrons.** Conductivity changes in germanium semiconductors have been observed and reported by Lark-Horovitz.<sup>(1)</sup>

Some germanium diodes from G. E. were investigated and their forward resistance, in the order of some hundred ohms, was measured before and after radiation with a neutron flux of  $10^{12}$  fast neutrons. An increase in resistance was observed, though very irregular, and the sensitivity is too low for health physics application by a factor of  $10^5$ .

Experiments with hydrogeneous piezo-electric crystals are in preparation.

(1) Lark-Horovitz, K. and Crawford, J. H. Jr. "Fast Neutron Bombardment Effects in Germanium," *Phys. Rev.* 78, 645 (June 1, 1950).

# RADIOCHEMICAL ANALYSIS

(formerly Urinalysis)

One person is presently engaged in the development of a procedure for determining radioactive phosphorus in body fluids. A satisfactory procedure for analysis of body fluids is needed for (1) routine analysis of personnel who work with large quantities of  $P^{32}$ , and (2) analysis of body fluids for induced beta activity resulting from slow neutron bombardment of the phosphorus of the body. In the latter case, analysis would be necessary only in event of accidental exposure to a person by an overdose of slow neutrons.

Gravimetric determination of alkaline earth phosphates is possible provided only one cation is present. However, the transfer of the phosphate precipitate to a convenient holder for counting the beta activity is difficult because the phosphates have a tendency to adhere to the container. To circumvent this difficulty one step in the proposed procedure provides a method for quantitative determination of total phosphates.

The final precipitate used for counting the beta activity can be weighed and the ratio of the phosphorus in the counting capsule to the total phosphorus can be calculated. Essentially the steps are as follows:

1. Precipitation of alkaline earth phosphates from urine.
2. Destruction of organic matter with nitric acid and hydrogen peroxide.
3. Removal of cations by passing the solution over a cation-exchange resin.
4. Titration of the effluent which contains hydrochloric acid and phosphoric acid from the primary phosphate to the secondary salt with sodium hydroxide.
5. Precipitation of the phosphate as magnesium ammonium phosphate.
6. Ignition to magnesium pyrophosphate.
7. Transfer of a convenient amount of the precipitate to a counting capsule, weigh and count.

Preliminary investigation indicates that an over-all recovery of 95% or better can be expected.

## EDUCATION AND TRAINING

**AEC Fellowship Program.** During this quarter, the eleven NRC Fellows who began this year's training October 5, 1949, have been occupied with the following courses and projects:

- a. Radiation Biology                      3 hours per week      Biology Division
- b. Health Physics Lectures              4 hours per week      E. E. Anderson
- c. Health Physics Laboratory            4 hours per week      L. C. Leibowitz
- d. Completion of projects with research groups in various divisions of the Laboratory
- e. Field training in health physics, since July 10.

A conference was held June 28 on the Atomic Energy Commission Fellowship Program for next year. The AEC, Vanderbilt University, University of Rochester, Oak Ridge Institute of Nuclear Studies, and Oak Ridge National Laboratory were represented. The following matters were discussed:

- a. The curriculum.
- b. Time schedule for Vanderbilt University and ORNL.
- c. Possibility of students from the University of Rochester receiving their field training at ORNL.
- d. Possibility of members of the Education and Training Section of the Health Physics Division of the ORNL going to Vanderbilt to teach Health Physics courses. This is being investigated at the present time.

**Training Programs for Military Personnel.** Six medical officers assigned to this division for eight weeks training in health physics completed their assignment May 26. The training included both lectures and field training, and followed a year of training in radiation bio-physics at Duke University.

On July 10, twenty-four officers from the Armed Forces Special Weapons Project arrived at the Laboratory for field training in radiation protection. Fifteen of these officers are from the University of California, Berkeley, California, the other nine from Ohio State University, Columbus, Ohio.

**Civilian Defense.** The five weeks Civilian Teachers' Training Course in Radiological Defense, jointly given by this Laboratory and the Oak Ridge Institute of Nuclear Studies was completed May 5. The field test, for which

the Laboratory assumed full responsibility, was held May 1 and 2. The splendid cooperation received by the Health Physics Division from other divisions of the Laboratory contributed greatly to the successful execution of the test.

The correcting, revising, and editing of a "Manual of Radiological Protection" for civilian defense was completed and two copies sent to the Atomic Energy Commission at Washington the latter part of April. No word concerning its release has been received to date.

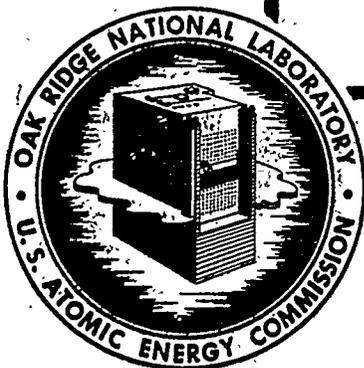
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Progress Report

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HEALTH PHYSICS DIVISION  
QUARTERLY PROGRESS REPORT FOR  
PERIOD ENDING OCTOBER 20, 1950



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OPERATED BY  
CARBIDE AND CARBON CHEMICALS DIVISION  
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K. Z. Morgan, Director  
F. Western, Associate Director

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**for Period Ending October 20, 1950**

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TABLE OF CONTENTS

INSTRUMENT DEVELOPMENT	5
Constant Water Monitor	5
Radio-frequency High Voltage Supply	5
Fast-neutron Survey Meter	5
RADIOACTIVE WASTE DISPOSAL RESEARCH	6
Water and Liquid-waste Decontamination Processes	6
Survey Studies of White Oak Drainage System and Clinch River	7
Instrumentation and Techniques	8
THEORETICAL PHYSICS	9
Empirical Evaluation of Effective Atomic Number	9
Calculation of Stopping Power at Intermediate Energies	9
Fast-neutron Tolerance Calculations	9
EXPERIMENTAL RADIATION MEASUREMENTS	11
Dispersal of Stack Gases	11
Geological Surveys	11
Radiation Background Studies	11
PHYSICS OF NUCLEAR RADIATION	12
Backscattering	12
Fast Neutron Monitoring	12
RADIOCHEMICAL ANALYSIS	14
Exploratory Survey for Rare Earth Fission-product Activity in Urine of Personnel at ORNL	14
PHYSICS OF RADIATION DOSIMETRY	16
Neutron Dosimetry	16
CONSULTATION AND SPECIAL PROBLEMS	17
EDUCATION AND TRAINING	18
AEC Fellowship Program	18
Program for Military Personnel	18
Physics Course for Division Personnel	18
Orientation Lectures	18
Miscellaneous Activities	18

## INSTRUMENT DEVELOPMENT

Personnel in this group previously engaged in physical research directed toward the development of components for radiation instrumentation have been transferred to a group newly organized within the Health Physics Division under the name "Physics of Radiation Dosimetry Group."

**Constant Water Monitor.** A scintillation counter was bread-boarded and tested. The low-energy beta activity was largely masked by the high efficiency for gamma counting, therefore the work on the scintillation counter was shelved.

A continuous-gas-flow proportional counter, 100 cm<sup>3</sup> in volume with an aluminum window 0.0005 in. in thickness, was tested. Preliminary measurements gave a background count of about 70 c/m over a 15-min interval, and 210 c/m when water having 440 d/m/cm<sup>3</sup> was under the counter window. This attack appears promising; the associated apparatus is being simplified and refinements are to be made.

**Radio-frequency High-voltage Supply.** A laboratory H-V supply to provide a regulated potential adjustable, from 500 to 2000 volts, maximum current drain 0.001 amp at regulated output and 0.0018 amp at short circuit for safety, is being packaged and drawings are to be made. The purpose of this H-V supply is to reduce the health hazard to Laboratory personnel.

**Fast-neutron Survey Meter.** The progress of development of proportional counters for various types of neutron measurements has been given in previous quarterly reports and is given below under "Physics of Radiation Dosimetry." A member of the Instrument Development Group is now considering the circuitry problems involved in engineering both a simplified fast-neutron survey meter and a fast-neutron dosimeter incorporating special designs of the fast-neutron proportional counter.

## RADIOACTIVE WASTE DISPOSAL RESEARCH

The personnel, facilities, and basic program of the Waste Disposal Research Section have continued, with minor changes, as reported previously. Cooperation with other groups and agencies and the conduct of joint research projects have continued to receive emphasis.

**Water and Liquid-waste Decontamination Processes.** Continued studies of conventional water-treatment methods to determine their efficiency in the removal of various radioactive materials have included laboratory jar tests and operation of the small experimental water-treatment plant. The experiments were designed to approximate average conditions which might be encountered in water-purification plants. The data obtained thus far are incomplete and have not been fully analyzed, but they indicate generally the efficiencies that may be expected. Although certain radioisotopes are almost completely removed from water by these methods, the overall efficiency in the removal of mixed fission products is rather low (of the order of 50 to 80 percent) under usual conditions of operations.

Studies on the removal of radioisotopes from liquids by the process of precipitating calcium phosphate flocs from solutions of high pH have continued. It is hoped that chemical treatment methods will be found which will be useful as a means either of increasing the efficiency of water decontamination processes or of treating economically large volumes of low-level radioactive wastes. The research participant from the University of Texas Sanitary Engineering Staff, who completed his three months' assignment to this project on September 22, has assisted in these studies. Several phosphate coagulants and a variety of experimental conditions were tested with individual radioisotopes and with mixed fission products. It was found that high levels of removal were obtained if an excess of phosphate was used with a pH above 11.3 during precipitation. A preliminary report of the results of these studies was made at the meeting of the American Chemical Society in Chicago, September 7.

The graduate student assigned to studies of sewage trickling filters has completed his shakedown experiment and has begun a series of studies to determine their efficiency in removal of radioiodine. These studies are expected to be completed about the end of December.

**Survey Studies of White Oak Drainage System and Clinch River.** Most of the survey work has been in connection with the TVA-AEC Ecological Study of White Oak Creek (described in the two preceding quarterly progress reports, ORNL 695 and 786). Members of the TVA-AEC staff are conducting reconnaissance surveys of the entire creek and lake area below the ORNL site. The fisheries biologist has completed field collections for an estimate of the population and of the specific characteristics of fish in White Oak Lake; the botanist and the limnologist, assisted by the biological aide, are collecting, preparing, and preserving for present and future study hundreds of specimens from this drainage area and from other streams and pools. It appears that the flora and fauna of the White Oak Creek area are typical for this region.

The physical survey of the area, largely by TVA, ORNL, and USGS personnel, is well advanced. The installation of field location monuments, preparation of a large-scale map for field survey use, and a silt-depth survey of White Oak Lake have been completed. A systematic mud survey, consisting in the collection and radioassay of mud samples from the entire lake and marsh area, was performed by the Survey Monitoring Section during September. Water samples for physical, chemical, and radiological analysis are collected biweekly. The first of a series of measurements by TVA specialists to determine the time of water travel downstream through the creek and lake at various stages of stream flow has been completed. An intercepting sewer and weir-box installation to permit accurate measurement and monitoring of the effluent from the settling basin is nearing completion.

A series of laboratory experiments with controlled exposure of aquatic organisms to radioactive materials has been begun. Small fish now being kept in aquaria containing dilute solutions of radioactive cesium will be sacrificed at various time intervals for study of the concentration of the cesium. These specimens will also be used in work to improve the techniques for analysis of biological samples from the natural environment.

During September the logging of radioactivity in the test wells installed under the AEC Geological Survey Project was resumed, and measurements have been made on approximately half of the 51 test wells. This work is to be continued until records are complete. It will be repeated in the future with a semiautomatic cable reel and recorder mounted on a small trailer; these instruments are now being constructed and assembled.

**Instrumentation and Techniques.** Further work has been done on the development of mud probes to estimate the radioactivity from 1 to 18 in. below the surface of the mud in White Oak Lake and under various depths of water up to 12 ft. The instrument consists of a thick-wall stainless-steel G-M tube detector mounted on the end of a jointed aluminum tube and assembled with a portable survey meter adapted for this purpose. The instrument has been calibrated with a radium standard to give readings approximately in milliroentgens per hour and has a range of from 0.01 to 100 mr/hr on four scales. It has been field-tested and used to estimate the exposure received by organisms submerged in the mud below White Oak Dam. A newly designed gamma detector for this probe is being constructed. A beta detector has also been designed.

Progress has been made in the further development and testing of other instruments for use in the Ecological Study and other field survey projects. The fish probes are being calibrated by taking readings on live fish through the mouth and then sacrificing the fish for dissection and radioassay. A continuous proportional sampler of the "Trebler" type has been delivered and is being installed in the effluent weir box at the settling basin. Some tests have been made of the auger-type mud sampler, and work has been started to develop an underwater sampler for taking samples at the water-mud interface.

Two workers in this group, with advice from specialists in other groups, are working on methods for improving the efficiency of counting the disintegrations in samples containing unknown mixtures of radioisotopes of various energies. The approach adopted is, first, to determine the counting efficiency of beta particles as a function of the energy of the particles, and, second, to develop a method to determine a mean energy for a mixture of isotopes from which a mean counting efficiency may be obtained. A tentative method has been developed, and work will be continued in an effort to evaluate the factors that affect the accuracy of the method.

The fisheries biologist of the Ecological Study and a radiochemist of this Section have developed techniques for handling fish tissues through digestion and radiochemical separation procedures on a volumetric basis so as to eliminate all routine weighing of samples after the initial weighing. This procedure has been tested and outlined in detail and is being adopted for routine use on all suitable biological samples.

Further details of the waste-disposal studies in the Health Physics Division are given in the quarterly progress report of the Waste Disposal Research Section for the period July 1 to September 30, 1950.

## THEORETICAL PHYSICS

**Empirical Evaluation of Effective Atomic Number.** Experimental values of the mass absorption coefficient for gamma and X rays,  $\mu/\rho$ , have been tabulated by J. M. Allen.<sup>(1)</sup> If the mass absorption coefficient  $\sigma/\rho$  corresponding to the Compton effect as computed from the Klein-Nishina formula is subtracted,  $\tau/\rho$ , the mass absorption coefficient for the photoelectric effect, is obtained.

Using least squares, these semiexperimental values of  $\tau/\rho$  are fitted by the formula  $\tau/\rho = kZ^p/E^q$ , where  $Z$  is the atomic number and  $E$  is the energy. It is found that with  $k = 6.4598 \times 10^{-9}$ ,  $p = 3.2315$ , and  $q = 2.9881$  the computed values of  $\mu/\rho$  are not in error by more than 20 percent for the range  $5 \leq Z \leq 20$  and  $0.01 \leq E \leq 0.2$  Mev. For the range  $1 \leq Z \leq 16$  and  $0.03 \leq E \leq 0.2$  Mev the error is within 11 percent, and it is within 6 percent over much of this range. Using the formula for  $\tau/\rho$ , a formula for effective atomic number can be derived in the usual way.

A detailed report of this project is in preparation.

**Calculation of Stopping Power at Intermediate Energies.** The proposed methods described in previous quarterly reports have been used in determining the stopping power for protons in gold, silver, and aluminum within the energy range from 300 to 600 Kev. The results obtained differ from experimental data of Warshaw<sup>(2)</sup> by 12 to 19 percent. The project has been completed, and the results will be described in detail in a report to be issued soon.

**Fast-neutron Tolerance Calculations.** The life histories of 2000 neutrons of initial energy 10 Mev scattering in an infinite space of tissue have been computed by the Monte Carlo method. The collision density as a function of energy and position has been tabulated for the case in which the neutrons are normally incident on a slab of 30 cm thickness and for that in which they are normally incident on a half-space.

The corresponding energy loss per neutron has been tabulated for the slab geometry and indicates a peak at the boundary of  $0.3 \text{ Mev/cm}^3$  and a second peak of nearly the same height at about 4 cm. The curve then falls off monotonically to  $0.085 \text{ Mev/cm}^3$  at 30 cm. Preliminary statistical tests indicate an accuracy of about 10 percent in these figures, but further investigation is in progress.

---

(1) In *Handbook of Chemistry and Physics*, 31st Edition, pp. 2031-2036, Chemical Rubber Publishing Co., Cleveland, 1949.

(2) Warshaw, S. D., "The Stopping Power for Protons in Several Metals," *Phys. Rev.* 76, 1759 (1949).

Using RBE (relative biological effectiveness) factors of 10 for the energy losses due to protons and 20 for energy losses due to the recoil of heavier nuclei, a dosage curve is obtained, the highest point of which indicates a maximum permissible flux of 14 neutrons/cm<sup>2</sup>/sec based on a tolerance value of 0.06 rem per 24-hr day. These figures are to be regarded as provisional pending a more detailed analysis of the data.

This method takes into account multiple scattering as well as the finite thickness of the body. For comparison, the tolerance given by K. Z. Morgan for 10-Mev neutrons and based on first scattering is about 12 neutrons/cm<sup>2</sup>/sec and assumes the RBE to be 10 for the processes considered above. Using an RBE factor of 10 throughout, our value would be 16 neutrons/cm<sup>2</sup>/sec.

A detailed report on the problem will be issued after further analysis of the data. It is planned also to use the data to obtain tolerance values for beams of lower energies, but this project cannot be carried out until computing machines are available.

## EXPERIMENTAL RADIATION MEASUREMENTS

**Dispersal of Stack Gases.** About 25 runs, each releasing roughly 200 curies of radioactive argon from the pile stacks, have been made during the past month. A thorough analysis comparing the data with meteorological conditions has not been completed.

**Geological Surveys.** During the past month, an aerial survey of regions in Wyoming and South Dakota was made for the purpose of discovering radioactive ore. Some anomalies noted in South Dakota will be investigated further. The equipment used in this survey consisted of 38 Geiger counters, each 2 in. in diameter and 10 in. long, connected in anticoincidence. Apparatus coupled to the radio-altimeter and using a cam arrangement to adjust the sensitivity of the recording rate meter to compensate for variation in height of flight above terrain was tried out and shown to be accurate within the statistical error of the recording.

**Radiation Background Studies.** A flight over the Arco area in Idaho is being considered to record the background of the area before operations are started. This is expected to take place next spring following the installation of scintillation counters, consisting of seven large sodium iodide crystals, each 4 in. in diameter and 2 in. thick, which will replace the Geiger Counters.

## PHYSICS OF NUCLEAR RADIATION

**Backscattering.** Studies of backscattering with the use of an extrapolation chamber discussed in the last report have been continued. Partial collimation of beta rays was used in an investigation of the backscattering by a number of materials of atomic number ranging from that of beryllium to that of lead. The minimum deflection between the primary direction and the final direction varied between  $71^\circ$  and  $86^\circ$  while the maximum deflection possible was always  $180^\circ$ . For saturation backscattering the intensity was considerably reduced with increasing collimation. The ratio of backscattered radiation from material of high atomic number to that of material of low atomic number increases with increasing collimation.

The energy of the backscattered radiation was investigated using aluminum absorbers of increasing thickness. In agreement with previous investigations it was found that the average energy of backscattered radiation increases with the increase in atomic number of the backscattering material. A qualitative theoretical explanation of this effect can be given by combining Rutherford's or Mott's scattering formula with Bloch's energy-absorption formula for fast electrons.

Investigations of the growth of backscattering with thickness of material were continued to determine the mass per unit area of each material required to produce one-half of the saturation backscattering for that material. It has been found that these values decrease with increasing atomic numbers, as would be expected theoretically. The following values were found with partially collimated backscattering: Al, 32 mg/cm<sup>2</sup>; Sn, 29 mg/cm<sup>2</sup>; Pb, 21 mg/cm<sup>2</sup>.

An investigation was conducted to determine the average energy distribution of the backscattered radiation with increasing thickness of the backscatterer. For lead and aluminum it was found that the average energy increased with increasing thickness. Further investigations with pressure chambers and different gases for backscattering are in progress. A detailed report of the results is being prepared.

**Fast Neutron Monitoring.** A series of tests has been run on ADP ( $\text{NH}_4\text{H}_2\text{PO}_4$ ) piezoelectric crystals to evaluate any possible frequency change which may occur under fast-neutron bombardment. Since this compound has a high hydrogen

content, it was considered possible that recoil protons produced by fast neutrons would disrupt the crystal lattice sufficiently to modify the frequency characteristics to a measurable extent.

The crystals were obtained from Brush Development Company. Zero temperature cuts were not available. The temperature coefficient of frequency averaged  $-280$  cycles/ $^{\circ}\text{C}$  between  $0^{\circ}\text{C}$  and  $23^{\circ}\text{C}$ . The high coefficient made very close temperature control necessary, which was accomplished by use of a bath of melting ice in which the crystal holder was immersed when cycle frequency was being measured.

Reproducibility of frequency at ice temperature ( $0^{\circ}\text{C}$ ) could be attained only to within about 80 cycles, the frequency of the crystals used being about 1 megacycle. Any effect of  $n_f$  bombardment was less than this, though there was a tendency for a reading after bombardment by approximately  $10^{12}$   $n_f/\text{cm}^2$  to be somewhat less than the reading just previous. At any rate, since weekly tolerance exposure is about  $10^7$   $n_f/\text{cm}^2$ , this method is too insensitive for personnel monitoring even if the effect is real.

Although ADP crystals cannot, as yet, be made with zero cuts, inquiries are being made toward the procurement of ethylene diamine tartrate (EDT) crystals, which are also rich in hydrogen and can be made with zero cuts. While this does not promise much in the way of a method of personnel monitoring, it may be that, when temperature effects are eliminated, the crystals may furnish a method for catastrophe monitoring.

Some of Eastman's boron- and lithium-loaded nuclear plates have been ordered. Calculations show that if enough boron screening is used to give essentially a flat response to high-energy neutrons, the emulsion is not so sensitive as the Eastman NTA-emulsion H-recoil response, but it is proposed that tests be made with boron-wedge screens under different circumstances in order to see what can be deduced from alpha-track distributions.

Preliminary calculations indicate that a fast-neutron pocket meter may be feasible. This is being investigated.

## RADIOCHEMICAL ANALYSIS

**Exploratory Survey for Rare Earth Fission-product Activity in Urine of Personnel at ORNL.** Among the beta-gamma-emitting radioisotopes to which laboratory employees are more commonly exposed,  $\text{Sr}^{90}$ ,  $\text{Sr}^{89}$ , and  $\text{Ba}^{140}$  are considered to be among the most hazardous. Since  $\text{Y}^{90}$  and  $\text{La}^{140}$ , the decay products of  $\text{Sr}^{90}$  and  $\text{Ba}^{140}$ , are also radioactive and have short half-lives, there exists the possibility that the content of  $\text{Sr}^{90}$  and  $\text{Ba}^{140}$  in urine samples may in some cases be more advantageously determined by the measurement of these rare earth daughter products in radioactive equilibrium than by the direct determination of the parent isotopes. This possibility is especially attractive in the case of urine samples submitted for the determination of plutonium content. Since in the procedure currently used for plutonium determinations rare earths occurring in the samples are precipitated along with the plutonium, an indication of the possible activity of  $\text{Sr}^{90}$  and  $\text{Ba}^{140}$  in the urine sample may be obtained by the simple expedient of counting the beta activity of the plates already prepared for alpha counting, provided that the daughter products have sufficient time to reach transient radioactive equilibrium in the urine before the chemical separations are made.

A survey was begun February 1 and continued through August 15 in order to determine (1) to what extent the plutonium samples would have measurable amounts of beta-gamma activity and (2) how well the beta-gamma activity corresponds to  $\text{Sr}^{90}$  and  $\text{Ba}^{140}$ .

Two hundred and forty-two samples that had been prepared for plutonium determination were counted in a thin-mica end-window G-M counter with a geometry of approximately 25 percent. About 5.5 percent of the samples had activities higher than 5 c/m, the highest being 28 c/m. Decay studies of samples with the higher levels of activity showed the presence of  $\text{Y}^{90}$  in most cases.

Thirty-seven samples were studied by determining the beta-gamma activity of the rare earth fraction and analyzing the urine supernatant for strontium and barium. The results are shown in Table I.

TABLE I

NO. OF SAMPLES	BETA-GAMMA ACTIVITY ON Pu PLATE (c/m)	BETA ACTIVITY RECOVERED FROM URINE SUPERNATANT (c/m)	APPROXIMATE DISTRIBUTION OF ISOTOPES
18	< 3	< 3	
5	< 3	3 to 9	Sr <sup>89</sup>
6	3 to 5	4 to 24	Sr <sup>89</sup> and Sr <sup>90</sup>
2	5 to 8	4 to 6	Ba <sup>140</sup>
5	5 to 10	8 to 14	Sr <sup>90</sup>
1	28	86	Sr <sup>90</sup>

The results give no indication of the presence or absence of Sr<sup>89</sup>, but this method is an easy one for survey of Sr<sup>90</sup> and Ba<sup>140</sup> in personnel who are not routinely checked but who may have ingested or inhaled such materials. It is not expected that this type of analysis will replace the procedure described in previous reports for gross fission products analysis in urine, but rather that it will supplement it.

## PHYSICS OF RADIATION DOSIMETRY

During the last month of the quarter this new group was organized. It consists of a senior physicist, new to the Division, and two men, who, with their current program of research in neutron dosimetry, were transferred from the Instrument Development Group.

**Neutron Dosimetry.** The development of fast-neutron proportional counters of specialized design was discussed in the Health Physics Division's last three quarterly reports, ORNL 596, 695, and 786.

Tests on the response of a fast-neutron dosimeter designed to give a counting rate proportional to the neutron dosage in a collimated beam of fast neutrons have been extended into the energy range from 4 to 5.5 Mev, using the Van de Graaff generator of the Carnegie Institution of Washington. These tests, together with tests previously reported, confirm the theoretical design for energies ranging from approximately 0.3 to 5.5 Mev. It should be noted that the accuracy of this instrument is dependent upon the collimation of the beam.

The nondirectional integrating fast-neutron dosimeter using a proportional counter designed in accordance with L. H. Gray's principle of radiation dosimetry has received further tests at Carnegie Institution. In these tests, integration of pulse heights representing absorption of energy in units of various sizes was performed manually with the use of an A-1 linear amplifier, and measured energy absorption was found to be proportional to the computed dose. In application, an integrating electrical circuit designed and built by the ORNL Instrument Department is used with the proportional counter to measure the dose. The integrating circuit has been tested and found to be linear in its response. This assembly is presently being used in neutron shielding research currently in progress in the Physics Division.

## CONSULTATION AND SPECIAL PROBLEMS

The chief effort of the group during the past quarter has been devoted to routine consideration of short-term problems related to radiation measurements and radiation protection and to studies of building design, from the point of view of radiation protection, in the current Laboratory building program.

One member of the group coordinated an investigation of clothing decontamination methods as applied to Army field laundry equipment. This investigation, a joint project of the Quartermaster Corps and the Chemical Corps, provided opportunity for a field test of a mobile radiological laboratory designed by the Army Signal Corps.

## EDUCATION AND TRAINING

**AEC Fellowship Program.** The 11 NRC Fellows who came to the Division last fall completed their work September 15. Three of them returned to school for further graduate study, and the remaining eight have accepted positions in the health physics field in universities, in national laboratories and institutes, or in industry.

The new group of AEC Fellows in Radiological Physics registered in the graduate school at Vanderbilt University September 25. They will remain there until June, taking course work in biology, physics, electronics, and health physics. Members of the Laboratory staff will teach the courses in health physics at Vanderbilt during the second semester, which course work is now being planned. In June the Fellows will come to ORNL for field training and research.

**Program for Military Personnel.** A group of medical officers, following their year of study in radiation biophysics at Rice Institute, came to the Laboratory for eight weeks (July 31 to Sept. 22) of training in health physics.

**Physics Course for Division Personnel.** A course in atomic and nuclear physics at the college level has been instituted for a group of health physics surveyors who expressed a desire for such a course. It is given in the evening three hours a week.

At the request of the group conducting the TVA-AEC Ecological Study, a course of lectures in nuclear physics is being given, designed to assist them in the interpretation and analysis of their field data.

**Orientation Lectures.** The Education and Training Section has taken over the responsibility for that portion of the weekly orientation program pertaining to health physics.

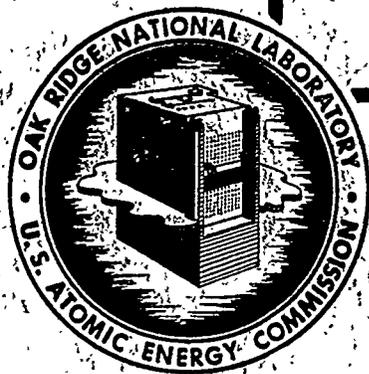
**Miscellaneous Activities.** Members of the staff are assisting in other teaching activities in the Laboratory, particularly in the Apprentice Training School and in the Reactor School.

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**HEALTH PHYSICS DIVISION**

K. Z. Morgan, Director  
F. Western, Associate Director

**QUARTERLY PROGRESS REPORT**

**for Period Ending January 20, 1951**

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## TABLE OF CONTENTS

1.	INSTRUMENT DEVELOPMENT SECTION	5
	Constant Water Monitor	5
	Fast-neutron Survey Meter	5
2.	RADIOACTIVE WASTE DISPOSAL RESEARCH	6
	Water and Liquid-waste Decontamination Processes	6
	Survey Studies and Ecological Study of White Oak Creek Drainage System	8
	Instrumentation and Techniques	9
3.	THEORETICAL PHYSICS	10
	Fast-neutron Tolerance Calculations	10
	Empirical Evaluation of Effective Atomic Number	10
	Calculation of Stopping Power at Intermediate Energies	10
	Stopping Power of Ions in Tissue	10
4.	PHYSICS OF NUCLEAR RADIATION	11
	Measurements of Neutron Dosage	11
	Piezoelectric frequencies	11
	Modification of conventional gamma pocket meters	12
	Particle film microscopy	12
	Beta Scattering	13
5.	RADIOCHEMICAL ANALYSIS	21
	Analytical Procedure for Analysis for Plutonium in River Water	21
6.	PHYSICS OF RADIATION DOSIMETRY	22
	Neutron Dosimetry	22
	Shielding Calculations	22
	Personnel Monitoring for Beta Rays	22
	X-rays	23
	Stopping of Heavy Ions	23
7.	EDUCATION AND TRAINING	24
	AEC Fellowship Program	24
	Physics Course for Division Personnel	24
	Miscellaneous Activities	24

## 1. INSTRUMENT DEVELOPMENT SECTION

**Constant Water Monitor.** An increase in sensitivity of the system being designed has been obtained by surrounding a thin-walled beta counter with a vertical cylindrical wall of water having about 1/8 in. air gap between the water wall and the counter. The wall of water is almost 1/2 in. thick, and there is no spray or splashing to contaminate the counter.

The continuous gas flow discharge counter 0.75 in. in diameter and about 2 in. in length was constructed largely of 0.0005-in. sheet aluminum so as to have a beta window area about 90 per cent of the total area of the counter. The counter, operated in the Geiger region, has a background counting rate of 11 c/min when shielded with 3 in. of lead. The beta window area is approximately 4.8 in.<sup>2</sup>

A sample solution of Sr<sup>90</sup> having an activity of 20 dis/cc/min was measured with the above apparatus with the following results: total counting rate, 32 c/min; background, 11 c/min; and net counting rate 21 c/min. In this case the activity counting rate is closely equal to the dis/cc/min of the activity. A test of activity measurement for 8 hr resulted in no increase of background counting rate although some water vapor did condense into a fine film on the lower part of the counter and thereby forcibly demonstrate the lack of carry-over of activity.

In brief, the work accomplished to date, although incomplete in fine detail, does indicate that a continuous water monitor can be constructed to have a significant reading (twice the background) where the activity of energetic betas is 11 dis/cc/min or more.

A modification of the instrument will permit rapid (10-min) measurements of beta activity in liquid solution of about 50 cc volume where the lower limit of activity is about 10 dis/cc/min. A desirable feature is in not having to reduce the activity to a solid. A disadvantage of the instrument is the counter shell which requires a beta energy of at least 45 Kev for penetration.

**Fast-neutron Survey Meter.** In collaboration with the Physics of Radiation Dosimetry Section, design information is being assembled so that commercial production of this instrument may be discussed.

## 2. RADIOACTIVE WASTE DISPOSAL RESEARCH

Physical facilities for research on problems of radioactive waste disposal will be expanded by construction of a laboratory and pilot plant building especially designed for this purpose. A contract for the construction of this building was awarded in December, 1950, and construction was begun early in January, 1951. Under the cooperative program with the U. S. Public Health Service and other agencies, this facility is being provided primarily for water decontamination research on both civilian and military problems, but it will also be an advantage in related waste-disposal studies. Completion is expected in the middle or latter part of the summer of 1951.

The principal change of program during this period has been in the reorganization and intensification of the laboratory and small pilot plant studies on various methods of water treatment for the removal of particular isotopes and mixed fission products. There is a greatly increased demand for information and advice regarding the problems of possible contamination of community water supplies with radioactive materials, particularly from water works and sanitation officials who are responsible for emergency water-supply protection in connection with civil defense programs. Considerable time and effort have been devoted to the assembly of available data on water decontamination and to discussions of these problems with various groups.

**Water and Liquid-waste Decontamination Processes.** Two types of fission product mixtures were used in experimental studies to obtain further data on removal by water-treatment procedures. In one series, radioisotopes were mixed in proportions estimated to approximate the contamination of water that might result from an atomic explosion. In the experimental water-treatment plant this radioisotope mixture was fed to tap water containing 100 ppm of clay turbidity and was treated by coagulation with alum, lime, and sodium silicate; sedimentation, and passage through gravity filter columns containing standard sand and Anthrafilt media. Efficiencies in the removal of individual radioisotopes varied widely but overall removals for the mixture were 70 to 73 percent. In the laboratory a specially developed jar test unit was used in a series of studies to determine the reduction in activity in an aged and previously treated tank waste by variable amounts of clay turbidity. For clay additions ranging from zero to 4400 ppm followed by stirring and clarification, reductions up to 88% were obtained.

No further experimental work has been done on the calcium phosphate precipitation process for the decontamination of waters and liquid wastes mentioned in a previous progress report (ORNL-877). A report on these studies has been prepared and released, *Studies on the Removal of Radioisotopes from Liquid Wastes by Coagulation*, by R. A. Lauderdale, Jr., ORNL-932.

A special progress report and summary of data obtained thus far from the water-decontamination studies at ORNL are being prepared and are to be completed during January, 1951. The purpose is to indicate, as definitely as present data will permit, the efficacy of normal and modified water purification procedures in the removal of radioactive contaminants from water. Considerable information concerning methods of water decontamination was reviewed in an article and in a paper prepared during this period: (1) "Observations on the Removal of Radioactive Materials from Waste Solutions" by Conrad P. Straub, scheduled for publication in *Sewage and Industrial Wastes*, February, 1951; and (2) "Recent Developments in the Treatment and Disposal of Radioactive Waste Liquors," by Conrad P. Straub, a paper presented at the 117th Meeting of the American Association for the Advancement of Science in Cleveland, Ohio, Dec. 29, 1950.

In an effort to meet the needs of civil defense agencies and others for a reliable method of decontaminating small quantities of drinking water, two workers of this section have developed and tested a small water-decontamination unit for this purpose. Numerous tests have indicated that by passage through this unit, quite large concentrations of mixed fission products can be reduced by a factor of  $10^4$  or greater. A preliminary report is to be completed soon describing the details of this unit and the results of evaluation tests that have been completed up to that time.

Some work on sewage-treatment processes has been continued. The graduate student of the Georgia Institute of Technology assigned to this section completed his thesis work on the removal of  $I^{131}$  from sewage by laboratory trickling filters, prepared a preliminary draft of his findings, and is compiling a final report and thesis on this project. In other series of experiments, the efficacy of activated sludge in the removal of mixed contaminants from a diluted waste-tank solution using jar tests with various periods of stirring and also the removal of  $I^{131}$  from raw sewage mixtures by contact during stirring were given further study.

### Survey Studies and Ecological Study of White Oak Creek Drainage System.

This category includes studies and installations that are of particular interest to the ORNL program and also those concerned specifically with the special Ecological Study being executed by TVA.

The weir installation below the settling basin has been completed, and the entire flow from the settling basin is now passed through the weir box. A continuous water-level recorder and a continuous sampler have been installed. Continuous records of outflow and facilities for proportional sampling of the effluent are therefore available.

The trailer-mounted automatic cable reel for the logging of radioactivity in the test wells previously installed at various points in the X-10 area was constructed, used for making about thirty logging records, and corrected for improved operation. Two new reels designed for operation by gravity instead of by motor drive are being constructed. When the development of these is completed it is expected that periodic logging of the fifty test wells will be adopted as a routine survey operation.

Studies by the staff of the Ecological Study program include physical studies, fisheries biology, botany, and limnology. A summary of progress in these studies includes the following:

1. The study of the time of water travel from the X-10 area through White Oak Lake was repeated using fluorescein dye instead of salt as the indicator of water movement.
2. A "Preliminary Study of the Fish Population of White Oak Creek, September - October, 1950" was completed, and a report of this study has been prepared for early distribution.
3. A detailed study of the level and distribution of radioactivity in fish of White Oak Lake is in progress and about 20% complete. This involves dissection and radioassay of specimens of each species of fish present in the lake and the calibration of the fish probes against the radioactivity found in the sacrificed fish.
4. The relation of vegetation to soil activity in the lake area is being studied by sampling and analysis, and an improved method of preparing soil samples for gross beta counting through the use of a graduated set of sieves has been developed.
5. Limnological investigations were directed particularly toward a survey of the plankton flora and fauna of White Oak Lake. These have included observations and appraisal of related conditions such as temperature, oxygen content, nitrogenous compounds, carbonates, and turbidity and the collection, classification, and quantitative estimation of plankton specimens at numerous selected points in the lake.

**Instrumentation and Techniques.** Progress in instrumentation for waste disposal studies has included redesign and shop work orders of the well-logging equipment mentioned above and further work and calibration on the several Ecological Study instruments mentioned in previous quarterly reports. A source of concentric tubing was located, and with improved shop techniques this permits construction of G-M tubes for beta probes with walls approximately 0.001 in. thick without strengthening ribs.

As a part of the project to measure and record water levels and radioactivity at White Oak Dam with telemetering to the X-10 Area, the float-operated water-level recorder was installed at White Oak Dam and has been in operation for some time. However, changes of the design for alterations and further construction at the dam may necessitate gauging and monitoring at a different location from that originally selected, and, therefore, the installation of telemetering and monitoring facilities has been deferred until the final design for these alterations has been adopted.

For the measurement of radioactivity in live fish, improved gamma probes have been constructed using copper tubes lined with bismuth instead of the stainless steel tubes. Also a scintillation type gamma detector using sodium iodide crystals has been designed and is being constructed in an effort to attain the desired gamma sensitivity in the fish probe instrument.

### 3. THEORETICAL PHYSICS

**Fast-neutron Tolerance Calculations.** Collision densities and energy losses from a 10-Mev beam of neutrons normally incident on a 30-cm slab of tissue have been obtained by a Monte Carlo procedure. A preliminary report summarizing the data, together with the resulting tolerance determination, is being prepared. As soon as machine time is available, the data will be used to obtain information concerning beams of lower energies.

**Empirical Evaluation of Effective Atomic Number.** A report on the determination and use of an effective atomic number for compounds is being written. It is found that while the gamma-ray mass absorption coefficient can, in general, be determined within 10 per cent by using such formulas for the range  $6 \leq Z \leq 20$  and for  $0.01 \text{ Mev} \leq E \leq 0.25 \text{ Mev}$ , the error in some few cases may be as much as 20%.

**Calculation of Stopping Power at Intermediate Energies.** The problem has been completed and the details are published in ORNL-884.

**Stopping Power of Ions in Tissue.** The problem consists in evaluating the relative damage caused by recoil H, C, N, and O ions in tissue due to fast-neutron radiation. The contribution due to atomic collisions has been evaluated. The ranges of energy considered are 0.25 Kev to 2.5 Mev for hydrogen ions and 2.5 Kev to 25 Mev for heavier ions.

#### 4. PHYSICS OF NUCLEAR RADIATION

**Measurements of Neutron Dosage.** (a) *Piezoelectric frequencies.* Previously mentioned (ORNL-786) 5- and 1-megacycle quartz crystals were further tested. One 5-megacycle crystal, 5-A, showed a frequency variation of 15 cycles in the course of several days of observation. Another specimen, 5-B, on being washed with distilled water and dried with hot air, showed a drop in frequency of about 100 cycles, after which there was a fluctuation of about 13 cycles. Crystal 1-A, activated at its second harmonic (approximately 2 megacycles), also showed a frequency range of about 15 cycles. Crystal 1-C, on being washed with distilled water, showed an immediate drop in frequency of about 30 cycles and an additional drop of approximately 20 cycles in the course of two weeks, after which its frequency varied within a range of about 5 cycles.

The cooperation of R. S. Livingston and his group was obtained to make exposures of these crystals to a beam of 1-Mev protons in their 22-in. cyclotron. Crystal 5-B was exposed to 10  $\mu$ a-sec at 1  $\mu$ a of the proton current. A drop in frequency of 320 cycles occurred, but the exposed face of the crystal was somewhat discolored, and it appeared possible that the frequency change was due to loading by some foreign material carried by the beam. After the crystal was washed with HCl, the frequency increased by about 25 cycles. Crystal 5-A was then exposed to 30  $\mu$ a-sec at 1.5  $\mu$ a, but it was shattered by this current. Crystal 5-B was accidentally chipped. Other exposures are planned, the crystal to be screened with aluminum foil, but these are to be sandwiched in as convenient to both parties.

Through the kind cooperation of V. W. Siebs of Western Electric Company, who are the only producers at present, we secured a few specimens of EDT (ethylenediamine tartrate) piezoelectric crystals. Since half the atoms of this material are hydrogen, any effects due to recoil protons from fast neutrons were expected to be maximum. The crystals had a fundamental frequency of 55.950 kilocycles, and an oscillator with multiplier stages was therefore constructed, giving the 18th harmonic of about 1 megacycle. These specimens were of zero cut at 26°C and were very stable, varying only about 2 cycles per megacycle in the course of two days. One specimen was exposed to  $4.8 \times 10^9$   $n_f/cm^2$  (Po-Be),  $8.1 \times 10^9$   $n_f/cm^2$  (Po-Be), about  $3 \times 10^{12}$   $n_f/cm^2$  (fission), and  $2.4 \times 10^{13}$   $n_f/cm^2$  (fission). At the end of this series there was a drop

in frequency of  $1.7 \pm 0.9$  — an insignificant change. Since this series of fast-neutron exposures comprises about  $9 \times 10^5$  weeks of tolerable exposure, it is evident that the material is not suitable for neutron monitoring.

(b) *Modification of conventional gamma pocket meters.* Work was begun on the modification of pocket meters to try to determine fast-neutron exposures. Calculations had indicated that, by modification of materials, differential response to  $n_f$  and  $\gamma$  radiation should be obtainable. While the response was not expected to correspond to rem, it was expected to be measurable.

The first test consisted in filling a group of the tenite II-walled Victoreen pocket meters with propane gas ( $C_3H_8$ ). On an average, seven of these chambers responded only 2 per cent more to Po-Be neutrons than eight air-filled chambers. At the same time,  $\gamma$  (Ra) response was increased by 34 per cent. From this it appeared that wall effects would have to be used.

In a second test 12 Victoreen pocket meters were used. Half had sleeves of 2S aluminum, sufficient to stop 10-Mev protons, inserted to shield the tenite walls. The other half had sleeves of an equivalent thickness of aquadag-coated polyethylene inserted. This latter had the dual purpose of both equalizing the collecting volume and enriching the walls in hydrogen content. Exposures to Ra  $\gamma$  gave a 24 per cent drop in average readings by the polyethylene-lined group, and a 20 per cent drop in the aluminum-lined group when compared to a control group of 20 unmodified chambers. Exposure to Po-Be neutrons gave an 18 per cent rise in the polyethylene-lined group, and a 49 per cent drop in the aluminum-lined group as compared to the control group.

Four chambers were then fabricated; two of them had aluminum walls and teflon insulators, to eliminate hydrogen, and the other two had polyethylene walls and insulators to maximize the hydrogen content of the walls. Preliminary tests indicate that the gamma response of the two groups is approximately the same, and the neutron response of the hydrogenous chambers is about 2.5 times that of the nonhydrogenous group. However, there has been considerable irregularity of leakage stability and the chambers are too few for conclusive tests. Six more of each type have been constructed and are about to undergo further tests. With some modification and refinement, this project shows promise of feasibility.

(c) *Particle film microscopy.* A rotating azimuthal dark-field condenser developed by E. H. Land, and described in AECU-700, has been fabricated at our shop. This device causes nuclear tracks, which consist of aligned silver

grains, to fluctuate in intensity of illumination as the beam rotates, while leaving random grains relatively constant. As a consequence, tracks are recognizable at lower magnification, and the area scanned by a microscope field is larger.

It was observed that at 100× the effectively illuminated area was 20 times that of one microscope field at about 900×. It was further noted that while a three-grain track can be distinguished at 900×, it cannot be distinguished at 100× even with the rotating dark-field. In fact, counting efficiency was about 35 per cent. Thus the effective improvement is by a factor of about 7. There is the further drawback that personal judgment of the observer is more significant than with 900× standard dark-field observation. A few films, counted by three observers, showed counts varying by about 30 per cent. On the other hand, the statistics of the counts are improved considerably, since tolerable exposure is indicated by about 150 tracks per 12 fields rather than 22 tracks per 10 fields as by the present method. Further practice may bring about more consistency.

**Beta Scattering.** Experiments discussed in ORNL-877 were continued. A modification of the design of the extrapolation chamber previously used permitted measurements in gases other than air and in vacuo. The modified chamber is described in ORNL-905. The purpose of the investigation in vacuo was to determine the actual electron backscattering. Most of the investigation was made with beta radiation from  $S^{35}$ .

The first part of the investigation consisted in the evaluation of the backscatter from the collector material. It was noted that the reversal of the collecting voltage, about 90 volts, between the source carrier and the collector produced a considerable change in intensity. Therefore, using a beryllium collector, the collecting voltage was varied from zero to about 14 volts between the source carrier and collector, keeping first the collector positive, later negative relative to the carrier. The change of intensity amounted to an increase of about 30 per cent for positive collection (positive collector), and a decrease of the same order for negative collection, taking the intensity at collector voltage zero as 100 per cent. The major portion of the variation occurred between zero and 3 volts in either direction.

Repeating these experiments with cadmium and lead collectors, the percentage variations increased up to 85 per cent while the actual intensities

decreased. This decrease of the total intensity with  $Z$  was expected and looked for owing to previous theoretical considerations. Extending the variation of the collector voltage up to 1500 volts, it was found that only a very slow, 5 to 10 per cent, gradual increase for positive collection and a still smaller decrease occurred for negative collection beyond 10 to 14 volts. These observations are in qualitative agreement with the report of I. J. Trump and R. J. Van de Graaff in *Physical Review* 75, 44-45 (1949). However, a preliminary evaluation will be given here pending further investigation.

The very large intensity variations between zero and 10 volts (Fig. 1) and the very small changes from 15 to 1500 volts (Fig. 2) indicate that two different processes have to be considered. The slowly varying intensity above 15 volts is apparently due to the effect of the battery voltage between source and collector on the primary and backscattered particles of comparatively high energy. Since  $S^{35}$  has an energy distribution varying from zero to 168 Kev, it is quite understandable that the effect of 1.5 Kev should be small.

The comparatively large effect of the very low potential from zero to 10 volts is apparently not due to real backscattering but to the production of actual secondary electrons of properties similar to those produced in a vacuum tube. Consider a high-velocity particle, primary or backscattered, moving through matter. The particle will produce ionization along its path and, therefore, electrons with energies up to a few volts. Inside the material these electrons will be stopped within some few atomic layers, but at the boundary between the material and the vacuum they can enter the vacuum if their energy exceeds the work function of the material. Let

$I_+$  = the current measured with the collecting electrode positive

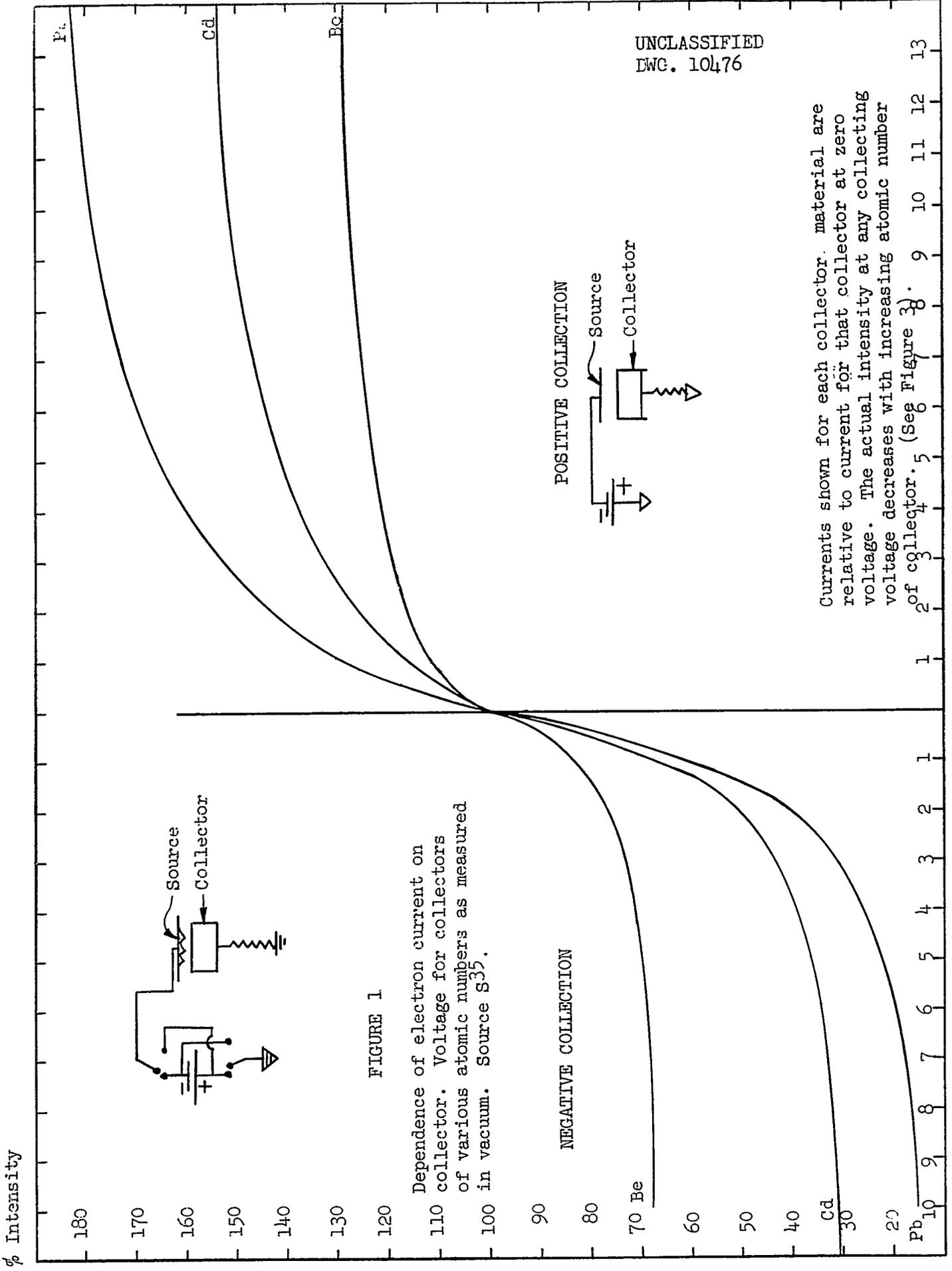
$I_-$  = the current measured with the collecting electrode negative

$I_\beta$  = the current carried by the primary beta particles emitted from the source

$a_Z$  = the fraction of  $I_\beta$  backscattered from the collector

$S_p$  = the number of secondary electrons emitted from the source carrier per primary beta particle

$S_Z$  = the number of secondary electrons emitted from the collector material, of atomic number  $Z$ , per backscattered beta particle



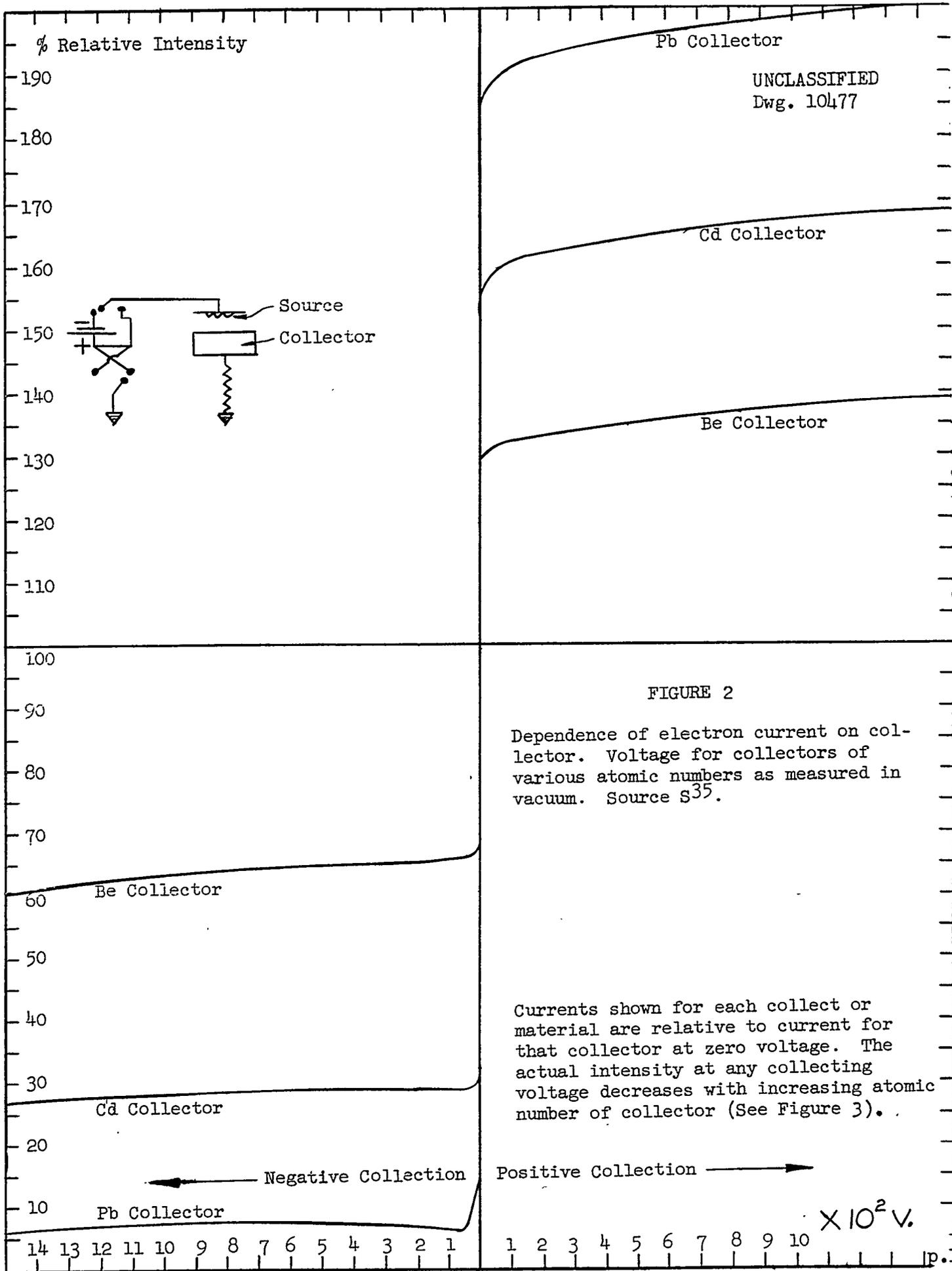
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FIGURE 1

Dependence of electron current on collector. Voltage for collectors of various atomic numbers as measured in vacuum. Source S35.

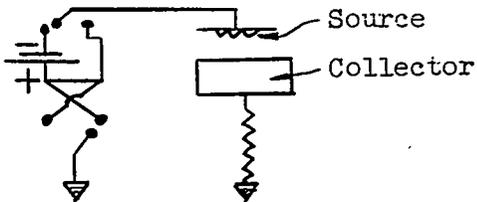
Currents shown for each collector material are relative to current for that collector at zero voltage. The actual intensity at any collecting voltage decreases with increasing atomic number of collector. 5 (See Figure 3).

Collecting Voltage



% Relative Intensity

190  
180  
170  
160  
150  
140  
130  
120  
110



Pb Collector

Cd Collector

Be Collector

100  
90  
80  
70  
60  
50  
40  
30  
20  
10

Be Collector

Cd Collector

Pb Collector

14 13 12 11 10 9 8 7 6 5 4 3 2 1

1 2 3 4 5 6 7 8 9 10

X 10<sup>2</sup> V.

10 p.1

$f(E_Z)$  = the distribution of energy of the beta particles backscattered from a collector of atomic number  $Z$ . (This distribution is, of course, dependent upon the distribution of energy of primary particles which, for purposes of this discussion, is assumed constant.)

$F(E_p)$  = the distribution of energy of the primary betas.

$E_B$  = battery voltage.

The currents will be given, neglecting second-order terms, as a rough approximation by

$$I_+ = I_\beta \left\{ 1 - \alpha_Z \left[ 1 - \int_0^{E_B} f(E_Z) dE \right] + S_p \right\} \quad (1a)$$

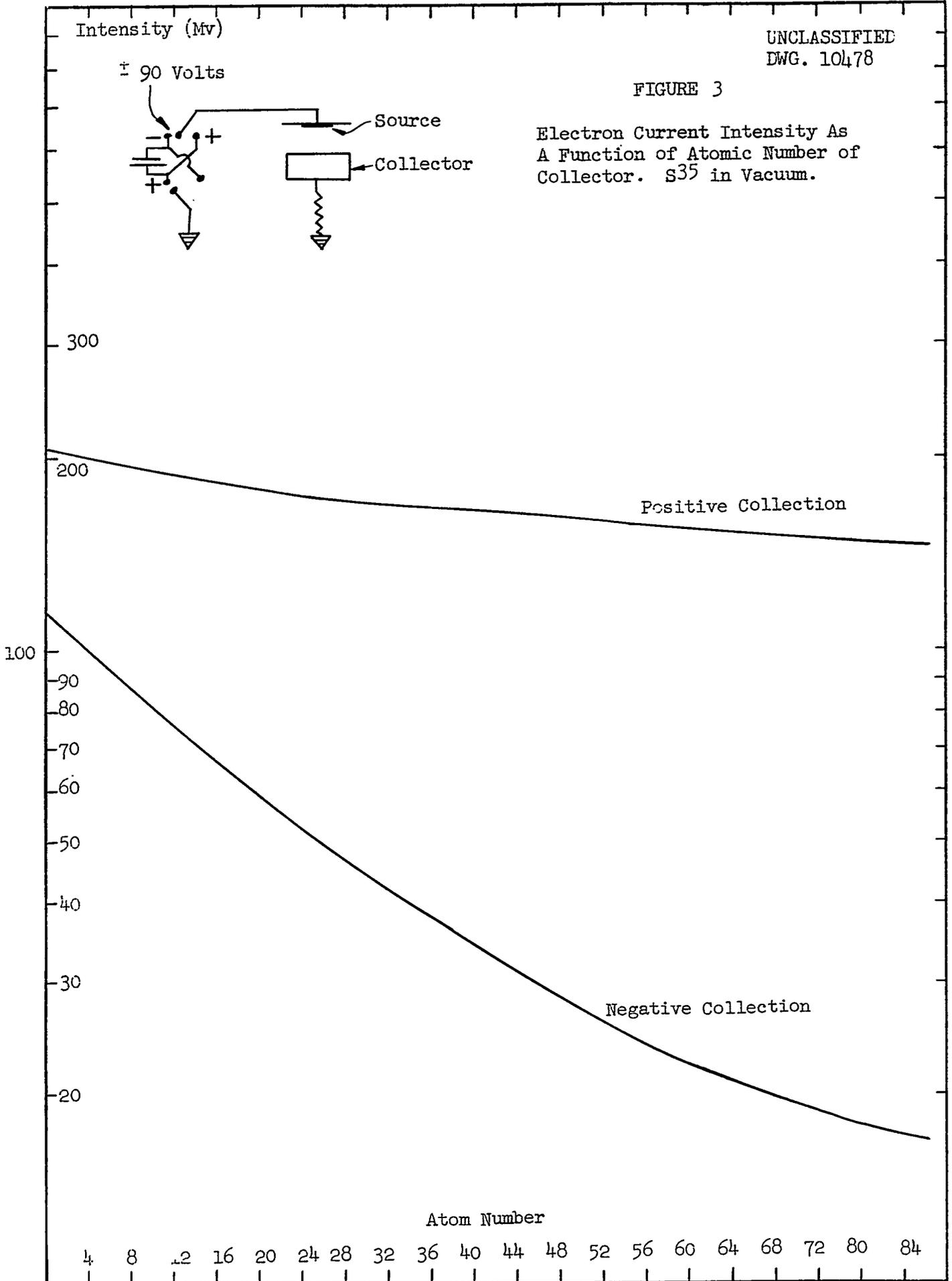
$$I_- = I_\beta \left[ 1 - \alpha_Z - \int_0^{E_B} F(E_p) dE - \alpha_Z S_Z \right] \quad (1b)$$

The following treatment makes the assumption that the fast particles are producing secondaries principally in the direction of their movement. For an exact quantitative result this is not quite correct.

The secondaries, except for a small number with energies more than 10 volts (see Figs. 1 and 2), opposed by the applied voltage  $E_B$  cannot reach the opposite electrode, i.e., in Eq. (1a) the secondaries originating from the collector, in Eq. (1b) those originating from the source carrier are eliminated. The secondaries in the direction of the applied field will reach or leave the collector and will be counted. In Eqs. (1a) and (1b) the electron current flowing into the collector is counted as positive and the electron current leaving the collector as negative. These equations show that for increasing values of  $\alpha_Z$  the total currents decrease. Since  $\alpha_Z$  always increases with  $A$ , the current measured decreases with increasing atomic number of the collector. Furthermore, owing to the positive sign of  $S_p$  and to the minus sign of  $\alpha_Z S_Z$ ,  $I_+$  is always larger than  $I_-$ . Both conclusions are fully confirmed by the experiment (Fig. 3).

FIGURE 3

Electron Current Intensity As  
A Function of Atomic Number of  
Collector. S<sup>35</sup> in Vacuum.



Equations (1a) and (1b) can be simplified for collector voltages less than 200 volts by neglecting the contributions of the integrals

$$I_+ = I_\beta(1 - \alpha_Z + S_p) \quad (2a)$$

$$I_- = I_\beta(1 - \alpha_Z - \alpha_Z S_Z) \quad (2b)$$

Plotting  $I_+$  and  $I_-$ , for a constant collector potential of 90 volts, on semilog paper (Fig. 3) the curves can be extrapolated to  $Z = 0$ . For  $Z = 0$ ,  $\alpha_Z$  should be equal to zero (no backscattering) and  $I_- = I_\beta$ ;  $S_p$  can now be obtained from Eq. (2a). Using the value of  $I_\beta$  as a constant and  $S_p$  as approximately constant, the  $\alpha_Z$  can be calculated from Fig. 3.

They were found to be

COLLECTOR	$\alpha_Z$
4 Be	6
13 Al	19
29 Cu	30.5
48 Cd	41.0
73 Ta	49.5
89 Pb	53.0

For applied potentials less than 15 or 20 volts, the secondary electrons will partially overcome the opposing field. Beginning with zero voltage and increasing the field for positive collection, the current of electrons flowing out the collector will be  $-\alpha_Z S_Z$  less those that cannot overcome the opposing voltage; i.e.,  $\alpha_Z S_Z \int_0^{E_B} f(E_{S,Z}) dE$ . The integral will be equal to 1 for  $E_B = \infty$ , which is actually approximated by  $E_B = 15$  volts.

Applying the same consideration for negative collection, the result is given by:

$$I_+ = I_\beta \left\{ 1 - \alpha_Z - \alpha_Z S_Z \left[ 1 - \int_0^{E_B} f(E_{S,Z}) dE \right] + S_p \right\} \quad (3a)$$

and

$$I_- = I_\beta \left\{ 1 - \alpha_Z - \alpha_Z S_Z + S_p \left[ 1 - \int_0^{E_B} f(E_{S,p}) dE \right] \right\} \quad (3b)$$

where  $f(E_{S,Z})$  and  $f(E_{S,p})$  are the distribution functions of the secondaries originating from the collector and from the source carrier.

## 5. RADIOCHEMICAL ANALYSIS

**Analytical Procedure for Analysis for Plutonium in River Water.** There exists a need for a procedure for analysis of river and stream water for plutonium. It is of special interest at Oak Ridge National Laboratory since water from the White Oak Dam is discharged into the Clinch River. The procedure which is presently used is unsatisfactory because of the difficulty of separating the plutonium from iron and other inorganic constituents of the sample. Also, indeterminate self-absorption of alpha radiation results from extraneous inorganic materials being plated with plutonium.

The development of a procedure has been complicated by such problems as (1) working with a minimum volume of 1 liter, (2) complete destruction of silicates, and (3) separation of plutonium from iron. At present a method for separation of plutonium from iron has not been satisfactorily worked out. Most promising is a procedure in which plutonium is coprecipitated with calcium oxalate at a pH of 2.5. However, separation from iron is not complete, and the control of the pH is difficult under the conditions of precipitation.

It is desired to have a procedure which is reproducible and quantitative to approximately 90 percent.

## 6. PHYSICS OF RADIATION DOSIMETRY

**Neutron Dosimetry.** The development of fast-neutron proportional counters of specialized design discussed in the Health Physics Division's last four quarterly reports, ORNL-596, 695, 786, and 877, has been written up in detail as a report just issued, ORNL-930, entitled *A Count-Rate Method of Measuring Fast Neutron Tissue Dose*.

Currently work is continuing on designs for a counter that will have a uniformly cylindrical electric field with negligible end corrections, to be used with the pulse integration type of neutron dosimeter previously described. The purpose of this field arrangement is to produce a uniform gas amplification throughout the active volume of the counter so that calibrations in terms of reps may be made with an alpha particle source built into the counter, instead of requiring a known neutron source each time recalibration is needed.

The Instrument Development Section of this Division has designed a circuit and preliminary packaging, and we have adapted one of the types of counters described in ORNL-930 to make a complete fast-neutron survey meter. This instrument represents a distinct improvement in weight, convenience, and reliability over the preliminary models of the instrument which have proved reasonably satisfactory in field work by our Radiation Survey Section. Commercial production of this instrument will be discussed in the near future.

**Shielding Calculations.** As a part of our cooperation with the Shielding Program of the Physics Division, calculations have been made and a report will shortly be made to the Shielding Group estimating the corrections to be made to the fast-neutron dosimeter readings inside a thick shield containing water. The purpose is to correct from the experimental observations within a large tank, where scattering material is on all sides of the dosimeter, to the practical situation where all the shielding material is between the dosimeter and the source. There will also be given a method of extending the theory of Bethe, Hurwitz, and Tonks (AECD-2790) to include neutron capture when the theory is used to calculate dosimeter readings in shields composed of heavy materials. This method reduces considerably the amount of work which is required to obtain numerical results.

**Personnel Monitoring for Beta Rays.** The widely used pocket ionization chamber has relatively thick walls and hence is opaque to beta rays of energy

less than 700 to 900 Kev. The ionization in its chamber produced by higher energy betas is reduced by about this amount, so the chamber is very insensitive to ordinary beta rays. Work is in progress on a chamber of similar gamma sensitivity but with a wall thickness of only  $6.7 \text{ mg/cm}^2$ , equivalent to the average thickness of the insensitive layer of the human epidermis and penetrable by beta rays of about 70 Kev energy. This thin paper wall is protected by a fine-mesh screen of metal or perhaps plastic for mechanical strength. Preliminary models show about the expected gamma sensitivity, and a response to known beta sources which is very promising. Leakage seems to compare very favorably with the commercial gamma chambers.

**X-rays.** A 250-kv-constant-potential X-ray machine has been purchased from Westinghouse and is in process of installation. This will be operated both for research projects of this section and as a service to the entire division.

**Stopping of Heavy Ions.** Preliminary studies are being made of the feasibility of experimental investigation on the damage caused by heavy ions to tissue-like materials in the region beyond the end of their ionization range. Protons may have energies of hundreds of Kev, and fission fragments may have energies of even several Mev, yet be going too slowly to ionize, at least according to presently accepted theories of Bohr and others. This residual energy has heretofore either been neglected in Health Physics calculations, or it has been assumed that the total damage is proportional to the ionization. The object of the project will be to investigate the validity of these assumptions.

## 7. EDUCATION AND TRAINING

**AEC Fellowship Program.** The present group of 20 AEC Fellows in Radiological Physics have completed the first quarter of their graduate work at Vanderbilt University with satisfactory records and have begun the second quarter of work there. Beginning February 12 members of the Laboratory staff will go to Nashville two days a week to teach the Health Physics course. The course will continue throughout the remainder of the school year.

**Physics Course for Division Personnel.** A course in atomic and nuclear physics at the college level which was instituted for a group of health physics surveyors who expressed a desire for such a course has continued throughout this period. It is given in the evening 3 hr per week.

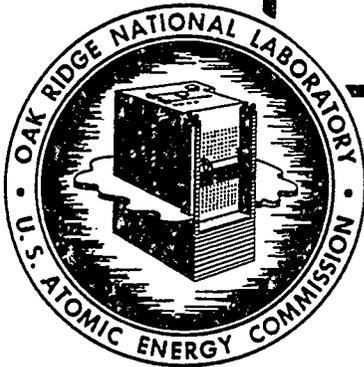
**Miscellaneous Activities.** Members of the staff are assisting in other teaching activities in the Laboratory, particularly in the Apprentice Training School and in the Reactor School. The Education and Training Section has assumed the responsibility for that portion of the weekly orientation program pertaining to health physics.

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FOR PERIOD ENDING APRIL 20, 1951



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- 158. Savannah River Operations Office, Wilmington
- 159. Western Reserve University
- 160-163. Westinghouse Electric Corporation
- 164. Yale University
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- 203-204. U. S. Army, Office of the Chief Signal Officer (Curtis T. Clayton  
thru Major George C. Hunt)
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- 208. UT-AEC Agricultural Research Program (Charles S. Hobbs)
- 209-212. General Electric, Richland

Reports previously issued in this series are as follows:

ORNL-166	Period Ending August 31, 1948
ORNL-227	Period Ending November 30, 1948
ORNL-346	Period Ending February 28, 1949
ORNL-375	Period Ending July 15, 1949
ORNL-495	Period Ending October 15, 1949
ORNL-596	Period Ending January 15, 1950
ORNL-695	Period Ending April 15, 1950
ORNL-786	Period Ending July 15, 1950
ORNL-877	Period Ending October 20, 1950
ORNL-968	Period Ending January 20, 1951

## TABLE OF CONTENTS

1.	INSTRUMENT DEVELOPMENT	5
	Constant Water Monitor	5
2.	RADIOACTIVE-WASTE-DISPOSAL RESEARCH	6
	Water and Liquid-Waste Decontamination Processes	7
	Survey Studies and Ecological Study of White Oak Creek Drainage System	8
	Instrumentation and Techniques	9
	Publications	10
3.	THEORETICAL PHYSICS	11
	Fast-Neutron Tolerance Calculations	11
	Empirical Evaluation of an Effective Atomic Number	11
	Radiation Damage Due to Electronic and Nuclear Collisions in Tissue	11
	Stopping Power of Protons, Alpha Particles, and Ions of Carbon and Oxygen in Tissue	11
4.	PHYSICS OF NUCLEAR RADIATIONS	12
	Measurements of Neutron Dosage	12
	Beta Particles	13
	Particle Problems	13
	Publications	14
5.	RADIOCHEMICAL ANALYSIS	15
	Analytical Procedure for Analysis of Urine for Uranium	15
6.	PHYSICS OF RADIATION DOSIMETRY	16
	Pulse-Integration Fast-Neutron Dosimeter	16
	Uniform-Response Neutron Proportional Counter	17
	Shielding Calculations	17
	X-Rays	18
	Cooperation with the School of Reactor Technology	18
7.	EDUCATION AND TRAINING	19
	AEC Fellowship Program	19
	Training Program for Military Personnel	19
	Training Program for AEC Contractors' Personnel	19
	Physics Course for Division Personnel	19
	Miscellaneous Activities	19

## 1. INSTRUMENT DEVELOPMENT

**Constant Water Monitor.** A production design of a constant water monitor has been completed and reduced to drawings, Nos. D-9029 through D-9035, which are on file in the Engineering and Maintenance Division. The drawings describe a continuous-flow water cell of 4 liters/min capacity, a 40-Kev beta-sensitive Geiger-Mueller counter, lead shielding, and control panel. The normal background count rate is about 7 c/m, and water of about  $2 \times 10^{-6}$   $\mu\text{c/ml}$  of  $\text{Sr}^{90}$  activity is detectable by an approximately 50% increase of the background counting rate.

An operating model has been constructed and assembled. It is now monitoring the drinking water supply in room 100, and is under observation for possible faults. The present method of recording the count rate uses a scale of 2 and a traffic counter to print 15-min count integrations, totalizing and recycling every hour.

The production design is being considered (by Chemical Technology Division) for application to some waste-water monitoring problems on and off the area.

We have been informed by the Patent Office that a patent search discloses no similar art; an application will be made for a U. S. patent covering the features embodied in the water cell and counter assembly.

A preliminary report is to be written, for purposes of record and discussion, as to feasibility of continued effort.

## 2. RADIOACTIVE-WASTE-DISPOSAL RESEARCH

Further progress has been made toward expansion of the cooperative program of research on water and liquid-waste decontamination, particularly through increased participation by the Public Health Service. One additional sanitary engineer has been assigned on loan for an indefinite period for work in the waste research program. A detailed plan and budget for further increases of Public Health Service personnel assigned to this project during the next fiscal year have been prepared and are being considered for approval and authorization.

Construction of the Health Physics Waste Research Building, mentioned in the previous quarterly report (ORNL-968), is proceeding on schedule, and procurement of laboratory and experimental equipment for this building has begun. Facilities necessary to meet immediate needs for additional work space and equipment are being provided on a site near White Oak Creek east of the settling basin. These include a prefabricated building, a raw-water intake on White Oak Creek, re-erection of a 35,000-gal wooden tank salvaged from the former X-10 water plant building, pipes and connections for disposal of test materials, and arrangements for access to this site from the exclusion area.

Various members of the Waste Disposal Research Group have continued to spend considerable time and effort in assisting in education and training activities and in making available information regarding methods of water decontamination and liquid-waste control. For example, a group of seven municipal and state water works and public health officials from Missouri, Indiana, and the City of Detroit visited the Laboratory for two days to discuss specific questions pertaining to potential radioactive contamination and methods of emergency protection of large water supply systems. Under present plans it is expected that two professors of sanitary engineering and two graduate students will join the group early this summer for extended periods of work and training experience. Other activities in this category have included four lectures as part of water and sewage works short courses, a lecture to a student engineering society, participation in a two-day conference on sanitary engineering training, including qualifications for work in the atomic energy field, and preparation of replies to numerous inquiries concerning the results of the ORNL studies on radioactive-waste-disposal problems and techniques.

**Water and Liquid-Waste Decontamination Processes.** Active work has been continued in studies of the removal of radioactive materials by water treatment procedures. An extensive series of jar-test coagulation experiments designed to show the factorial interaction of four variable conditions has been completed. The radioactive test material was a mixture of radioisotopes which might be found in a water supply soon after an atomic explosion. The variables tested were: pH, turbidity (clay), coagulant dosage (alum), and level of radioactivity. In the experiments three values of each of the above variables were represented. Removals of radioactivity were in the range of 50 to 60%.

A series of studies on adsorption has been begun and is still in progress. In water contaminated with a storage-tank waste (evaporator concentrate) at least ten adsorbents are being tested, including montmorillonitic clays, tannins, and lignins. These experiments on a jar-test scale indicate removals of 10 to 50% of the radioactive contaminants.

A series of jar-test coagulation experiments to determine removals of yttrium, cerium, and iodine, singly and in combination, with variations of pH and turbidity has been completed. Under the best conditions, the removals of yttrium and cerium in a mixture and also individually ranged up to 98% while removals of iodine were about 77%.

Pursuant to an inquiry and request from the Engineering and Maintenance Division, sanitary engineers of the Waste Disposal Research Group are cooperating in a study to evaluate the efficiency of operation of the new ORNL sewage treatment plant, particularly in the removal of suspended solids. Changes in the routine of pump operation are being made to obtain better equalization of the flow of raw sewage to the treatment plant, after which a program of sampling and analytical determinations will be carried out.

Further studies have been made on the methods for emergency decontamination of drinking water. Experimental work has been completed for the evaluation of the small water-decontamination unit, mentioned in a previous report (ORNL-968), and a descriptive report of this unit and of the results obtained with it has been completed for publication in May. Also, some work has been done on the evaluation of a small commercial mixed-resin ion-exchange water-treatment unit of the type recommended for deionization of small quantities of water for laboratory use. The purpose is to appraise the operating characteristics of such a unit as well as performance of the materials it contains.

## Survey Studies and Ecological Study of White Oak Creek Drainage System.

The following studies have been made during the past quarter:

1. A determination of the time of water travel through White Oak Creek and Lake, using fluorescein dye, was made at the time that the rate of flow in the creek was about 7 cfs and the lake level was approximately 3 ft below the elevation of the spillway. It was found that under these conditions dye applied to the head of the lake first reached the dam in 29 hr and that the first peak moved through the lake and arrived at the dam in about 36 hr after dosage. A second peak somewhat higher than the first arrived on the fourth day and it was estimated that the mean time of travel or period of retention in the lake was approximately six days. Arrival at the dam of the fastest moving water particle in 29 hr indicates a minimum displacement of only 13% of the six million cubic feet of water contained in the lake at this water level. No stratification of flow in the lake was observed.

A second determination of the time of water travel through the creek and lake has been made at a higher rate of flow in the stream and at a higher elevation of the lake, again without stratification. The results of the determination have not been reported.

2. The fish population study for the spring of 1951 is due to be completed on April 25. Preliminary estimates of the fish population indicate a decrease in numbers of about 25% from the estimate of last fall. This is considered within the natural range of winter mortalities in fish populations.
3. The botanist has completed the collection of several hundred sheets of plant specimens for definition of flora during the early spring period, and identification of specimens collected last fall has been practically completed subject only to checking and verification. Some absences of species of flora expected in this region have been noted but have not been explained.
4. In the limnological study increased time has been devoted to the collection of bottom organisms. These and other aquatic specimens showed normal changes during the winter season.
5. Physical and chemical studies have included completion of the silt survey of White Oak Lake, continued biweekly sampling of water at various points in the lake, and collection of a monthly sample for mineral analysis at the upper and lower end of the lake.

An analysis of the data on the discharge of radioactivity from White Oak Lake and diluting flows in the Clinch River during the past several years was prepared and presented at the meeting of the AEC Waste Processing Committee

at ORNL on February 5 and 6. Available data from past surveys of the Clinch River are being collected to aid in the preparation by the Tennessee Valley Authority of a comprehensive report on conditions in the entire Tennessee River Basin. This report deals principally with domestic sewage and other water pollutants, but any available information concerning radioactive contaminants was requested.

Preliminary laboratory experiments to determine the various factors that affect the uptake of radioactivity in small fish were carried out in tap water to which was added Cs<sup>137</sup>. An extensive factorial series of further experiments to aid in evaluating the significance of five variable factors at three levels of radioactivity has been designed with assistance from the ORNL Mathematics Panel.

Well-logging measurements to determine and record the levels of gross radioactivity in the test wells installed in connection with the Geological Survey of the Laboratory area have been continued. To date a total of 80 records on 40 wells have been completed. An improved design of the cable reel apparatus is being used and two new reel outfits are being constructed. A summary report of well-logging data obtained up to March was prepared and furnished to the geologists together with tables, interpretations, and suggestions for further work. It was suggested that to aid in defining the subsurface background of radioactivity and in interpreting the well-logging data, two additional test wells should be drilled in an uncontaminated area of approximately the same geological formation that prevails where the 51 test wells have been installed for study of the X-10 site.

**Instrumentation and Techniques.** For use by the Health Physics Division and particularly in the development of instruments for waste-disposal research, a dry box has been completed for grinding and polishing sodium iodide crystals for scintillation-counter construction. An electric power grinder for grinding small crystals has been designed and is to be constructed.

Preliminary work has been done to explore the feasibility of measuring the concentration of fluorescein dye as used in time-of-water-travel studies by means of photoelectric methods.

A detection and recording assembly has been completed and is being used in connection with continuous-flow ion-exchange experiments. The purpose is to detect residual contamination if present in the ion-exchange resins as received and also to measure radioactivity in the effluent during the experiments.

In response to requests for information from water works officials and sanitary engineers, two Landsverk analysis units have been repaired and tested. Further experiments will be made to determine the sensitivity and suitability of these units for the measurement of radioactivity in water supplies in the event of accidental or emergency contamination.

In preparation for the equipment and use of the Waste-Research Building when completed, considerable time has been spent in the selection and preparation of procurement data for control instruments and equipment which will be needed in laboratory and pilot plant experimental studies.

**Publications.** The following is a list of reports which have been published during the past quarter:

1. *Studies on the Removal of Radioisotopes from Liquid Wastes by Coagulation*, R. A. Lauderdale, Jr., ORNL-932 (Jan. 23, 1951).
2. "Observation on the Removal of Radioactive Materials from Waste Solutions," Conrad P. Straub, *Sewage and Industrial Wastes* 23, No. 2, pp. 188-193 (February, 1951).
3. "Problems in Disposal of Radioactive Wastes," Conrad P. Straub, *Wastes Engineering* 22, No. 2, pp. 70-71 (February, 1951).

### 3. THEORETICAL PHYSICS

**Fast-Neutron Tolerance Calculations.** Collision densities and energy losses from a 10-Mev beam of neutrons normally incident on a 30-cm slab of tissue have been obtained by a Monte Carlo procedure. A preliminary report summarizing the data, together with the resulting tolerance determination, is being prepared. The neutron histories obtained for the 10-Mev beam are now being analyzed to obtain the energy losses of beams of lower initial energies.

**Empirical Evaluation of an Effective Atomic Number.** A report on the determination and use of an effective atomic number for compounds is being written. It is found that while the gamma-ray mass absorption coefficient can, in general, be determined to within 10% by the use of such formulas for the range  $6 \leq Z \leq 20$  and for  $0.01 \text{ Mev} \leq E \leq 0.25 \text{ Mev}$ , the error in some few cases may be as much as 20%.

**Radiation Damage Due to Electronic and Nuclear Collisions in Tissue.** The problem consists in evaluating energy losses due to fast-neutron radiation. The electronic and nuclear stopping powers of recoil ions of H, C, N, and O have been evaluated, using Bohr's formula [*Phys. Rev.* 59, 271 (1941)]. The electronic stopping power as calculated does not agree with some experimental values, and therefore a semiempirical approach is used as suggested by Knipp and Teller [*Phys. Rev.* 59, 658 (1941)].

**Stopping Power of Protons, Alpha Particles, and Ions of Carbon and Oxygen in Tissue.** In the projects discussed above we are concerned with the relative damage due to electronic vs. nuclear collisions for slow ions released by a fast-neutron stream. In this project we calculate the losses due to electronic collisions only, over an extended range of energies including those for which the nuclear collision losses are negligible. The method used is based on results of Hirschfelder and Magee [*Phys. Rev.* 73, 207 (1948)] and Knipp and Teller [*Phys. Rev.* 59, 658 (1941)].

#### 4. PHYSICS OF NUCLEAR RADIATIONS

**Measurements of Neutron Dosage.** Work this quarter consisted mainly of further investigation of the practicability of monitoring exposure to fast neutrons against a gamma background by means of the difference in the responses of pocket chambers with walls of hydrogenous and nonhydrogenous materials. The responses of pocket chambers of various materials and dimensions were studied, using polonium-beryllium and polonium boron neutron sources. The polonium-beryllium source has an energy spectrum averaging approximately 4.5 Mev with a maximum of about 11 Mev, while the polonium-boron source has an average of approximately 2.5 Mev with a maximum of about 6 Mev.

Materials used included polyethylene, carbon, and aluminum. The inside diameters of the chambers varied from 0.68 to 1.76 cm. Electrodes used in the smaller chambers were of aluminum 0.16 cm (1/16 in.) in diameter, while electrodes used in the larger chambers were of various materials and ranged upward to 1.12 cm in diameter. The purpose of these variations in size was to change the surface-to-volume ratio; other consequences were changes in collecting volume and in capacitance.

In order to have a basis of comparison, the response of each chamber to a neutron source is expressed by giving the number of milliroentgens of radium gamma radiation required to give a response equivalent to that observed from an exposure of  $10^7$  neutrons/cm<sup>2</sup> from the source.

The best neutron responses occurred with polyethylene walls and electrodes and were approximately 55 mr equivalents per  $10^7$  Po-Be neutrons/cm<sup>2</sup> and approximately 43 mr equivalents per  $10^7$  Po-B neutrons/cm<sup>2</sup>. This ratio of approximately 1.3 for the two energy spectra appeared in all chambers with organic walls. Aluminum walls and electrodes showed neutron responses of 17 to 20 mr equivalents per  $10^7$  Po-Be neutrons/cm<sup>2</sup> and approximately 11 mr equivalents per  $10^7$  Po-B neutrons/cm<sup>2</sup>. The ratio of responses ranged between 1.58 and 1.77. Graphite wall and electrode gave 22.7 mr equivalents per  $10^7$  Po-Be neutrons/cm<sup>2</sup> and a ratio of 1.83.

It is thought that the responses of the hydrogen-free meters under the conditions of these experiments are not entirely due to gamma radiation. The fraction of the response which may be ascribed to neutron irradiation of the meters is under investigation.

The pocket meters described above are read by observing the position of an electrometer filament. Another construction underway uses the capacitance change of a leaf electrometer when discharged by radiation. This meter is inserted in a high-frequency circuit where the capacitance variation produces a frequency variation measured against a crystal-controlled frequency standard. This method may become very sensitive, since small fractions of 1  $\mu\mu\text{f}$  can cause a frequency change of several kilocycles. This construction is still in the initial stage.

**Beta Particles.** Absorption measurements were completed with collimation for  $\text{P}^{32}$ ,  $\text{Sr}^{90}$ , and  $\text{S}^{35}$ , using absorbers of varying thicknesses and atom numbers from 4 to 82. Organic substances and wet tissues were investigated particularly. The extrapolation chamber and Geiger counter were used for these measurements to obtain the attenuation by energy absorption (chamber) as well as the reduction of number of particles (counter).

In addition, the attenuation by air was investigated with the counter up to 500 cm ( $\text{P}^{32}$ ,  $\text{S}^{90}$ ) distance between source and detector.

**Particle Problems.** Facilities for radioactive particles technology are under construction in Building 2001. Their completion is anticipated during the next quarter. The laboratory will be under positive pressure with incoming and outgoing air carefully filtered to make it as dustproof as possible. Micromanipulators, a microforge, and thermal precipitators have been acquired, and a Leitz "Panphot" photomicrographic apparatus with necessary accessories is on order.

During this quarter a technique for the measurement of particles down to 0.006  $\mu$  (60 A) in diameter has been investigated with good preliminary results. Measurements in the range of 0.003 to 0.006  $\mu$  are somewhat questionable, and measurements below 0.003  $\mu$  do not seem feasible with the equipment presently available. A size analysis of particles penetrating CWS No. 6 filter paper shows that the greatest penetration does not occur with particles of 0.3  $\mu$ . Using a group of influent particles ranging from 0.01 to 2.8  $\mu$  with a medium size of 0.13  $\mu$ , it was observed that the size giving maximum penetration lies below 0.02  $\mu$ . Below 0.01  $\mu$  the discrimination between particles and background becomes difficult.

**Publications.** The following are reports which have been published by this section during the past quarter:

1. *Construction and Operation of a Variable Pressure Extrapolation Chamber*, T. E. Bortner, ORNL-905 (Mar. 19, 1951).
2. *Dose Rates of Radiation from Thorium and from Enriched Uranium*, T. E. Bortner and H. K. Richards, ORNL-761 (Apr. 9, 1951).

## 5. RADIOCHEMICAL ANALYSIS

**Analytical Procedure for Analysis of Urine for Uranium.** Preliminary work has been done on the development of a better procedure for the analysis of urine for uranium. For the determination of uranium isotopes with short half-lives at levels of urinary excretion which are considered safe, it is necessary to measure the alpha activity of the sample rather than depending upon fluorometric analysis.

The *Health Physics Division Quarterly Report for Period Ending February 28, 1949* (ORNL-346) described a method for isotopic determination of uranium in urine. However, the procedure is long and time-consuming. The primary objective in seeking a new analytical procedure is for efficiency of time and ease of routine operations.

The details of the procedure now under investigation will be reported upon completion of the work. In 12 experimental runs, made thus far, an average of 88% of tracer uranium has been recovered from 100-ml urine samples. The reproducibility of results is favorable in that the maximum deviation from the average was 4%.

## 6. PHYSICS OF RADIATION DOSIMETRY

**Pulse-Integration Fast-Neutron Dosimeter.** Recently reported neutron cross-sections [R. K. Adair, *Revs. Mod. Phys.* 22, 249 (1950)] have been used to compare the energy absorbed per gram of tissue to the energy absorbed per gram of ethylene due to fast-neutron irradiation. It was found that the ratio of tissue dose to ethylene dose is very nearly independent of the neutron energy in the region of 100 Kev to 20 Mev. Thus ethylene is tissue-equivalent insofar as fast-neutron dosimetry is concerned. Since paraffin has almost the same atomic composition it may be used as a wall liner for chambers containing ethylene.

More careful investigation of the problem of measuring the fast-neutron tissue dose with the proportional counter, mentioned in *Health Physics Division Quarterly Progress Report for Period Ending January 20, 1951*, ORNL-968, reveals that the proportional-counter method is completely analogous to the ionization-chamber method, provided special consideration is given to the following:

1. The gas amplification of the counter must be known at all times. This may be achieved by permanently installing an alpha source in the counter. The problem is now being investigated.
2. A correction must be made for energy of those protons which recoil with an energy less than that which will be rejected by the bias which is used to discriminate against gamma-ray pulses. A preliminary calculation has been made and the results are as follows in the case of 0.2 Mev bias energy:

NEUTRON ENERGY (Mev)	PERCENT OF TOTAL ENERGY LOST UNDER BIAS
0.2	100.0
0.4	26.0
1.0	5.0
2.0	2.0
4.0	1.0

3. The linear amplifier which is used to observe the pulses produced in the proportional counter must have a rise time and a decay time such that the maximum height of the output pulse is not appreciably affected by the rise time of the counter pulse. The distribution in rise times is being measured and the necessary amplifier characteristics are being determined.

Arrangements have been made for the use of the Cockcroft-Walton machine in the High Voltage Laboratory for the purpose of using the counter to measure the dose from well-defined beams of monoergic neutrons. A target and counter assembly has been designed and constructed for the D-D and the D<sub>2</sub>T thick-target reactions.

**Uniform-Response Neutron Proportional Counter.** The uniform-response neutron counter, mentioned in *Health Physics Division Quarterly Progress Report for Period Ending April 15, 1950*, ORNL-695, has been calibrated with the polonium-beryllium and the polonium-boron neutron sources. The counter has an equal sensitivity of  $(1.75 \pm 0.10) \times 10^{-2}$  counts/neutron/cm<sup>2</sup> for the two sources. The sensitive area is about 20 cm<sup>2</sup> and the background less than 10 counts per hour. In order to make these calibrations, it was necessary to correct for the neutrons scattered from the floor and walls of the laboratory. This correction was first made by suspending the source and counter about 15 ft from the ground. With this geometry a 15-in. cone of paraffin placed between the source and counter reduced the count rate to 3% of the rate when the cone was not used. If it is then assumed arbitrarily that half this reading is still due to scattered neutrons (from the suspension), then the cone is effective in reducing the direct neutrons to 1.5%. This assumption seems reasonable when it is considered that the scattering near a floor amounts to 13%. The cone is then used to make scattering corrections under the conditions of laboratory geometry.

The counters have the physical size of the count-rate dosimeters described in ORNL-930. It is calculated that their response is uniform from 0.5 to 10 Mev, while being insensitive to less than 2 r/hr of gamma radiation. Their response to monoergic neutrons of various energies will be determined when sources become available.

**Shielding Calculations.** Calculations have been made of the contribution of neutrons scattered in air to the total dose at different distances from a spherically symmetric shield assuming constant cross-sections, isotropic scattering, and no absorption in the air. The calculations were made by evaluating the exact solution of the Boltzmann equation for this case. The results do not agree with those (NEPA-997 and 1657) which treat only first and second collisions. It has been shown that<sup>(1)</sup> the diffusion type solution is approached rapidly as the distance from the source is increased so that the method of treating only the first two collisions seems to be in error and to give results which are too low.

(1) G. Placzek, *Notes on Diffusion of Neutrons Without Change in Energy*, Montreal Report MT-4 (April, 1943).

It may be shown that the dose received in air at a distance  $R$  from a spherically symmetric shield of radius  $r$  is  $\frac{1}{2} (r/R)^2 D$  if  $r \ll R$ .  $D$  is the dose measured at the outside of the shield. This result is independent of the angular distribution of the dose at the shield surface.

In determining thermal-neutron flux in water by the foil method, a correction must be made for the difference in flux perturbation in water and in the standard graphite pile. The theory proposed by Skyrme<sup>(2)</sup> was used to calculate this correction for a 1-mil foil. The activity found in water should be increased by 5%.

To obtain an idea of the error in Skyrme's theory, which is correct to second order only, a one-dimensional model of a delta source and a foil in an infinite capturing medium was considered. This model should be a good approximation for large foils in water. The flux at any point in the infinite medium may be described by an integral equation which involves the symmetric kernel  $E(x - x')$  and which is integrated over all space. It may be converted to a much simpler integral equation by applying a Fourier transformation. The resulting equation is integrated over the foil only and has as a kernel the solution for the undisturbed density in an infinite medium. Numerical work with this equation is planned.

To determine a more accurate value of the diffusion length of thermal neutrons in graphite from experimental data, the solution for the thermal-neutron density in a rectangular parallelepiped containing a point nonthermal source has been given to the Mathematics Panel in a form suitable for computation. It will be iterated over the data to obtain an improved value for the diffusion length.

**X-Rays.** Further work on pocket ionization chambers has been delayed by the necessity of improving the shielding on the X-ray machine before it can be used. Extensive lead shielding has been added to the tube head, and modified controls are under construction to permit a wide range of dosage rates.

**Cooperation with the School of Reactor Technology.** One member of the section has been assisting the School of Reactor Technology Laboratory in the completion of an experiment on the space distribution of neutron flux in the X-10 pile.

(2) T. H. R. Skyrme, Montreal Report MS-91 (no date).

## 7. EDUCATION AND TRAINING

**AEC Fellowship Program.** The present group of 20 AEC Fellows in Radiological Physics are in their third quarter of work at Vanderbilt University. Since February 12, members of the Health Physics Division have been spending two days a week in Nashville teaching a four-semester-hour course in health physics.

**Training Program for Military Personnel.** On April 2 six medical officers were assigned to this Section for an eight-week training course in health physics. Training includes both lectures and field training, and follows a year's training in radiation biophysics at Duke University.

**Training Program for AEC Contractors' Personnel.** On March 23 an eight-hour health physics seminar was conducted for personnel from the American Cyanamid Company, E. I. du Pont de Nemours & Co., and the California Research and Development Corporation.

Beginning April 2, and extending for three weeks, a course in health physics was given one hour a day, five days a week, for the Phillips Petroleum employees currently assigned to ORNL for training.

A medical doctor from the American Cyanamid Company is participating in the health physics program for the present military group.

**Physics Course for Division Personnel.** A course in Atomic and Nuclear Physics at the college level, which was instituted for a group of Health Physics surveyors who expressed a desire for such a course, has continued throughout this period. It is given in the evening, three hours a week.

**Miscellaneous Activities.** Members of the staff continue to assist in other teaching activities in the Laboratory, particularly in the Apprentice Training School and in the Reactor School.

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HEALTH PHYSICS DIVISION

K. Z. Morgan, Director

QUARTERLY PROGRESS REPORT

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QUARTER ENDING JULY 20, 1951

## TABLE OF CONTENTS

	Page
Instrument Development .....	1
Constant Flow Water Monitor .....	1
Batch-Wise Liquid Monitor .....	
Radioactive Waste Disposal Research .....	2-4
Water and Liquid Waste Decontamination Processes .....	2
Survey Studies and Ecological Study of White Oak Creek Drainage System .....	2-3
Instrumentation and Techniques .....	3-4
Training Activities .....	4
Theoretical Physics .....	5
Fast Neutron Tolerance Calculations .....	5
Stopping Power of Protons, Alpha Particles and Ions of Carbon and Oxygen in Tissue .....	5
Collision Densities for Thermal Neutron Irradiation of Thin Foils .....	5
Physics of Nuclear Radiations .....	6-9
Fast Neutron Pocket Chambers .....	6-7
Measurement of Radiation by Frequency Variation of an RF Oscillator .....	7-8
Beta Particles .....	9
Energy Measurement of Beta Particles by Means of Magnetic Analyser .....	9
Particle Problems .....	9
Radiochemical Analysis .....	10
Analytical Procedure for Analysis of Urine for Radioactive Strontium .....	10
Physics of Radiation Dosimetry .....	11-12
Neutron Dosimetry .....	11
Shielding Calculations .....	11-12
X-Ray Control Equipment .....	12
Education and Training .....	13
AEC Fellowship Program .....	13
Training Program for Military Personnel .....	13
Training Program for AEC Contractors' Personnel .....	13
Lectures .....	13
Civil Defense .....	13
Miscellaneous Activities .....	13
Experimental Radiation Measurements .....	14-15
Background Instrumentation .....	14
Air Activity Studies .....	14-15

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## HEALTH PHYSICS DIVISION PROGRESS REPORT

### TABLE OF CONTENTS (continued)

	Page
Permissible Internal Dose – Radioisotopes .....	16
Previous Investigation and Calculations .....	16
University of Tennessee Research and Development Subcontract .....	16
Consultation and Special Problems .....	17
Disaster Emergency Program .....	17
Use of Commercially Available G. M. Survey Equipment with Light Aircraft to Locate Contaminated Areas .....	17
Thermal Neutron Measurements .....	17
Publications and Special Reports .....	18 - 20

## INSTRUMENT DEVELOPMENT

## CONSTANT-FLOW WATER MONITOR

The apparatus reported in ORNL-1004 has been extended in sensitivity to include the detection of alpha and soft beta radiation by using a 20-kev beta-sensitive Geiger counter having a beta window of 0.7 milligram per square centimeter, a window area of about 4.5 square inches, and a background counting rate of 12 counts per minute. The thin-wall counter is described in detail in ORNL Drawing No. D-9638. Sulfur<sup>35</sup> in solution is detected at a level of  $1.5 \times 10^{-4}$  microcuries per cubic centimeter (maximum permissible concentration of sulfur<sup>35</sup> in drinking water is  $5 \times 10^{-3}$  microcuries per cubic centimeter). A unique feature of this thin-wall counter is the resilience of the wall material. In spite of the thin and fragile pliofilm wall, it can be crushed out of shape but immediately blown back into shape.

Where the monitored water contains high-energy beta emitters (or mixed fission products), commercially available G. M. tubes having a shell mass of 30 milligrams per square centimeter are feasible. For example, a six-month-old solution of mixed fission products is detected by the RCL Mark 1 model 11 G. M. tube with an efficiency 80 per cent of that of the 20-kev thin-wall counter mentioned above.

## BATCH-WISE LIQUID MONITOR

The instrument developed for the purpose of calibrating the continuous-flow water monitor can also be used for the measurement (batch-wise samples of 80 cubic centimeters or less) of radioactive liquids. This instrument is described in ORNL Drawings Nos. D-9047, D-9048, D-9049, D-9050, C-9203, and D-9638, and comprises a motor-driven flanged cup to hold 80 cubic centimeters of a liquid sample, the 20-kev beta sensitive Geiger counter mentioned above, and lead shielding. Rotation of the flanged cup at 1800 revolutions per minute produces a cylindrical void in the liquid sample into which the beta counter is lowered. The beta counter is essentially surrounded but not touched or contaminated by the sample solution. Various radioactive isotopes are being procured for the purpose of repeating the energy-dependence calibration with greater accuracy.

The sensitivity of the instrument is sufficient to measure the normal radioactivity ( $K^{40}$ ) in human body fluid. For example, where the background counting rate was 10 counts per minute, 80-cubic-centimeter samples of urine measured a net counting rate of about 10 counts per minute.

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## RADIOACTIVE-WASTE-DISPOSAL RESEARCH

**D**URING this period, the facilities and activities for research on radioactive-waste-disposal problems have been continued without major changes. A temporary building was moved to a site east of the settling basin and equipped to provide additional work space for newly assigned personnel. A large wooden tank of approximately 35,000 gallons capacity, was moved and erected on the same site. Personnel added to the group for temporary periods or work on special projects have included one sanitary engineer research participant, two sanitary engineers for work on M. S. thesis problems, and a radiochemist assigned from the U. S. Corps of Engineers.

WATER AND LIQUID WASTE  
DECONTAMINATION PROCESSES

Detailed studies of conventional and modified water-treatment processes have been continued on a laboratory and also a small pilot-plant scale. The effect of acid (HCl) or salt (NaCl) on the adsorptive capacity of a variety of adsorbents was investigated. The acid and salt were used in pretreatment of the adsorbent materials. No appreciable effect was apparent.

Studies were begun on a series of fission products to determine the effect of turbidity (added clay slurry) and standardized coagulation in the removal of these materials from water. Experiments with cesium<sup>137</sup> were completed in which coagulation was accomplished by dosages of 1.0 grain per gallon each of calcium hydroxide and aluminum sulfate and 0.04 grain per gallon of sodium silicate. Additional studies are anticipated, including filtration through sand, Anthrafilt, soil, and various ion-exchange materials.

In preparing for future studies involving sludge digestion, the effect of recirculation upon the concentration of radioisotopes in the sludge materials was investigated. There appeared to be some beneficial effects from recirculation of the

sludge, although the rate of gas production (on the basis of volumes of gas produced per gram of volatile matter consumed) and the total volume of gas produced were less than in the control non-recirculated bottles.

Rate controllers were designed for the sand-filter columns of the small model water-purification plant, and were constructed by the Health Physics Research Shop.

Studies and tests were completed in the development of a simple column apparatus for the treatment of small quantities of drinking water containing radioactive contaminants. This apparatus was found capable of reducing the activity level of water from 2.5 to less than  $10^{-4}$  microcuries per milliliter.

Two members of the Health Physics Waste Research Group have been assigned and have spent a major portion of time in working with personnel on loan to the Laboratory who are engaged on special projects in connection with water-decontamination studies. The purpose is to obtain basic and practical data which may be of value in the treatment of water supplies for emergency purposes, including possible civil defense and military needs associated with the contamination of water supplies with radioisotopes.

SURVEY STUDIES AND ECOLOGICAL STUDY  
OF WHITE OAK CREEK DRAINAGE SYSTEM

Equipment is being assembled for an extensive statistically designed study to determine the controlled uptake of radioactivity by fish.

Routine well-logging has continued with at least two series of logs on all wells except three. As a result of the information obtained by logging, five wells were selected for more detailed study by an ion-exchange assay technique and radiochemical analysis where feasible. Subsequent probing of Well No. 41 east of burial ground No. 3 indicated

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QUARTER ENDING JULY 20, 1951

rather high activity. A sample of water from this well indicated that 57 per cent of the activity was due to ruthenium and 30 per cent due to cerium.

Arrangements are in progress for river studies to be undertaken cooperatively by ORNL and K-25. As a preliminary to planning studies, samples of water were collected from Clinch River mile 21.65 and mile 13.2 to determine minimum sample requirements. These samples indicated little evidence of stratification at the above two points. The "flounder" instrument measurements of radiation intensity from bottom muds made at the same time suggested that the velocity of water movement has resulted in the deposition of more radioactive contamination between K-25 and the Tennessee River than in the stretch of river above K-25.

Progress during the period in studies by the staff of the Ecological Study program has included the following:

1. A second determination of time of water travel under nonstratified conditions in White Oak Lake was completed. In general, both studies revealed complete dispersion in the lake. The fastest-moving water particle arrives at the dam in a time which corresponds to the displacement of approximately 15 per cent of the water volume in the lake. The passage of water through the lake is completed in a time corresponding to the displacement of slightly more than 100 per cent of the lake volume. For release of dye during a short period of time, the peak concentration reaching the dam was greatly reduced from the initial concentration, but for prolonged release there was virtually no reduction in concentration.

2. Age and growth studies were made on scale samples collected from fish during the spring population study. No variations from the growth and age distribution prevailing in nearby TVA lakes were observed. Spawning in White Oak Lake was observed during the spring, and both nesting and eggs taken from the nests appeared normal.

On May 14, 325 gravid female *Gambusia affinis*

*affinis* were introduced into the settling basin, and within a very few days young *Gambusia* were dropped. Both the adults and the new-born appear to be surviving and growing well, in spite of an average activity during the past two months of  $3.4 \times 10^{-4}$  microcuries per cubic centimeter of water in the settling basin.

3. Collection of botanical specimens for the herbarium and preparation of various plant materials for radioassay continued. Generally speaking, the bark of woody species contained more radioactivity than any other part, while the leaves of herbaceous plants showed higher activity than stems or flowers. There is some indication in rose bushes that the activity may build up to a certain level during the first growing season and remain virtually unchanged thereafter. Identification of radioisotopes by adsorption curve analysis revealed the greater part of the activity in *Salix nigra* (black willow), *Cornus* (dogwood), *Rumex* (dock), and *Juncus* (rush) to be due to strontium<sup>90</sup>-yttrium<sup>90</sup>.

4. Studies of bottom organisms in White Oak Lake indicate that the productive zone is largely limited to the 0-3-foot depth. It is assumed that, below this depth, siltation is the limiting factor. Plankton collections revealed a *Volvox* bloom reached its maximum abundance during the middle of May and subsided to negligible proportions in June. It was replaced largely by rotifers and crustaceans.

5. Routine biweekly water sampling of White Oak Lake water for physical and chemical analysis was continued.

## INSTRUMENTATION AND TECHNIQUES

Scintillation counting equipment is being built and tested for its utility in the survey of water and mud radioactivity and for biological sampling. For use in this work, electric-motor-operated equipment for grinding small crystals was completed and installed in a dry box.

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## HEALTH PHYSICS DIVISION PROGRESS REPORT

The Bakelite detector housing for the well-probing equipment developed cracks and had to be replaced with a more rugged housing. Aluminum was used for the new unit which was altered to provide easier access to the detector tube and associated parts. At the same time, a more satisfactory water seal at the electric-cable entrance was developed. Trailers have been received and work begun on assembling two new well-probing outfits.

Since plans for alterations to White Oak Dam have been deferred, work has resumed and considerable progress has been made on the installation of facilities for monitoring and telemetering at this location.

Further experimentation with techniques for photoelectric measurement of the concentration of fluorescein dye used for flow measurement indicated that such an instrument for field use could be produced, but, to cover the desired range,

would require more expensive equipment than could be justified.

The erection of the 35,000-gallon wood-stave tank (formerly a part of the ORNL water plant) which will be used for instrument calibration and evaluation was completed. Before contaminating it for calibration purposes, it is being used for several weeks by the U. S. Geological Survey for studies of submerged and distributed sources.

### TRAINING ACTIVITIES

The two sanitary engineers mentioned previously who are engaged in work on problems for a master's thesis have been assigned to this section, and a member of the group serves on the two committees appointed to supervise their projects. One of these students will conduct studies on ion exchange in the removal of radioactive contaminants from water, and the other will study the efficacy of water-softening procedures for the removal of strontium<sup>90</sup> - yttrium<sup>90</sup>.

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## THEORETICAL PHYSICS

### FAST-NEUTRON TOLERANCE CALCULATIONS

Calculations of the maximum permissible flux of normally incident neutrons of 5 mev are nearly completed.

### STOPPING POWER OF PROTONS, ALPHA PARTICLES, AND IONS OF CARBON AND OXYGEN IN TISSUE

The stopping cross-sections have been computed, using the results of Hirschfelder and Magee (*Phys. Rev.*, 73, p. 207 (1948)) and Knipp and Teller (*Phys. Rev.*, 59, p. 658 (1941)). These

values are being compared with the values obtained by means of the method of ORNL-884.

### COLLISION DENSITIES FOR THERMAL-NEUTRON IRRADIATION OF THIN FOILS

In this study, we attempt to answer rather precisely the following question: How thick may a foil of a given material be taken so that the collision density within the foil, due to irradiation by a beam of thermal neutrons, will be constant to within  $k$  per cent? Graphs giving the required thicknesses are in preparation. The similar questions for irradiation for various angular distributions of incident flux are being considered.

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## HEALTH PHYSICS DIVISION PROGRESS REPORT

### PHYSICS OF NUCLEAR RADIATIONS

#### FAST-NEUTRON POCKET CHAMBERS

As previously noted, responses of hydrogen-free (graphite and aluminum-lined) chambers to artificial fast-neutron sources were higher than would be expected from the primary gamma radiation present. An attempt was made to differentiate fast-neutron from gamma effects by the use of a series of lead and iron shields. The lead series ranged from 1/32 inch to 1.5 inches, and the iron series ranged from 1/16 inch to 2.0 inches.

Table 1 shows results of responses in minometer readings of graphite- and polyethylene-lined chambers to cobalt<sup>60</sup> gammas, polonium-beryllium neutrons and polonium-boron neutrons through some of the shields.

From these results, it is apparent that (1) while the gamma attenuation is exponential, the response to the neutron sources is not; (2) while the response of the hydrogenous chambers to

neutrons is about three times that of the non-hydrogenous chambers, the response of the latter is still appreciable; and (3) while the percentage drop in response to a neutron source, because of shielding, is less for the hydrogenous chambers than for the graphite, the actual drop is very similar in the two cases.

These results indicated the possibility that (1) recoil carbon atoms were being measured in each case, there being a conducting coat of Aquadag on the polyethylene liners; or (2) there is a recoil or nuclear reaction in the gas itself - in this case, air.

If recoil carbon atoms were involved, they would have an extremely high specific ionization but a short path, in which case the leakage due to such ionization current would remain relatively constant if the gas pressure were lowered until the paths of such recoil atoms would just cross the chamber radius. A sealed graphite-lined chamber was

TABLE 1

Shield (inches)	Chamber Lining	100-Milliroentgen Cobalt <sup>60</sup> Gammas	10 <sup>7</sup> Polonium-Beryllium Neutrons	10 <sup>7</sup> Polonium-Boron Neutrons
None	Graphite	290	30	17.5
None	Polyethylene	275	85	58
0.5 Pb	Graphite	108	21	12
0.5 Pb	Polyethylene	100	75	53
1.5 Pb	Graphite	26	16	10
1.5 Pb	Polyethylene	24	66	51
0.5 Fe	Graphite	144	27.5	16.5
0.5 Fe	Polyethylene	130	76	55
2.0 Fe	Graphite	51	19.8	11.5
2.0 Fe	Polyethylene	46	60	43

fabricated. This was attached by a tube to a plenum chamber which could be evacuated, and to which was also connected a mercury manometer to measure the air pressure. Exposure to both polonium-beryllium and polonium-boron neutron sources at various pressures failed to establish the presence of this carbon recoil effect.

The same plenum chamber will be used to test the gas effect. Other gases at measured pressures will be introduced into the system. By this means, it is hoped that the reactions involved can be identified.

### MEASUREMENT OF RADIATION BY FREQUENCY VARIATION OF AN RF OSCILLATOR

Experimental investigations were initiated to measure nuclear radiation by observing the frequency variation of an RF oscillator in conjunction with an electrometer whose capacitance varies as a function of applied charge.

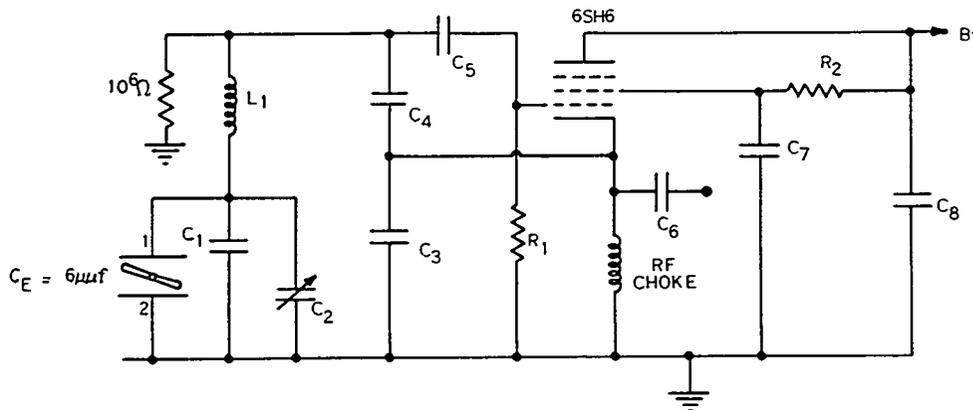
Charge leakage equivalent to irradiation of 5 milliroentgens per hour produced a frequency change of 1 to 2 cycles per second. The sensitivity of this method of radiation measurement can

be increased manifold by a proper design of the variable capacity electrometer.

A capacitive inductance controlled oscillator, as shown in Figure 1, will vary its frequency if the capacitance varies according to the expression,

$$\Delta f = \frac{\Delta C}{2C} f,$$

where  $f$  = frequency and  $C$  = the effective capacitance. A variable capacitance  $C_E$  (in Figure 1) is provided by an electrometer, as seen in detail from Figure 2. If the two electrode pairs are grounded electrostatically, a charged copper leaf can rotate between the two pairs of plates from a 45-degree rest position (lower detail) against the torsion of a steel wire or quartz fiber, moving into the space between the plates. The position of the leaf determines the capacitance between the electrode pairs 1 and 2 of the meter. The maximum capacitance will be reached when the leaf is lined up with the two electrodes. The two electrode pairs are electrostatically grounded, representing one electrode, but they remain two separate electrodes in the RF circuit, and since they are coupled by the movable leaf, they are providing the variable capacitance.



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- $C_E$  = ELECTROMETER
- $C_1$  =  $33\mu\mu f$
- $C_2$  =  $1.5-7\mu\mu f$
- $C_3 = C_4 = 1000\mu\mu f$
- $C_5 \sim 1000\mu\mu f$
- $C_6 = 5\mu\mu f$
- $C_7 = C_8 = 0.1\mu f$
- $L_1 = 110\mu h$
- $R_1 = 100K$
- $R_2 = 12K$

Fig. 1 - R-F OSCILLATOR AND ELECTROMETER

Figure 2 gives also the equivalent electrostatic and RF circuits. The amount of the electrical charge determines the leaf position and thus the frequency of the oscillator. The  $\Delta C$  due to the leaf position varies up to about 0.5 micro-microfarad. Since the frequency-determining capacitance  $C$  (see Figure 1) was about 40 micro-microfarads and the operating frequency 2.2 megacycles, the frequency change for  $\Delta C = 0.1$  micro-microfarad is about 2750 cycles. In order to stabilize the circuit, the equipment was used in an air-conditioned room. The high capacitances  $C_2, C_3$  kept the influence of capacitance variations inside of the oscillator tube to a minimum. The frequency was measured by feeding the oscillator frequency into an amplifier and beating against a crystal-controlled oscillator. The beat frequency was measured with an interpolation oscillator by means

of an oscilloscope. It was found that the frequency remained constant within a very few cycles over 1 hour and more.

When the leaf was charged, it took some time before the oscillatory movement of the leaf came to rest. A deflection of several thousand cycles (up to 7000) could be observed depending on the applied voltage, varying from 45 - 150 volts. Instead of applying the charge from a battery, a charged ionization chamber can be connected to the electrometer. Radiation applied to the meter of about 5 milliroentgens per hour produced a frequency change of 1 to 2 cycles per second.

The wire used for the suspension of the electrometer leaf shows some defects by not returning always to the same position when recharged, but

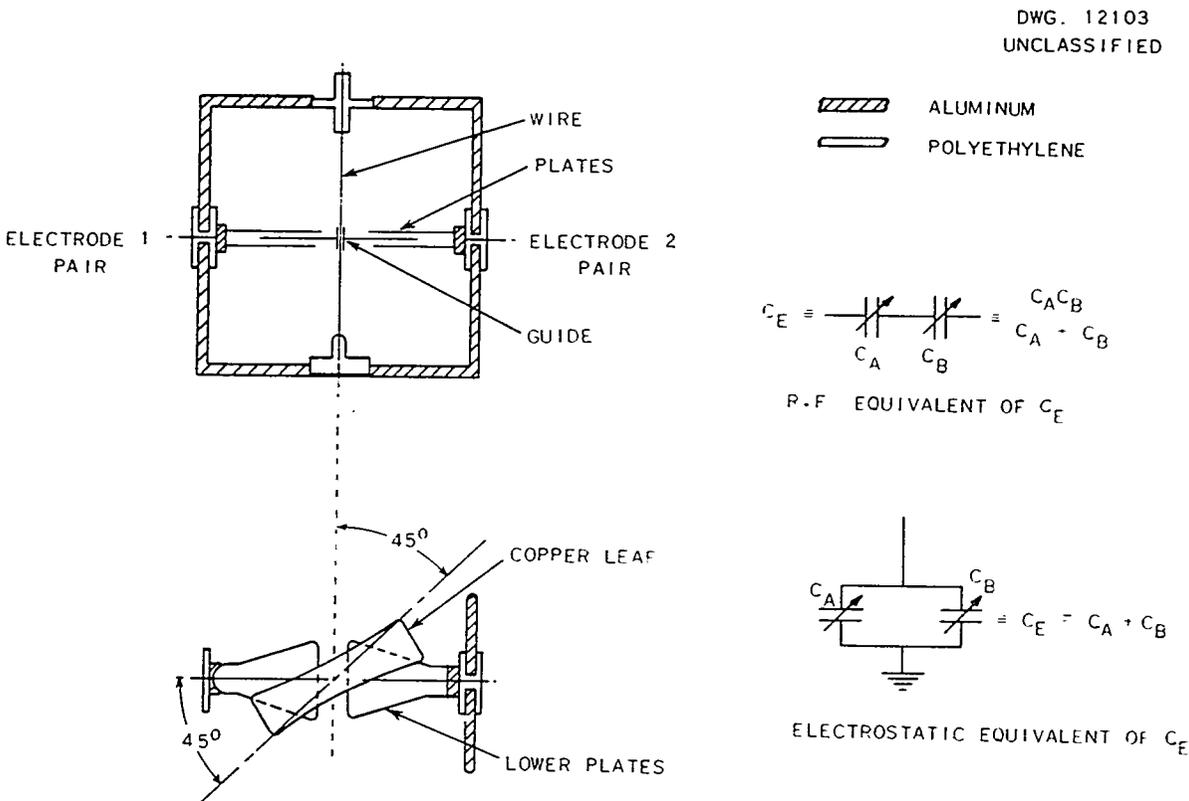


Fig. 2 - ELECTROMETER WITH VARIABLE CAPACITANCE

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the zero position is usually kept within some few cycles. It is believed that this defect can be eliminated by improving the method of suspension, and it is intended to use magnetic damping to reduce the wire-leaf oscillations. The present investigations will probably lead to considerable variations of the experimental setup.

## BETA PARTICLES

Absorption of a collimated beam of beta particles was measured with a thin-window counter down to 0.1 per cent of their initial intensity and a number of graphs recorded, using absorbers of different atomic number.

An anthracene scintillation counter has been assembled in which a gate circuit permits separation of different velocity ranges.

A cable with teflon insulation is being investigated with the purpose of connecting a thimble chamber directly to the electrometer. Measurements indicate that flexing of the cable does not introduce variations over an extended period of time in the electrometer current as is the case with other cables tested.

## ENERGY MEASUREMENT OF BETA PARTICLES BY MEANS OF A MAGNETIC ANALYSER

Experiments have been continued on the absorption of the 626-kev conversion electrons from barium<sup>132</sup>. The energy spectra have been obtained after passing through aluminum foils varying in thickness from 5.34 to 33.5 milligrams per square centimeter.

The most probable and average energy losses appear to vary linearly with the foil thickness.

The experiments are now being continued with beryllium foils for the same range of thicknesses.

## PARTICLE PROBLEMS

The completion of the radioactive particulate laboratory is expected in the near future. Particulate material data obtained from Project "F" will be presented in an ORNL report.

Investigation of isotope production showed again the need of a low-level-activity analytical laboratory for evaluation of airborne material. Percentage of gross beta found on the leached filters taken from constant air monitors operated near the gate to the restricted area were as follows:

	5-15-51 filter (per cent)	5-18-51 filter (per cent)
Barium	1.5	10
Total rare earth	115.0	28
Strontium	30.0	4 - 14
Ruthenium	10.0	0.5

Analysis of meteorological, operational equipment, and monitoring data indicated that run No. 44 was a major cause of high air activity. The early air activity appears to come from processing of the metal waste, and is not all gaseous, but is composed of both gaseous and small particulates, whereas the latter high air activity is mainly particulate in nature and represents material processed during the latter stages of the operation. Radioautographs of filters taken from constant air monitors used during this period indicated higher specific activities in the latter particles than those observed during the earlier part of the run.

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## HEALTH PHYSICS DIVISION PROGRESS REPORT

### RADIOCHEMICAL ANALYSIS

#### ANALYTICAL PROCEDURE FOR ANALYSIS OF URINE FOR RADIOACTIVE STRONTIUM

A survey of analyses of urine for fission products conducted at the Laboratory during the last two years reveals that, where measurable amounts of activity have been found, it has been due in most cases to the radioisotopes of strontium.

Since the present analytical procedure (described in AECD-2692) being used is designed to isolate a number of elements including barium, strontium, yttrium, lanthanum, and other rare earths, and is

lengthy and time-consuming, it appears expedient to develop a procedure specifically for strontium.

Attempts at separating strontium from calcium on cation exchange resins have been most promising. Using Dowex 50 resin, it has been found possible to separate calcium from strontium with 0.1 molar ammonium citrate at a pH 5.5. The calcium is displaced from the resin more readily than the strontium. The peaks of elution of calcium and strontium are sufficiently apart to provide a separation of these two elements. Final details of the procedure are yet to be worked out.

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## PHYSICS OF RADIATION DOSIMETRY

## NEUTRON DOSIMETRY

## Thermal-Neutron Survey Meter

The first model of a thermal-neutron survey meter has been completed and turned over to the Survey Section for field tests. The detector is a boron trifluoride proportional counter, having a sensitivity of 1 count per 150 thermal neutrons per square centimeter. Thus, a flux ranging from less than 100 to more than 20,000 neutrons per square centimeter per second can be measured rapidly and conveniently with a simple thyratron-powered rate meter. The volume of the counter is known, since hypodermic needles are used on the ends of the center wire to limit the region of gas amplification. Using the known volume and the thermal-neutron cross-section for boron, the count rate from an unknown field of thermal neutrons may be interpreted in terms of flux. This measure of the flux agrees to within 5 per cent of the value determined by the indium-foil method. The instrument is insensitive to radiations other than thermal neutrons.

## Fast-Neutron Dosimetry

The work on the proportional-counter method of measuring fast-neutron tissue dosages, CF-51-4-122, has progressed in two respects. A special counter of this type was constructed containing on the inside a collimated alpha particle source which could be moved parallel to the axis of the counter. With this, a measurement of the sensitive volume of the counter and the way in which the gas amplification varied through this volume was made. The data were used to design a similar counter containing a fixed alpha particle source which could be exposed when needed for absolute energy measurements of the dose received from fast neutrons.

A new method of integrating the amount of energy represented by the recoil protons produced in the counter by fast neutrons has been developed with

the cooperation of members of the Instrument Department. The method consists of feeding the output of a bank of discriminator tubes, biased to conduct at a series of carefully chosen voltages, into various stages of two binary-type scalars. The total reading of the two scalars is proportional to the dose, or total energy dissipated in the counter by the neutrons. The circuit, to be reported in detail later, has proved in preliminary tests to be very reliable and simple to operate.

An approximate calculation has been made of the wall losses in the count-rate fast neutron dosimeter (ORNL-930). The loss in net counting rate due to recoil protons which struck the walls before losing enough energy in the gas to be counted above the bias was determined. The result was that neutrons of 10 mev would produce a count rate not more than 10 per cent smaller than that previously calculated for this energy without considering wall losses and reported in ORNL-930.

## SHIELDING CALCULATIONS

A preliminary value of 49.9 centimeters for the diffusion length of thermal neutrons in graphite has been computed from experimental data taken in the sigma pile. The single- and double-source data give results which agree to 1/4 of 1 per cent. A detailed report will be issued at a later date.

An approximate calculation has been made and reported to the Shielding Group of the energy dependence of a Hofstadter-type scintillation gamma spectrometer and a triple-coincidence scintillation gamma pair spectrometer (NEPA 1638). Also, the effect of wall losses upon energy resolution was found to be small.

The results reported in CF-51-4-103 on the correction of indium foil activations made in water have been found experimentally to be nearly independent of foil spacing. Thus, the correction factor given is a function of the foil thickness only, to a good approximation.

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## HEALTH PHYSICS DIVISION PROGRESS REPORT

Calculations of the air scattering of neutrons using the exact solution in the one-velocity approximation (MT-4) have been carried out. The results are as follows:

$r$	$4\pi\lambda^2 r N(r)$
0.0	2.48
0.3	2.74
0.6	2.85
0.9	2.90
1.2	2.94
$\infty$	3.00

where  $r$  is the distance in units of mean free path ( $\lambda$ ) from an isotropic point source of unit strength, and  $N(r)$  is the density of the neutrons which have experienced at least one collision. It is interesting to note that, if a first collision density is calculated, assuming no exponential attenuation in air, the result is

$$4\pi\lambda^2 r N = \frac{\pi^2}{4},$$

which coincides exactly with the above  $r = 0$ .

### X-RAY CONTROL EQUIPMENT

In order to produce the small dose rates of interest in Health Physics, the controls of the 250-kilovolt constant-potential X-ray machine have

been considerably supplemented. After extensive experimentation, an amplifier was designed with the assistance of the Experimental Radiation Measurements Section of this division. This consists of a Brown vibrator and transformer, a three-stage feedback AC amplifier driving a cathode follower, and a half-wave voltage doubler. The purpose is to take an input of 5 microamperes from the X-ray tube target and build it up to 0.5 milliamperes at 70 volts to run the stabilizer in the X-ray machine. The peculiar demands of the X-ray controls precluded the use of any conventional amplifier. Additional controls were built incorporating this amplifier and various safety features to prevent damage to the X-ray tube in case of failure or improper setting of the controls. It is now possible to produce stabilized currents from 5 microamperes to 20 milliamperes in the X-ray tube, giving dose rates from as little as 3 milliroentgens per hour at 30 kilovolts up to the full rating of the machine, several hundred roentgens per minute at 250 kilovolts. The beam can be confined to a cone as small as 0.16 degree, or opened up to the full aperture of the machine, 12.5 degrees each side of the axis of the beam.

An extensive dose-rate calibration is in progress so that in the future the proper voltage, current, and filtration can be set immediately for any desired dose rate and energy within the capacities of the machine. The calibration is being made both against a Victoreen roentgen meter and against an air-wall chamber of the type developed at the National Bureau of Standards.

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## EDUCATION AND TRAINING

## AEC FELLOWSHIP PROGRAM

The present group of twenty AEC fellows in Radiological Physics, having completed their academic work at Vanderbilt University June 6, transferred to the Oak Ridge National Laboratory June 11, where they are now doing their twelve weeks of field training.

TRAINING PROGRAM FOR  
MILITARY PERSONNEL

Six medical officers from Duke University completed their eight-week training course on May 25.

On June 9, nine military officers from the University of California and twelve from Ohio State University, two from the Army Chemical Center, Maryland, and one from West Point were assigned to this section for six weeks of training in health physics. Their training includes both lectures and field work.

TRAINING PROGRAM FOR  
AEC CONTRACTORS' PERSONNEL

On July 9 and 10, staff members of this section gave four lectures, totaling 5 1/2 hours, for duPont and the American Cyanamid Company.

This section has had the responsibility for the

on-the-job training program for two senior health physicists of the Phillips Petroleum Company.

Three Health Physics surveyors from duPont and four from the American Cyanamid Company have been with this section since June for on-the-job training, and beginning July 16, this section has been giving special classroom work for the group, since it was felt necessary to supplement the on-the-job training.

A representative from the Health Physics Division of the Dow Chemical Company was with this section for approximately two weeks in June.

## LECTURES

Two series of lectures have been conducted for ORINS, as well as lectures at King's College, Bristol, Tennessee; University of West Virginia; and Georgia Institute of Technology.

## CIVIL DEFENSE

At the present time, we are engaged in revising the manual on *Radiological Protection* for the AEC.

## MISCELLANEOUS ACTIVITIES

Members of the staff continue to assist in other teaching activities in the Laboratory, particularly in the Apprentice Training School and in the Reactor School.

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## EXPERIMENTAL RADIATION MEASUREMENTS

## BACKGROUND INSTRUMENTATION

In cooperation with the U. S. Geological Survey, a test probe for measuring slow neutrons in drill holes is being built. The counter is of the enriched boron trifluoride type. The slow-neutron density should be higher near uranium ore, due to spontaneous fission, and should also be specific for uranium. Tests will be made at Grand Junction, Colorado on a simulated test hole made up of layers of concrete and uranium ore. While the expected count will not be high enough to serve as an efficient ore-detecting device, it may serve as a check instrument on holes which have been logged with a gamma-ray probe and give further information as to whether or not the radium and uranium are in equilibrium.

A sodium iodide scintillation probe is also being constructed for test purposes on the simulated drill hole to test the feasibility of this type of probe. The possible advantages of the scintillation probe are greater sensitivity and the possibility of gaining further information from energy distribution curves. Knowledge of the energy distributions may make it possible to differentiate between a near small source and a distant large source.

Development of equipment used in the U. S. Geological Survey plane for radiation measurements is still in progress. The light piping from the 4-inch-diameter, 2-inch-thick sodium iodide crystal to the 5819 photomultiplier tube has been improved by making the Lucite light piper as short as possible. The next step in improvement is to mount the crystal directly onto the phototube.

An improved recording rate meter has been utilized which has no memory effect, obviates the use of scalers, and has a resolving time of the

order of 2 microseconds. The device simply uses a small condenser, which is discharged by each count and then recharged from a large (1 microfarad) condenser. The voltage on the large condenser is then measured at the end of a counting interval with a recording electronic voltmeter circuit and recharged. Two large condensers are used alternately so that the voltage on one condenser is being recorded while the other is being discharged by the count. At the end of the counting interval, a switch reverses the connections so the condenser whose voltage was being recorded is charged and becomes the one to be discharged, and vice versa. The time interval of the switch is controlled by a Bodine motor with a relay, so that the time interval used is 1 second. Ceramic wafer switches mounted on a rotary solenoid did not stand up under continuous use. A new type switch is being constructed which, it is hoped, will remove this difficulty.

Work on radiation-absorption measurements is under way to find the perturbations introduced into White's results (*Phys. Rev.* 80, 154 (1950)) by the presence of cylindrical air cavities of various diameters surrounding the detector.

## AIR ACTIVITY STUDIES

Air activity studies were made at Gainesville, Florida and Corryton, Tennessee from April 13 to May 24, to detect any activity resulting from the recent Eniwetok tests. Twenty-four-hour air-filter samples were taken and counted twice at intervals of 4 and 24 hours after removal. After counting, each filter paper was radioautographed. Rainwater was also filtered and the filter papers processed the same way as air filters. Toward the end of the period, water used to rinse a plate collecting fall-out of particles was treated and studied for radioactivity. The highest long-life activity collected at Gainesville was of the same order of magnitude as the activity due to thorium B and thorium C content in air. At Corryton the highest



PERMISSIBLE INTERNAL DOSE - RADIOISOTOPES

PREVIOUS INVESTIGATION  
AND CALCULATIONS

Preliminary calculations of maximum permissible concentration (MPC) of radioactive isotopes in air, food, and water have been made on ten alpha emitters and twenty-eight beta-gamma emitters, using whatever data were available in the literature.

A thorough literature search revealed, however, that very little data had been developed regarding "critical body organs," normal concentration of various chemical elements in critical organs, the fraction of chemical elements inhaled, ingested, or absorbed through the skin that reaches the critical organ, and the biological half-life of the elements in the critical organs. These data, along with already available information regarding the energy and physical half-lives of the radioisotopes in

question, are necessary in making calculations regarding maximum permissible concentrations.

Efforts have been directed toward obtaining these data by (1) publicizing the need for answers to specific questions among other Atomic Energy Commission laboratories and (2) ORNL sponsorship of research along these lines.

UNIVERSITY OF TENNESSEE RESEARCH  
AND DEVELOPMENT SUBCONTRACT

A research and development subcontract has been formalized with the University of Tennessee for the university to determine spectrographically the concentration of trace elements in human tissues and organs. Treatment of other subjects pertinent to this program is planned for the near future.

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## CONSULTATION AND SPECIAL PROBLEMS

### DISASTER EMERGENCY PROGRAM

Planning was completed on a program to cope with off-plant emergencies involving nuclear radiation. Personnel have been selected, and equipment and survey instruments have been placed at the Turnpike and Kerr Hollow Portals of the restricted area. Following a request from the AEC, personnel and equipment could be dispatched to the scene of an emergency with a minimum time delay. This program is coordinated with the interplant emergency program.

### USE OF COMMERCIALY AVAILABLE GEIGER-MULLER SURVEY EQUIPMENT WITH LIGHT AIRCRAFT TO LOCATE CONTAMINATED AREAS

Exploratory flight tests were made over a 6-curie cobalt<sup>60</sup> source and isodosage curves constructed which indicated that a light aircraft flying

at low ground speed and at an elevation of 500 to 1000 feet could be used with commercially available Geiger-Muller survey equipment to locate such point sources. Calculations indicated that such flights could be made to locate, at 500 feet elevation, areas where a relatively uniform surface contamination results in a tolerance dose rate near the surface of the earth (300 milliroentgens per week at about 3 feet above the surface). Significant surface contamination associated with radiological warfare could be located at a much greater elevation.

### THERMAL NEUTRON MEASUREMENTS

Discrepancies in the response of boron-coated pocket chambers exposed to thermal-neutron fluxes at ORNL and at the National Bureau of Standards were investigated. A thorough check of the flux-evaluation method used at ORNL disclosed no apparent significant errors.

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## HEALTH PHYSICS DIVISION PROGRESS REPORT

### PUBLICATIONS AND SPECIAL REPORTS

#### PUBLICATIONS

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2. R. D. Birkhoff, "Distribution of Energy Loss of Electrons in Aluminum," *Phys. Rev.*, 82, 3, 448 (May 1, 1951).
3. J. Turkevich and H. H. Hubbell, "Low-Angle X-Ray Diffraction of Colloidal Gold and Carbon Black," *J. of Am. Chem. Soc.*, 73, 1 (January 1951). (Work done earlier at Princeton University. H. H. Hubbell now at ORNL.)
4. B. J. Spinrad, G. H. Goertzel, and W. S. Snyder, "An Alignment of Monte Carlo Solution of the Transport Problem," *Math Series* 12, Bureau of Standards (June 11, 1951).
5. O. R. Placak, "The Radioactivity Problems in Water Supplies," *Proceedings of the Inservice Training Course in Water Works Problems*, School of Public Health, University of Michigan (May 1951).
6. K. Z. Morgan, "Quantitative Limits of Permissible Exposure of Personnel (Internal and External)," *Manual of Lectures*, Inservice Training Course in Radiological Health, University of Michigan, School of Public Health (February 5-8, 1951).\*
7. K. Z. Morgan, "Historical Sketch of Radiation Protection Experience and Increasing Scope of Radiation Protection Problems," *Manual of Lectures*, Inservice Training Course in Radiological Health, University of Michigan, School of Public Health (February 5-8, 1951).\*
8. G. S. Hurst, "A Proportional Counter Method of Measurement of Fast-Neutron Dose," C. F. 51-4-122 (April 27, 1951).
9. E. O. Klema and R. H. Ritchie, "Preliminary Results on the Determination of Thermal Neutron Flux in Water," C. F. 51-4-103 (April 24, 1951).
10. F. P. Cowan and R. A. Love, Brookhaven National Laboratory, and L. B. Farabee, ORNL, "Health Physics and Medical Aspects of a Strontium<sup>90</sup> Inhalation Incident," AECU-1169.
11. V. I. Knobf, "Studies of Radioactivity in Fish from White Oak Lake and the Clinch River," ORNL-1031 (July 9, 1951).
12. C. P. Straub and P. N. Hensley, "Experimental Jar Test Laboratory Stirring Device," ORNL-965 (May 1951).
13. E. E. Anderson, "Units of Radiation and Radioactivity," *Manual of Lectures*, Inservice Training Course in Radiological Health, University of Michigan, School of Public Health (February 5-8, 1951).\*

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\**Manual of Lectures*, Inservice Training Course in Radiological Health, published May 1951.

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14. E. E. Anderson, "Basic Principles of Radiation Protection," *Manual of Lectures*, Inservice Training Course in Radiological Health, University of Michigan, School of Public Health (February 5-8, 1951).\*

## SPECIAL REPORTS

1. C. P. Straub, "Radioactive Materials and Their Effects on Environmental Health," presented at Annual Meeting of Georgia Public Health Association, May 17, 1951.
2. O. R. Placak, "Disposal of C<sup>14</sup> in Garbage," preliminary report to the Subcommittee on Waste Disposal and Decontamination.
3. K. Z. Morgan, "Maximum Permissible Concentrations of Radioisotopes in the Air, Water, and in the Human Body," preliminary report to the Subcommittee on Internal Dose (May 16, 1951).
4. Conrad P. Straub, "Experimental Water Treatment Plant. IV-Removal of Iodine (I<sup>131</sup>)," (April 30, 1951).
5. C. P. Straub, T. W. Brockett, and Robert Stepp, "Experimental Water Treatment Plant. V-Removal of Fission Products" (May 1, 1951).
6. C. P. Straub, "Water Decontamination. II-Studies on W-6 Tank Wastes" (May 2, 1951).
7. C. P. Straub, T. W. Brockett, and Robert Stepp, "Water Decontamination. III-Studies on Ce<sup>144</sup>, Y<sup>91</sup>, and I<sup>131</sup>" (May 3, 1951).
8. C. P. Straub, and D. Pecsok, "Water Decontamination. IV-Mixed Fission Products, Factorial Experiment" (May 29, 1951).
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10. C. P. Straub, D. Pecsok, and T. W. Brockett, "Laboratory Studies with Adsorbents. II-Bentonitic Montmorillonite Clay. Variable Radioactivity and Adsorbent Concentrations. W-6 Tank Wastes" (June 2, 1951).
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13. R. J. Morton, "Problems of Control and Disposal of Radioactive Waste Materials," Public Health Engineering Conference, College of Engineering, University of Florida (March 29, 1951).

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\**Manual of Lectures*, Inservice Training Course in Radiological Health, published May 1951.

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15. T. H. J. Burnett, "Shielding Estimate - LITR Irradiation 'Bomb' " (February 20, 1951).
16. T. H. J. Burnett, "Comparative Dosage Study: Ra vs. MsTh." (The above reports are recorded here because they were not previously reported.)
17. M. A. Churchill, "Investigations of Water Movement in White Oak Creek and Lake," TVA Hydraulic Data Branch (June 22, 1951).
18. D. M. Davis and J. C. Hart, "Aerial Surveying with Light Aircraft for Radioactive Contamination on the Ground" (June 30, 1951).
19. E. J. Kuna, "A Radioautographic Study of X-10 Area - December 3, 1950 through January 5, 1951" (June 13, 1951).

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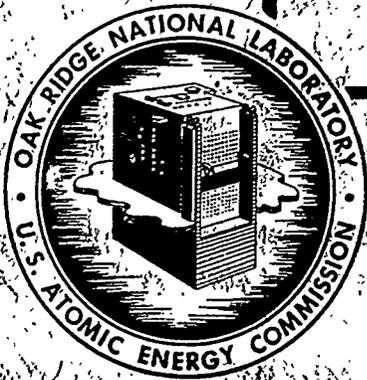
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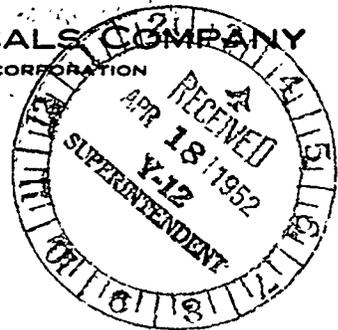
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K. Z. Morgan, Director

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## TABLE OF CONTENTS

	PAGE
RADIOACTIVE WASTE DISPOSAL RESEARCH	1
Water and Liquid-Waste Decontamination Processes	1
Survey Studies and Ecological Study of White Oak Creek Drainage System	3
Instrumentation and Techniques	5
THEORETICAL PHYSICS	6
Fast-neutron Tolerance Calculations	6
Stopping Power of Protons, Alpha Particles, and Ions of Carbon and Oxygen in Tissue	6
PHYSICS OF NUCLEAR RADIATION	7
Fast-neutron Pocket-meter Investigation	7
Straggling of Conversion Electrons from Barium <sup>137</sup> as Measured with the Solenoidal Spectrometer	8
Measurement of Radiation by Frequency Variation of an R-F Oscillator	8
Range Measurements of Beta Particles	9
RADIOCHEMICAL ANALYSIS	12
Analysis for Plutonium on Air Filters	12
PHYSICS OF RADIATION DOSIMETRY	13
Calibration of X-ray Machine	13
Fast-neutron Dosimeter	13
Distribution of Flux in X-10 Graphite Pile	13
Thermal-neutron Survey Instrument	13
Proportional-counter Development	13
Pulse-height Integrator	13
Physical Calculations	13
EDUCATION AND TRAINING	14
AEC Fellowship Program	14
Training Program for Military Personnel	14
Training Program for AEC Contractor Personnel	14
Miscellaneous Activities	14
EXPERIMENTAL RADIATION MEASUREMENTS	15
Airplane Measurements	15
Radon Measurements	15
Drill-hole Measurements	16

	PAGE
PERMISSIBLE INTERNAL DOSE - RADIOISOTOPES	17
Radioisotopes - Maximum Permissible Concentrations	17
University of Tennessee Research and Development Subcontract	17
CONSULTATION AND SPECIAL PROBLEMS	18
Open-air Measurements of a 300-curie Cobalt Source	18
PUBLICATIONS AND SPECIAL REPORTS	19

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## RADIOACTIVE WASTE DISPOSAL RESEARCH

R. J. Morton

The construction and installation of major equipment of the Health Physics Waste Research Building has been practically completed during this period, and this facility is to be occupied early in November 1951. According to present plans this new building will be used primarily to house laboratory and pilot-plant studies on water and liquid-waste decontamination processes and also for the location of other study projects that require relatively large space and apparatus or use of the controlled temperature rooms that are provided.

The cooperative program of research on radioactive waste problems by the U. S. Public Health Service and the Laboratory has been reorganized, as previously planned, to include increased participation by the Public Health Service. The Technical Advisory Board for Research on Radioactive Water Decontamination met in Washington, D.C., September 28, 1951, for further review and to make recommendations regarding this joint program.

Personnel changes have included the assignment of one additional sanitary engineer from the Public Health Service, assignment of a limnologist and two scientific aides by the Tennessee Valley Authority to complete the research staff of the Ecological Study of White Oak Creek, and completion of the assignment and stay at the Laboratory of the sanitary engineering research participant from North Carolina State College.

## WATER AND LIQUID-WASTE DECONTAMINATION PROCESSES

T. W. Brockett	W. J. Lacy
A. G. Friend	D. A. Pecsok
W. A. Hoyt	O. R. Placak
C. P. Straub	

Laboratory studies were made of the removals of tracer quantities of  $Ce^{137}$  and of  $Cd^{115}$  from water by using conventional water treatment processes. Adsorption of cesium on suspended clay particles resulted in substantial removals, whereas coagulation and sand filtration effected no further removals. Both adsorption by clay particles and coagulation were somewhat effective in removing cadmium, resulting in gross removals up to about 90%. Water-softening procedures gave essentially no removal of cesium, whereas cadmium was removed up to about 99% by excess lime-soda treatment. Both isotopes exhibited practically complete removal by filtration through columns containing either cationic exchange resins or granular burnt clay.

The removal of  $I^{131}$  from water by various procedures that have been adopted for fluoride removal in water supplies was attempted. Coprecipitation of iodide with excess lime-soda treatment and with magnesium oxide treatment proved ineffective. Filtration through bone-charcoal beds showed some removal and apparently the iodate ion rather than the iodide ion was preferentially removed. Further

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

studies with filter-column beds of Defluorite (a proprietary bone-char compound) are planned.

Aeration experiments using activated sewage sludge showed similar removals for cesium, cadmium, and iodine. Removals of from 60 to 80% were obtained following various periods of aeration, although the addition of carrier iodine to the  $I^{131}$  solution markedly lowered the removal.

The study of the removal of various radioisotopes from Oak Ridge tap water, by means of 14-mm columns containing a depth of 24 in. of ion-exchange resins, is the thesis research project of a graduate student (A. G. Friend, Virginia Polytechnic Institute). Tests conducted on the removal of carrier-free  $I^{131}$  in concentrations of  $1.5 \times 10^{-2} \mu\text{c}/\text{cc}$  indicate that removals of about 99.4% can be expected with the use of a strongly basic anion-exchange resin operating on the hydroxyl cycle at a flow rate of 2.5 gal/min/ft<sup>3</sup> of resin. The pH of the effluent in these tests was approximately 11.0. By mixing an equivalent amount of a strongly acid cation-exchange resin on the hydrogen cycle with the anion resin, the removal was increased to 99.9% and the pH of the effluent was lowered to 7.2.

**Lime-Soda Softening Process.** A study of the lime-soda softening process in the removal of  $\text{Sr}^{90}$  from water is the thesis project of another graduate student (W. T. Hoyt, N.C. State College). Removal of up to 99.7% of the activity of  $\text{Sr}^{90} + \text{Y}^{90}$  added to water has been obtained by the use of the excess lime-soda softening process in jar tests. The required lime-soda doses (no excess lime) effected removals of about 75% of the activity (all of that due to yttrium), with partial removal of the strontium activity. The effectiveness of removal of yttrium was indicated

by the fact that after the lime-soda treatment the activity in the water increased as one would expect from the buildup of yttrium, and in about 10 days the activity had approximately doubled due to the growth of the yttrium. The excess-lime treatment consisted of the addition of lime as  $\text{CaCO}_3$  with the required amount of soda ash to precipitate the calcium as the carbonate. The results for various excess doses were as follows:

EXCESS LIME (ppm)	ACTIVITY REMOVAL (%)
0	75.0
20	77.0
50	80.1
100	85.3
150	97.3
200	99.4
300	99.7

Adding strontium nitrate,  $\text{Sr}(\text{NO}_3)_2$ , as a carrier in the following amounts and enough soda ash to precipitate it as the carbonate gave removals of the  $\text{Sr}^{90} + \text{Y}^{90}$  up to about 90%:

$\text{Sr}(\text{NO}_3)_2$ CARRIER (ppm)	ACTIVITY REMOVAL (%)
50	77.0
100	79.8
150	89.5

Studies of the effect of pH and mixing time on activity removal showed small increases in the removal of  $\text{Sr}^{90} + \text{Y}^{90}$  with the increase of mixing up to 30 min and of pH up to 12.0, as shown below:

MIXING TIME (min)	ACTIVITY REMOVAL (%)
10	71.0
20	75.0
30	76.2
40	75.2
60	75.6

pH	ACTIVITY REMOVAL (%)
10.5	77.5
11.0	80.5
11.5	81.4
12.0	83.5

The addition of coagulant as an aid in the treatment process proved to have little effect on  $Sr^{90} + Y^{90}$  activity removal. For the required lime-soda doses alum, sodium aluminate, and ferric chloride increased removals only about 1%. Trisodium phosphate and sodium silicate showed increased removals of about 3%. For excess lime-soda doses the silicate treatment had less than 1% effect on activity removal, but it greatly improved the settleability of the fine floc that forms at high excess doses.

Throughout this period, active work has continued on the special project concerned with the evaluation of the equipment and processes for the emergency treatment of water supplies.

**SURVEY STUDIES AND ECOLOGICAL STUDY OF WHITE OAK CREEK DRAINAGE SYSTEM**

- |                  |                  |
|------------------|------------------|
| M. J. Cook       | L. A. Krumholtz  |
| J. M. Garner     | R. A. Lauderdale |
| V. I. Knobf      | W. T. Miller     |
| O. W. Kochtitzky | F. R. Nease      |
| O. R. Placak     |                  |

Controlled fish experiments in the laboratory were begun for the purpose of verifying and explaining the data obtained in the ecological study of White Oak Lake. A factorial experiment, designed to evaluate the significance of numerous factors simultaneously, was planned and outlined by a member of the ORNL Mathematics Panel. The plan of the experiment is to vary four factors (water spiking, food, food spiking, and time of removal) at three temperature levels as fish are

exposed in water spiked at three different levels with radioisotopes and distributed in fruit jars. In the first of these exposures *Gambusia affinis affinis* weighing 0.3 to 1 g, was used.  $Ce^{137}$  was used as the test radioactive material, because this isotope has been determined to be of importance in the studies of fish under natural conditions in the White Oak Lake system.

A survey was made of the intensity of radiation from bottom deposits in the river and lakes below White Oak Creek by means of a "flounder," a water- and sediment-scanning instrument. The survey extended for a distance of approximately 200 miles downstream from White Oak Lake in the Clinch and Tennessee Rivers. In the near future, additional background data will be obtained to aid in the interpretation of the survey results. A preliminary review indicates slight elevations above background radioactivity in the bottom sediments throughout the 200 miles, except where water velocities have scoured the bottom clean.

A rotating cup-type liquid counter<sup>(1)</sup> for measuring the level of radioactivity in river samples was obtained from the Health Physics Instrument Development Section. The sensitivity of this instrument ( $10^{-6} \mu c/cc$  of beta activity) is expected to permit measurements at a level of  $10^{-7} \mu c/cc$  in water when the samples are concentrated by evaporation to one-tenth of the initial volume. It is planned to run samples concurrently by several assay techniques in order to determine the least time-consuming procedure that is satisfactory. The purpose is to facilitate the procurement of more numerous and more accurate data from water sampling surveys. Because of fluctuations in the background of the

(1) Health Physics Division Quarterly Report for Period Ending July 20, 1951, ORNL-1086.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

counter in its present location, considerable difficulty has been experienced at the extremely low levels being counted.

Routine logging of the 51 test wells is to be resumed after the two additional probe and cable reel assemblies have been completed. Through the use of an ion-exchange column detector (description to follow) gross beta determinations were made on 5-gal samples of water from each of five selected test wells that had shown higher than the average level of radioactivity during well-logging observations. The highest level of activity found in any of the water from these five wells was  $8.5 \times 10^{-7}$   $\mu\text{c}/\text{cc}$ . By the same method of gross beta analysis the level of natural background activity in an uncontaminated spring in the White Oak Creek area upstream from the Laboratory was found to be  $2.5 \times 10^{-7}$   $\mu\text{c}/\text{cc}$ .

### Ecological Study of White Oak Creek.

Progress of the study during the period by the ecological staff with cooperation from the Laboratory and from other units of the Tennessee Valley Authority has included the following:

1. A determination of the time of water travel under stratified conditions in White Oak Lake was completed. the time of travel of the fastest moving water through the lake to the dam was about the same as found in previous determinations.

The collection and analysis at ORNL of routine biweekly water samples from White Oak Creek and White Oak Lake have been assumed by the ecological staff because of the transfer from Knoxville to Chattanooga of the TVA laboratory that formerly did the work.

2. The population of *Gambusia affinis affinis* planted in the settling

basin during the spring was destroyed, apparently by some toxic chemical waste. Another planting was made September 18 and it appears to be thriving. It is intended that specimens will be collected for detailed examination after a period of exposure.

Weekly collections, dissections, and radioassays of three bluegill and three crappie from the lake are being made, because the analyses of fish from White Oak Lake have given some indication of great differences of strontium content in the bone during winter as compared with summer periods. It is planned to continue this routine through enough seasons to determine whether environmental changes, such as temperature, affect the rate of uptake and of elimination of radioactivity from the various fish tissues. The details of radiochemical analyses of the fish tissues have been worked out with the Analytical Chemistry Division, which is making these analyses.

During September a second five-weeks' fall study of fish population was initiated.

3. In the botanical studies, specimens for addition to the herbarium and for radioassay have been collected and the vegetation of the area is now well represented.

The survey was completed of the prominent vegetation species in study plots around White Oak Lake and on White Oak Creek up to Haw Gap Bridge. Samples for gross beta assay, totaling about 2000, were taken from every important species of plant occurring around White Oak Lake.

4. Limnological studies, which have lagged behind work on the physical and chemical, fisheries, biological, and botanical phases of the study, are being accelerated since the limnologist reported for duty on October 1.

## INSTRUMENTATION AND TECHNIQUES

J. M. Garner

R. A. Lauderdale

Developmental work on a column-type of water monitor for use in the detection of low levels of activity is nearing completion and a report on this instrument is being prepared. The unit, which consist chiefly of a 10-in., thin-walled (30 mg/cm<sup>2</sup>), glass GM-tube surrounded by a bed of Dowex-50 cation-exchange resin, operates by concentrating the radioactive elements from large volumes of water passed through the bed. The buildup of activity in the resin bed is recorded on a strip chart as a line of constant slope for each concentration of activity. The slope of the line is therefore a measure of the concentration of activity in the water.

This water monitor unit was calibrated by the use of tap water spiked with different concentrations of an aged, mixed fission-product solution having an average  $\beta$  energy of about 0.7 Mev. From the data obtained, it has been calculated that activities as low as  $10^{-9}$   $\mu\text{c}/\text{cc}$  of mixed fission-product activity can be detected by passing 40 gal of water through the unit. By plotting the known activity of the feed as a function of the slope of the recorded line in counts per minute per liter a straight line was obtained that may be represented by an equation of the type

$$\mu\text{c}/\text{cc in feed} = \frac{1}{K} \times \text{recorded c/m/liter},$$

where  $K$  is essentially a counting efficiency correction that will depend on the dimensions of the detector assembly and on the energy and type of radiation.

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## THEORETICAL PHYSICS

J. Neufeld

W. S. Snyder

### FAST-NEUTRON TOLERANCE CALCULATIONS

Collision densities and energy losses of a monoenergetic beam of neutrons normally incident on an infinite slab of tissue of 30 cm thickness have been obtained with the assistance of members of the ORNL Mathematics Panel by means of a Monte Carlo procedure. Table 1 summarizes the results to date:

### STOPPING POWER OF PROTONS, ALPHA PARTICLES, AND IONS OF CARBON AND OXYGEN IN TISSUE

The stopping cross sections have been computed by using the results of Hirschfelder and Magee<sup>(1)</sup> and Knipp and Teller.<sup>(2)</sup> These values are tabulated for comparison with those obtained by use of the method described

TABLE 1  
Collision Densities and Energy Losses of a Monoenergetic Beam

ENERGY OF NEUTRONS	10 Mev	5 Mev	2.5 Mev	0.5 Mev
Maximum energy absorption at surface (ergs/cm <sup>3</sup> /neutron)	$6.43 \times 10^{-7}$	$7.16 \times 10^{-7}$	$4.75 \times 10^{-7}$	$1.91 \times 10^{-7}$
Per cent of energy loss due to hydrogen scattering	83.3	89.6	93.0	92.2
Maximum dose at surface (rep/cm <sup>3</sup> /neutron)	$8.10 \times 10^{-8}$	$8.03 \times 10^{-8}$	$5.32 \times 10^{-8}$	$2.21 \times 10^{-8}$
Maximum permissible flux (neutrons/cm <sup>2</sup> /sec) based on 40 hr/wk	25.7	25.9	39.2	94.3
Per cent of neutrons thermalizing in a 30-cm slab	50.3	63.4	71.1	65.8

In all cases the maximum absorption of energy occurs at the surface. The maximum dosage figure is calculated by using a relative biological effectiveness of 10 for energy losses due to protons and a relative biological effectiveness of 20 for heavier tissue ions (carbon, oxygen, nitrogen). It is assumed that 93 ergs/cm<sup>3</sup> is the equivalent of the roentgen. Calculations for the resulting thermal doses are under way.

in ORNL-884.<sup>(3)</sup> The lateral energy distribution (width of track) is being computed.

(1) J. O. Hirschfelder and J. L. Magee, "Range-Energy Relations for Protons in Substances Containing C, H, O, A, and Xe," *Phys. Rev.* 73, 207 (1948).

(2) J. Knipp and E. Teller, "On the Energy Loss of Heavy Ions," *Phys. Rev.* 59, 65, 659 (1941).

(3) J. Neufeld, "Ionization and Excitation Losses of Charged Particles of Intermediate Energies," ORNL-884 (Dec. 14, 1950).

## PHYSICS OF NUCLEAR RADIATIONS

H. K. Richards

## FAST-NEUTRON POCKET-METER INVESTIGATION

J. S. Cheka

The possibility of an ionization current caused by carbon-recoil atoms in a graphite-lined chamber exposed to fast neutrons was mentioned in a previous report. In order to evaluate this possible recoil-atom effect, a beryllium- and an iron-lined chamber were made to the same dimensions. These dimensions were: inside diameter, 1.76 cm; length, 9.25 cm; and electrode diameter, 1.12 cm. Beryllium should increase such a recoil ion effect and iron should eliminate it.

Several gas fillings were also tried by the use of a plenum chamber. Exposures were made to  $\text{Co}^{60}$   $\gamma$  and to neutrons (and associated gamma radiation) from a Po-B and Po-Be source. In the tables following, all gas pressures are corrected to 760 mm Hg, and corrections are made for the capacitance differences of the three chambers. Table 2 shows response to  $\text{Co}^{60}$   $\gamma$  radiation. The figures in Table 2 show discharge in divisions per minute on a minometer scale at a fixed geometry and are valid for comparison only.

TABLE 2

Ionization-Current Response of Chambers To Gamma Rays from  $\text{Co}^{60}$ 

GAS	CHAMBER WALL		
	Be	C (Graphite)	Fe
Air	31.6	31.2	35.0
$\text{CH}_4$	29.5	31.4	34.5
He	6.3	6.1	6.8
$\text{H}_2$	5.3	5.3	5.8

Table 3 shows response of these chambers to Po-B neutrons. Again the figures indicate divisions per minute at a fixed geometry, corrected to 760 mm Hg pressure. The table is self-consistent, but responses are not evaluated in terms of neutron flux.

TABLE 3

## Ionization-Current Response of Chambers to Neutrons (and associated gamma rays) from Po-B

GAS	CHAMBER WALL		
	Be	C (graphite)	Fe
Air	1.96	1.45	1.58
$\text{CH}_4$	2.06	1.65	1.80
He	0.72	0.59	0.56
$\text{H}_2$	0.62	0.43	0.42

Table 4 shows response to polonium-beryllium neutrons on the same basis as given in Table 3.

TABLE 4

## Ionization-Current Response of Chambers to Neutrons (and associated gamma rays) from Po-Be

GAS	CHAMBER WALL		
	Be	C (graphite)	Fe
Air	3.82	2.99	3.13
He	0.95	0.76	0.81

Some tentative results are indicated from these tables, assuming that response to the gamma component of the neutron sources follows a pattern somewhat similar to response

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

to  $\text{Co}^{60}$   $\gamma$ . (1) Ionic current in the Fe chamber is about 11% greater than in the C chamber for the  $\text{Co}^{60}$   $\gamma$  radiation. (2) The carbon-atom current, if present, is small, being about 3% with the Po-B source and 7% with the Po-Be source in the C-air chamber; however, this is the order of the probable error of the data. (3) About 40% of the current in the Be-air chamber originates from the Be recoils and the  $\text{Be}^9(n,\alpha)\text{He}^6$  reaction for both Po-B and Po-Be sources. (4) The current caused by proton recoils is about 13% of the total current in the Be- $\text{CH}_4$ , C- $\text{CH}_4$ , and Fe- $\text{CH}_4$  chambers with the Po-B source. (5) The current caused by the He recoils is about 50% of the total current for the Po-B source and about 25% of the total current for the Po-Be source in the Be-He, C-He, and Fe-He chambers. (6) The current due to the proton recoils is about 40% of the total current in the Be- $\text{H}_2$ , C- $\text{H}_2$ , and Fe- $\text{H}_2$  chambers for the Po-B source.

It must be noted that these are relative figures, and the use of a light gas filling reduces total current, e.g., the use of He, instead of air, reduces sensitivity to  $\text{Co}^{60}$   $\gamma$  by a factor of 5 and the response to Po-B neutrons and associated gamma rays by a factor of 3.

By the use of the same geometry with the  $\text{Co}^{60}$   $\gamma$  source, the interposition of a 1-in. Bi shield decreased the ionization current by a factor of 3.1 and a 2-in. Bi shield decreased it by a factor of 10.9 in all three chambers when filled with air, and within a few per cent of these values when filled with He.

In the case of the neutron sources the attenuation with 1-in. of Bi was variable with the different gases and

was much less than for  $\text{Co}^{60}$  gamma rays. With air it was about 1.6 for the Po-B source, and about 1.8 for the Po-Be source. The Fe wall has been replaced by a polyethylene wall and new tests are under way.

### STRAGGLING OF CONVERSION ELECTRONS FROM BARIUM<sup>137</sup> AS MEASURED WITH THE SOLENOIDAL SPECTROMETER

R. D. Birkhoff

Experiments have been concluded on the absorption of the internal conversion electrons from  $\text{Ba}^{137}$  in various thicknesses of materials of several atomic numbers. Some of the results of the experiments are indicated in Figs. 1 and 2. Excellent agreement with the Bethe-Bloch theory for the average rate of energy loss is obtained over the range of the periodic table. In addition, the most probable rate of energy loss calculated from the Landau theory appears to be verified by our results. The width at half maximum (see Fig. 3) of the observed straggling curves, however, is about 2.5 times as large as predicted from the Landau paper.

An attempt will be made to calculate the beta dose at various distances below the surface of an irradiated slab by the use of the data previously given and an absorption curve obtained from the areas of the straggling distributions for various foil thicknesses.

### MEASUREMENT OF RADIATION BY FREQUENCY VARIATION OF AN R-F OSCILLATOR

H. K. Richards

The experiments to measure ionizing radiation by frequency variation were continued. A 29-cycles/min frequency

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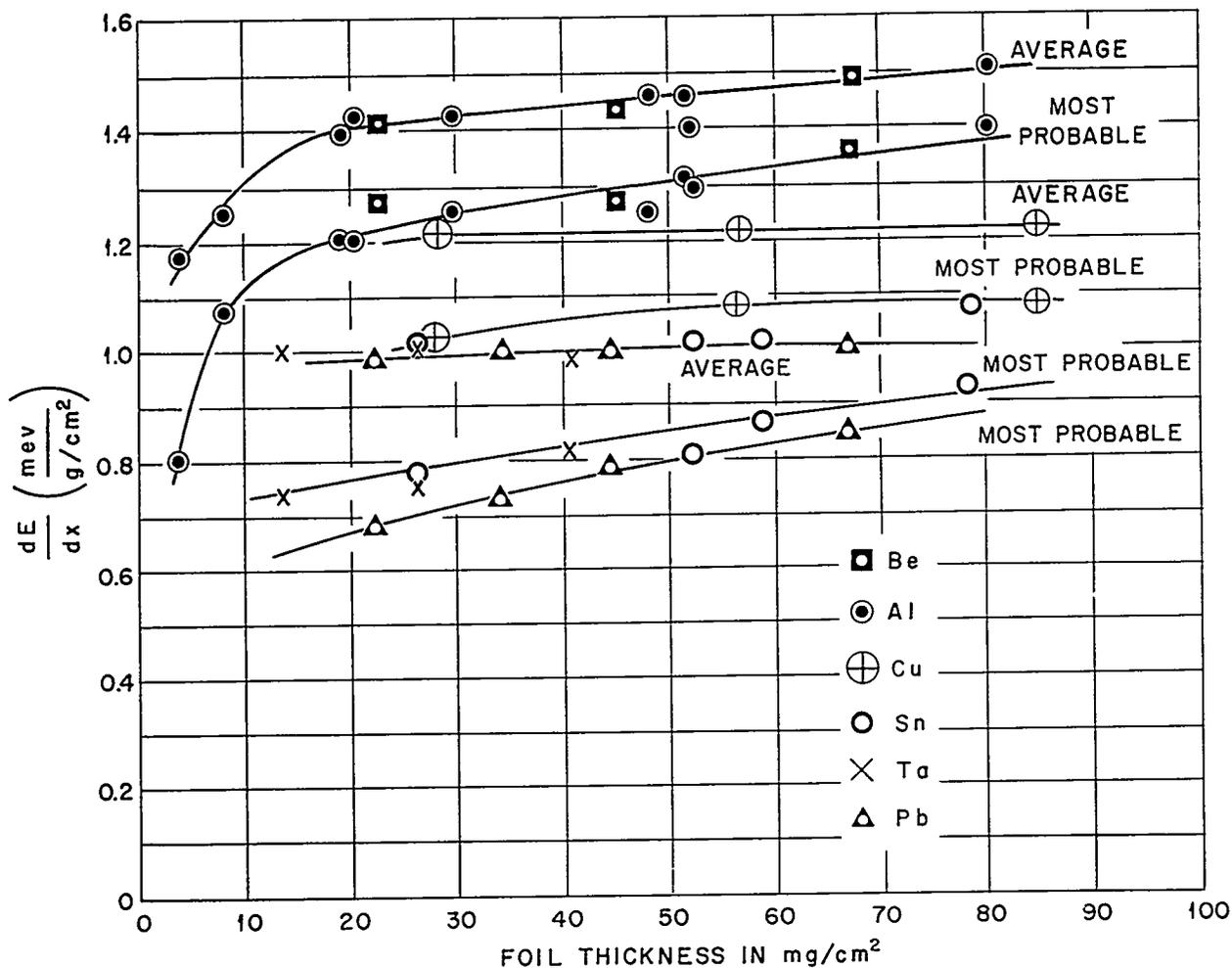


Fig. 1. Most Probable and Average Rate of Energy Loss at 626 kev vs. Foil Thickness.

shift was produced with 1.37 mr/hr of Ra gamma rays.

A new construction in progress will replace the steel-wire suspension of the variable-capacitance-producing leaf by a quartz fiber to provide a better reproduction and stability of the system.

#### RANGE MEASUREMENTS OF BETA PARTICLES

T. E. Bortner

Work of the past quarter is being continued on the measurement of the range of beta particles in absorbers of various atomic numbers. These measurements are being accomplished by using a standard thin-window beta counter with necessary corrections being made. Parallel experimental range measurements are also being made by using a windowless counter.

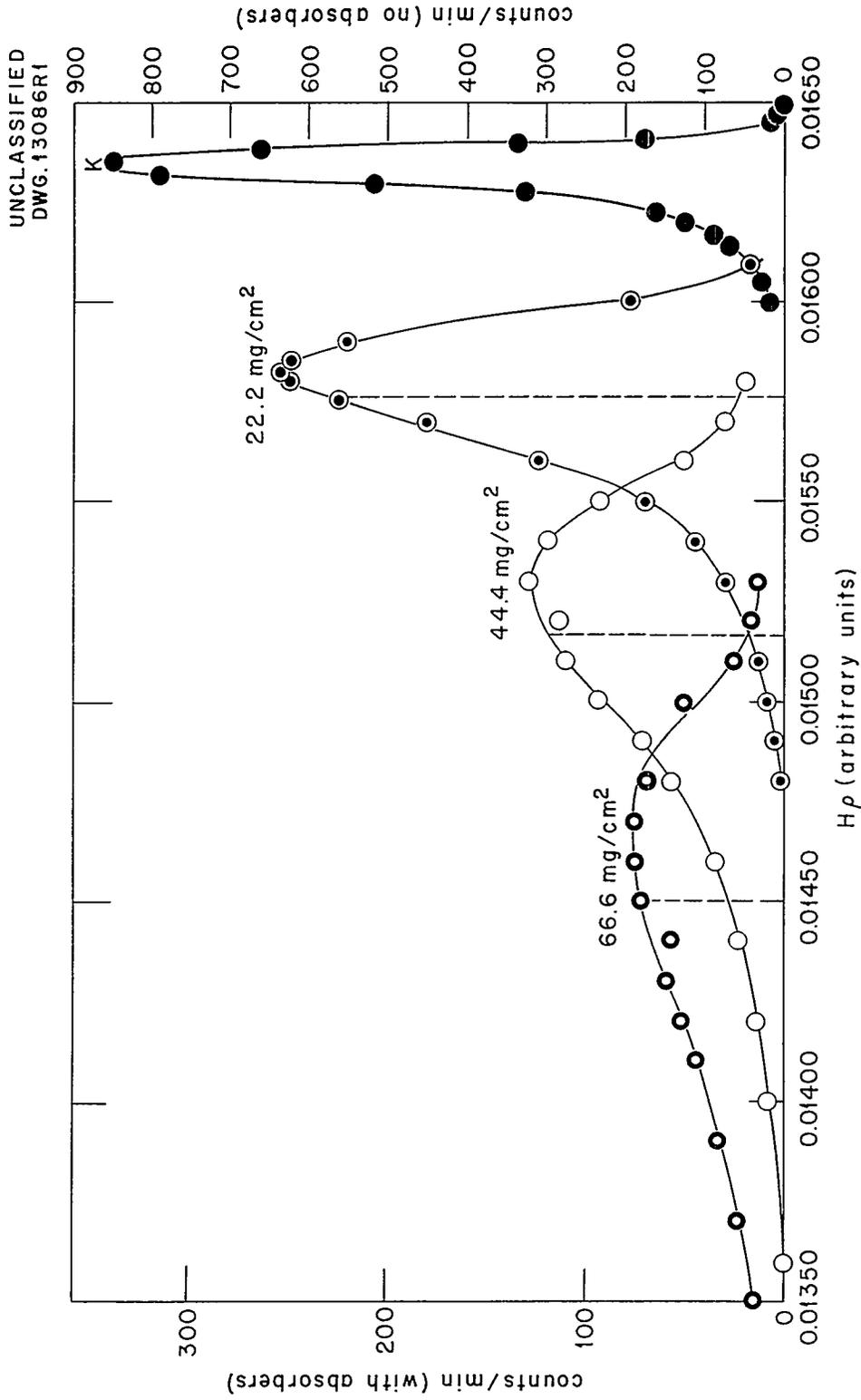


Fig. 2. Straggling of K-Conversion Electrons from Barium<sup>137</sup> in Beryllium.

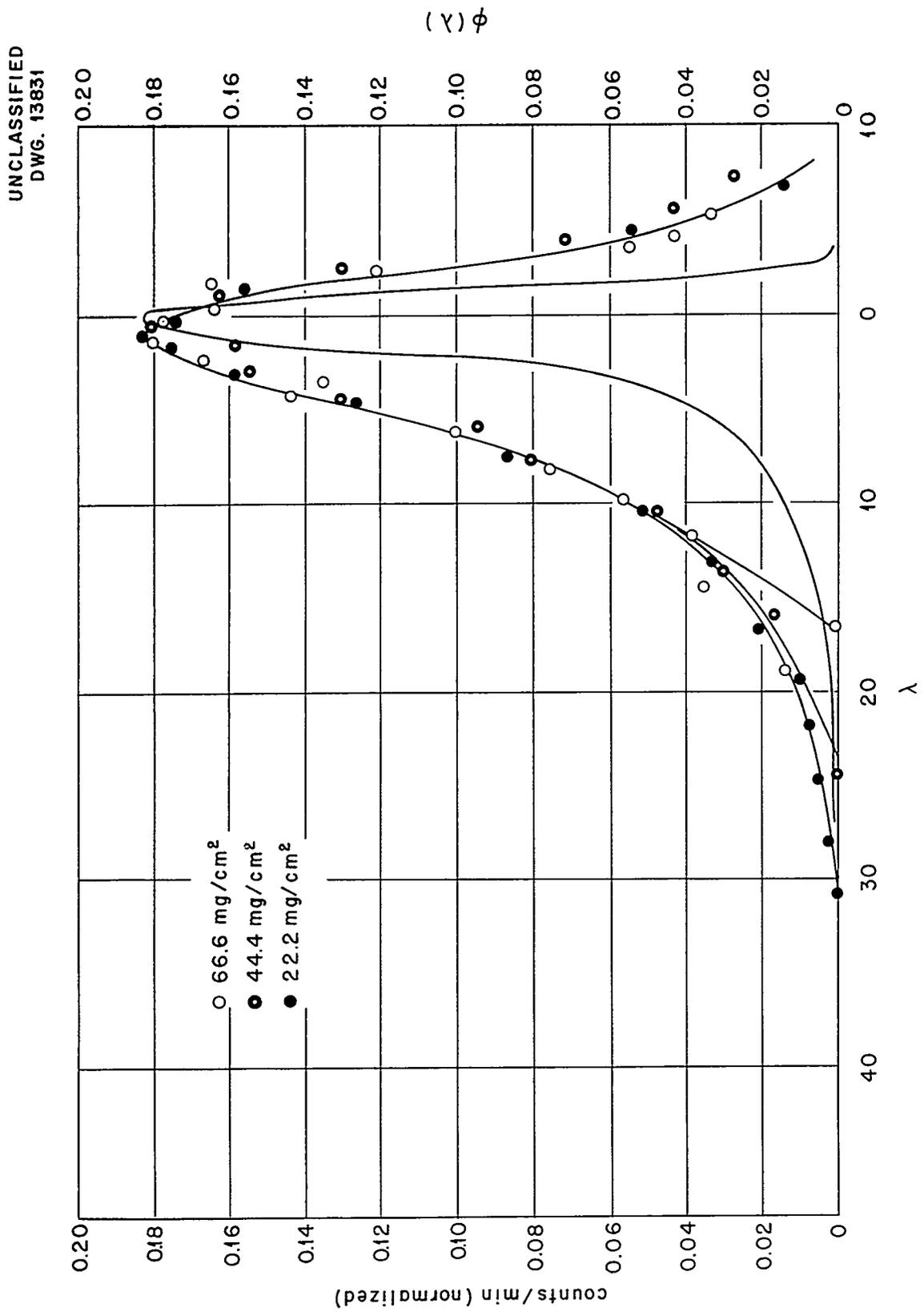


Fig. 3. Beta Straggling Distributions vs. Landau's  $\lambda$  Function (Beryllium Absorber)

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## RADIOCHEMICAL ANALYSIS

L. B. Farabee

### ANALYSIS FOR PLUTONIUM ON AIR FILTERS

The technique for quantitative determination of plutonium on constant-air-monitoring filters by direct counting of the alpha is unreliable owing to: (1) indeterminate self-absorption on the filter and (2) the presence of large amounts of other alpha-emitting isotopes. It was expedient to develop procedures of analysis for plutonium on two types of filters presently used at Oak Ridge National Laboratory. Such procedures could be used specifically for two purposes: (1) to detect plutonium present in particulate matter that is filtered from the air in the Oak Ridge

National Laboratory area and (2) to determine the extent of the expulsion of plutonium through hood ducts that open directly into the air.

The asbestos base filter was reduced to soluble compounds by burning the cellulose in the flame of a Meker burner and dissociating the remaining silicates by perchloric acid and hydrofluoric acid. For the Whatman filter No. 41, wet oxidation by the use of nitric acid and perchloric acid was found satisfactory and easy to carry out. Conventional procedures were then employed to separate plutonium from the inorganic constituents of the filters.

## PHYSICS OF RADIATION DOSIMETRY

H. H. Hubbell

### CALIBRATION OF X-RAY MACHINE

The dose-rate calibration of the 250-kv x-ray machine has been continued for a variety of currents, voltages, and filtrations.

### FAST-NEUTRON DOSIMETER

Further design and testing work has been done on the fast-neutron survey dosimeter preparatory to commercial production of the instrument.

### DISTRIBUTION OF FLUX IN X-10 GRAPHITE PILE

The experiment on the space distribution of neutron flux in the X-10 graphite pile has been improved and repeated with the cooperation of the School of Reactor Technology laboratory personnel. The curves obtained show plainly the general trend of the flux falling off from center to edge of the pile and, in addition, a small ripple owing to absorption of thermal neutrons by uranium slugs and a large depression in flux due to a control rod. A report will be issued on this project.

### THERMAL-NEUTRON SURVEY INSTRUMENT

G. S. Hurst

A report<sup>(1)</sup> describing a thermal-neutron survey instrument will be issued in the near future. The report contains a complete description of the electronic circuit as well as the drawings necessary to reproduce the proportional-counter detector.

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<sup>(1)</sup>G. S. Hurst, D. J. Knowles, and Catherine Yochem, "A Neutron Survey Instrument," ORNL-1134 (Jan. 2, 1952).

### PROPORTIONAL-COUNTER DEVELOPMENT

G. S. Hurst

The equations describing the shape of a proportional-counter pulse for the case of an extended track of ionization have been derived. Secondly, the equations giving the shape of the pulse after being amplified by an amplifier have been developed. Numerical work is being done by the Mathematics Panel so that one may know the conditions under which the pulse height after amplification is proportional to the number of ion pairs producing the pulse, independent of the orientation of the track.

### PULSE-HEIGHT INTEGRATOR

G. S. Hurst

A method of weighting pulses by their height has been developed in cooperation with the Instrument Department. The instrument will be described completely in a forthcoming report.

### PHYSICAL CALCULATIONS

R. H. Ritchie

Further calculations for the determination of the diffusion length in the sigma pile have been initiated with the cooperation of the Mathematics Panel.

Some work has been done on a theory of multiple scattering of electrons in foils, which includes both energy and angular distribution of electrons as a function of depth in the foil.

Efficiency calculations have been carried out for a cylindrical scintillation counter and a particular source geometry. This work will appear in a forthcoming memorandum.

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## EDUCATION AND TRAINING

E. E. Anderson      M. F. Fair  
M. R. Ford

### AEC FELLOWSHIP PROGRAM

The 1950-51 group of 20 AEC Fellows completed field training on August 31. Four of the Fellows applied for and received an extension of the fellowship and now are doing research work for completion of their Master's degrees. Arthur Smith and Charles Wright elected to return to Vanderbilt University. Luis Garcia and Ford Kalil remained at the Laboratory. The 1951-52 group of 20 Fellows registered at Vanderbilt University September 24.

### TRAINING PROGRAM FOR MILITARY PERSONNEL

The 21 NME officers and the two from the Army Chemical Center completed their training period on August 17. Captain H. W. Curtis, West Point, remained until September 1.

### TRAINING PROGRAM FOR AEC CONTRACTOR PERSONNEL

During this quarter the Education and Training Section has been responsible for the training of one health physicist for Dow Chemical Company, eight American Cyanamid Company personnel, and six personnel for the DuPont Company.

### MISCELLANEOUS ACTIVITIES

One member of the staff began teaching a course in Nuclear Physics on September 17, in the Staff Educational Program for the Reactor School. Another member of the staff has been working full time on samples in connection with the Nevada Testing Program. Classes for the Apprentice Training School began during this period.

## EXPERIMENTAL RADIATION MEASUREMENTS

F. J. Davis

## AIRPLANE MEASUREMENTS

F. J. Davis      P. W. Reinhardt

A series of flights over sources of  $\text{Na}^{24}$ ,  $\text{Co}^{60}$ ,  $\text{Cs}^{137}$ , Ra, and  $\text{Ta}^{182}$  were made at heights from a few hundred feet to, in some cases, more than 3000 feet. The variation of gamma-ray response of the NaI-crystal scintillometers indicated a buildup factor roughly proportional to the altitude. A more exact representation would be a quadratic, such as  $1 + ah + bh^2$  or  $1 + ah^b$ , where  $a$  and  $b$  are constants, depending on the energy of the primary radiation, and  $h$  is the height. For the purpose of altitude compensation of aerial radiation measurements of radiation coming from the ground, a buildup factor proportional to the height is good enough. A project measuring the absorption of gamma rays in water and other media to obtain a more exact relation for buildup factors and their dependence on energy is being contemplated.

Assuming a buildup factor proportional to height and integrating over a uniformly distributed source in the ground, one obtains the simple relation that the attenuation is proportional to  $e^{-\mu h}$ , where  $\mu$  is the the absorption coefficient for air. A few flights were made to check this relation by flying first over water and then over land at various altitudes, by using the natural radioactivity of the ground for a plane distributed source. The data obtained fit the theoretical relation within experimental error.

A curve of the variation of the background vs. altitude was obtained

by making a series of flights over the Pacific Ocean. The curve shows little change in background for altitudes up to about 8000 feet and then increase with altitude to a background at 15,000 feet about double that at low altitudes.

## RADON MEASUREMENTS

W. C. King      L. F. Garcia

Three samples of dolomite rock were obtained from one of the oil wells in the Panhandle gas field in Texas. The radon emanation from the samples was measured in order to determine whether the radon escaping from the wells could be accounted for by the natural activity in the dolomite. The three samples, for which the radium and radon values are given in Table 5 were described as:

- Sample A - finely porous, strong oil odor, porosity probably more than 10%;
- Sample B - less porous than A, faint oil odor;
- Sample C - dense, only slightly porous, oil odor.

It is not surprising to have less emanation from the powder than the rock, since radon adsorbs readily on many surfaces.

Two additional problems that have been undertaken by trainees assigned to this section are (1) the study of the variation of the radon and radium content of the Clinch River and (2) a study of the radon variation in the air.

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

TABLE 5

Radium and Radon Values

SAMPLE	RADIUM CONTENT (g/g x 10 <sup>-12</sup> )	RADON EMANATION FROM ROCK, 130 <sup>g</sup> (curies/g x 10 <sup>-12</sup> )	ROCK EMANATION FROM ROCK POWDER, 100-MESH (curies/g x 10 <sup>-12</sup> )
A	0.294	0.0311	0.0315
	0.286	0.0310	
B	1.32	0.1135	0.101
	1.28	0.1142	
C	0.202	0.0159	0.0134
	0.199	0.0157	

DRILL-HOLE MEASUREMENTS

J. A. Harter

A NaI-scintillation probe and enriched-BF<sub>3</sub> neutron counters were tested at Grand Junction, Colorado, for possible application in logging of carnotite deposits. Five simulated drill holes, with ore layers of known quantity and assay, were logged. The 1 11/16-in.-OD scintillation probe (using a 1 1/2-in.-diameter by 1-in. sodium iodide crystal and a C7151 photomultiplier tube) was used both as a high-efficiency detector and as a spectrometer to measure the carnotite

gamma-energy spectrum as a function of sand-absorber thickness. The maximum counting rate at the center of a 4-ft diameter, 20-in.-thick layer of 4.25% ore was in excess of 6 million cpm, compared to a background of 4500 cpm. Quite accurate determination of the ore-layer thickness was possible for strata measurement. Some shift in energy spectrum was observed; the data is being further analyzed. The neutron-counter characteristics drifted so badly between manufacture and test that they could not be used; this drift is attributed to BF<sub>3</sub>-gas impurities. The counters are being refilled for further tests.

PERMISSIBLE INTERNAL DOSE - RADIOISOTOPES

K. Z. Morgan      M. R. Ford  
M. J. Cook

RADIOISOTOPES - MAXIMUM PERMISSIBLE  
CONCENTRATIONS

Preliminary calculations of maximum permissible concentrations of radioisotopes in total body, in air, and in water have been made for 35 additional isotopes, largely fission products.

The complete list of isotopes on which preliminary calculations have been made up to October 1 follows.

Common radioisotopes that are alpha emitters: U-natural (soluble and insoluble),  $U^{233}$  (soluble and insoluble),  $Ra^{226}$ ,  $Rn^{222}$ ,  $Pu^{239}$  (soluble and insoluble),  $Po^{210}$  (soluble and insoluble).

Radioisotopes of common body elements:  $C^{14}$ ,  $H^3$ ,  $Ca^{45}$ ,  $P^{32}$ ,  $K^{42}$ ,  $S^{35}$ ,  $Na^{24}$ ,  $Cl^{36}$ ,  $Fe^{55}$ ,  $Fe^{59}$ ,  $Mn^{56}$ ,  $Cu^{64}$ ,  $I^{131}$ .

Other radioisotopes of current interest:  $Sr^{89}$ ,  $Sr^{90}$  +  $Y^{90}$ ,  $A^{41}$ ,  $Xe^{133}$ ,  $Xe^{135}$ ,  $Co^{60}$ ,  $Au^{198}$ ,  $Au^{199}$ ,  $Cr^{51}$ ,  $Ni^{59}$ ,  $Mo^{99}$ ,  $Th^{234}$ ,  $As^{76}$ ,  $Ga^{72}$ ,  $Ba^{140}$  +  $La^{140}$ ,  $F^{18}$ ,  $Be^7$ ,  $Sc^{46}$ ,  $V^{48}$ ,  $Ge^{71}$ ,  $Rb^{86}$ ,  $Y^{91}$ ,  $Nb^{95}$ ,  $Tc^{96}$ ,  $Ru^{106}$  -  $Rh^{106}$ ,  $Rh^{105}$ ,  $Pd^{103}$ ,  $Cd^{109}$  -  $Ag^{109m}$ ,  $Sn^{113}$ ,  $Te^{127}$ ,  $Te^{129}$ ,  $Cs^{137}$  -  $Ba^{137m}$ ,

$La^{140}$ ,  $Re^{183}$ ,  $Ir^{190}$ ,  $Ir^{192}$ ,  $Pb^{203}$ ,  $At^{211}$ ,  $Am^{241}$ ,  $Cm^{242}$ ,  $Ce^{144}$  -  $Pr^{144}$ ,  $Pr^{143}$ ,  $Pm^{147}$ ,  $Sm^{151}$ ,  $Eu^{154}$ ,  $Ho^{166}$ ,  $Tm^{170}$ ,  $Lu^{177}$ ,  $Ag^{111}$ ,  $Ag^{105}$ .

Further biological studies of these and other isotopes are needed, especially under conditions of chronic ingestion and inhalation.

A re-examination of the maximum permissible concentration (mpc) of radon in air indicates that  $10^{-8}$   $\mu c/cc$  ( $10^{-11}$   $\mu c/l$ ) of radon in air is probably a reasonable and acceptable mpc. If the air is well ventilated and free of dust, it would seem reasonable to increase the mpc of radon in air to  $2 \times 10^{-8}$   $\mu c/cc$  or perhaps to  $10^{-7}$   $\mu c/cc$ .

UNIVERSITY OF TENNESSEE RESEARCH  
AND DEVELOPMENT SUBCONTRACT

I. H. Tipton

The spectrographic laboratory at the University of Tennessee is in operation making a preliminary qualitative survey of trace elements in human heart, liver, kidney, bone, and skeletal muscle. A quantitative analysis of these tissues and others is to begin by December 1.

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## CONSULTATION AND SPECIAL PROBLEMS

### OPEN-AIR MEASUREMENTS OF A 300-CURIE COBALT SOURCE

H. A. McAlduff

In cooperation with the Medical Division of the Oak Ridge Institute of Nuclear Studies, open-air measurements were made of a large 300-curie cobalt source to be used for cancer therapy.

Preliminary examination of the data confirms the fact that determination of the source strength of large sources by open-air measurements is grossly inaccurate due to limited information concerning the buildup factor introduced by air- and ground-scattering. A report of the data obtained will be forthcoming in the near future.

PUBLICATIONS AND SPECIAL REPORTS

PUBLICATIONS

1. C. P. Straub, R. J. Morton, and O. R. Placak, "Oak Ridge Reports Results on Water Decontamination Study," *Eng. News-Record* 147, 7, 38-41 (Aug. 16, 1951).
2. R. A. Lauderdale, "Treatment of Radioactive Water by Phosphate Precipitation," *J. Ind. Eng. Chem.* 43, 1538-1541 (July 1951).
3. F. J. Davis, "Fall-Out in Southeastern U.S. During January and February 1951, from Nevada Atomic Tests," ORNL-1081 (Nov. 8, 1951).
4. C. P. Straub, R. J. Morton, and O. R. Placak, "Studies on the Removal of Radioactive Contaminants from Water," *J. of Amer. Water Works Assoc.* 43, (Oct. 1951).
5. D. M. Davis, F. J. Davis, "Air Activity Studies Conducted at Corryton, Tennessee, and Gainesville, Florida," ORNL CF 51-9-63 (Oct. 25, 1951).
6. R. J. Morton, "Water Decontamination," Part of Panel Discussion on Engineering Aspects of Atomic Energy, 1951, *Conference of State Sanitary Engineers*, Washington, D.C., May 9, 1951.
7. R. J. Morton, "Environmental Problems of Radioactive Waste Materials," lecture presented on September 4, 1951, at *Third Annual Oak Ridge Summer Symposium*, TID-5031, The Role of Engineering in Nuclear Energy Development (December, 1951).
8. K. Z. Morgan, "Standards of Radiological Protection and Control," lecture presented on August 30, 1951, at *Third Annual Oak Ridge Summer Symposium*, TID-5031, The Role of Engineering in Nuclear Energy Development (December, 1951).

SPECIAL REPORTS

(Copies available upon request)

1. O. R. Placak, "Disposal of C<sup>14</sup> Wastes," a section in the tentative report and recommendations being prepared by the Subcommittee on Waste Disposal and Decontamination of the *National Committee on Radiation Protection*.
2. C. P. Straub, "Radioactive Materials and Environmental Health," paper presented at the *Twentieth Annual Georgia Water and Sewage School*, Georgia School of Technology, Atlanta, Georgia (Sept. 21, 1951).
3. C. P. Straub, "Effects of Radioactivity on Water Supplies," paper presented at the *Joint Annual Meeting of the Missouri Section of the American Water Works Association and the Missouri Water and Sewage Conference*, St. Joseph, Missouri (Oct. 2, 1951).

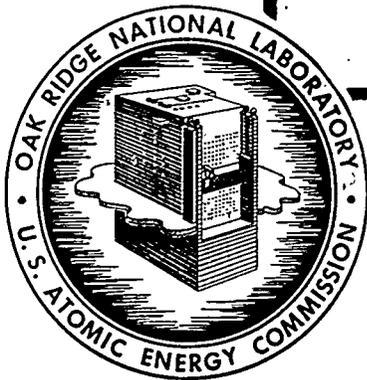
4. C. P. Straub, "Effect of Radioactive Materials on Water Supplies," paper presented at the *Fortieth Annual Convention of the Southwest Section of the American Water Works Association*, Fort Work, Texas (Oct. 15, 1951).

5. K. Z. Morgan, "Maximum Permissible Concentration of Radon in the Air," prepared for *Subcommittee on Internal Dose of the National Committee on Radiation Protection* (Oct. 4, 1951).

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HEALTH PHYSICS DIVISION  
QUARTERLY PROGRESS REPORT  
FOR PERIOD ENDING JANUARY 20, 1952



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**HEALTH PHYSICS DIVISION**

K. Z. Morgan, Director

**QUARTERLY PROGRESS REPORT**  
for Period Ending January 20, 1952

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## TABLE OF CONTENTS

	PAGE
RADIOACTIVE WASTE DISPOSAL RESEARCH	1
Water and Liquid-Waste Decontamination Processes	1
Survey Studies and Ecological Study of White Oak Creek Drainage Area	1
Instrumentation and Techniques	4
THEORETICAL PHYSICS	4
Fast-Neutron Tolerance Calculation	4
Distribution of Energy Losses of Moving Ions	4
PHYSICS OF NUCLEAR RADIATIONS	5
Fast-Neutron Pocket Meter Investigation	5
Measurement of Ionizing Radiation by Frequency Variation of an RF Oscillator	6
Beta Particles	6
Straggling of Conversion Electrons from Barium <sup>137</sup> as Measured with the Solenoidal Spectrometer	6
Calibration of Monitoring Equipment	6
Skin Fluorescence After X and Gamma Irradiation	7
Experiments on Beta-Ray Backscattering	7
RADIOCHEMICAL ANALYSIS	8
Analytical Procedure for Detecting Plutonium in River Water	8
PHYSICS OF RADIATION DOSIMETRY	9
X-Ray Dosimetry	9
Tissue Depth Dose for Fast Neutrons	9
Fast-Neutron Dosimeter	9
Proportional-Counter Development	9
Physical Calculations	9
Biophysics	10
EDUCATION AND TRAINING	11
AEC Fellowship Program	11
Training Program for AEC Contractors Personnel	11
Lectures and Seminars	11
Miscellaneous Activities	11
EXPERIMENTAL RADIATION MEASUREMENTS	12
Variations in the Radium and Radon Content of the Clinch River	12

	PAGE
Variations in the Natural Radioactivity of the Free Atmosphere at ORNL	12
PERMISSIBLE INTERNAL DOSE - RADIOISOTOPES	14
University of Tennessee Research and Development Subcontract	14
PUBLICATIONS AND SPECIAL REPORTS	14
Publications	14
Special Reports	15

# HEALTH PHYSICS DIVISION

## QUARTERLY PROGRESS REPORT

### RADIOACTIVE WASTE DISPOSAL RESEARCH

R. J. Morton

#### WATER AND LIQUID-WASTE DECONTAMINATION PROCESSES

H. E. Butcher	D. A. Pecsok
M. W. Carter	O. R. Placak
W. J. Lacy	C. P. Straub

**Trickling Filter Study with Urine Waste Containing Radioactive Iodine.** A study is in progress to determine whether  $I^{131}$ , which is contained in the urine discharged from patients treated with radioactive iodine, can be removed from sewage by trickling filters. In previous studies it has been found that trickling filters can remove carrier-free  $I^{131}$  from sewage up to about 85% when the flow rate does not exceed two million gallons per acre per day. Much lower removals were obtained when double the flow rate was used with the carrier-free iodine, and still lower removals were obtained at this higher flow rate when the carrier potassium iodide was added to the  $I^{131}$  solutions.

The present study is designed to evaluate the effects on urine and the other constituents of hospital wastes upon the removal of radioactive iodine by trickling filters and should permit a comparison with the results of the previous experiments. Four trickling filters will be used, each 6 ft long and 2 in. in diameter. The urine waste obtained from the Oak Ridge Hospital will be added to domestic sewage for continuous dosage to two of the test filters. The third filter will receive sewage containing carrier-free  $I^{131}$ , and as a control the fourth filter will receive plain settled sewage.

**Removal of Radioisotopes from Water by Metallic Dusts.** The removal of various isotopes from solution by slurries of metallic dust has been studied. Representative data, taken from a report now in preparation, are reproduced in Table 1. The data given indicate the removals by using only a 500-ppm dose of various metallic dusts and a 90-min period of contact mixing followed by settling. Other mixing times and dosage rates not included in the table were also investigated.

The effect of a larger amount of a metallic dust may be seen. By using 2000 ppm of iron dust, with a 90-min contact period, better removals, in general, were obtained. The only metallic dust used with  $Y^{91}$  was zinc; for 90 min of contact time and 2000 ppm of dust the indicated removal was 99.1%, compared with 97.5% for 500 ppm of dust.

#### SURVEY STUDIES AND ECOLOGICAL STUDY OF WHITE OAK CREEK DRAINAGE AREA

E. R. Eastwood	L. A. Krumholz
J. M. Garner	W. T. Miller
V. I. Knobf	R. L. Nichols

**Radioactivity in Fish and Other Aquatic Animals.** The study of fish in White Oak Lake to determine seasonal differences in the radioactivity in various tissues has been continued. This study is accomplished by weekly collection, dissection, and analyses of three fish of each of two species that are prevalent in White Oak Lake. Preliminary indications imply that the

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

TABLE 1

Percentage of Removal of Indicated Radioisotopes from Water by Treatment with 500 ppm of Metallic Dusts for 90 Minutes

ISOTOPE	PERCENTAGE OF REMOVAL					
	Zn	Cu	Al	Mg	Fe	Fe (2000 ppm)
Ru <sup>106</sup> -Rh <sup>106</sup>	99.2	84.0	92.5	95.9	99.1	99.1
Y <sup>91</sup>	97.5					99.1
Zr <sup>95</sup> -Cb <sup>95</sup>	98.5	97.5			98.9	99.8
P <sup>32</sup>	98.6		81.8		99.6	99.7
Cs <sup>137</sup>					4.9	14.7
Ta <sup>182</sup>	91.6		99.9		99.9	99.8
I <sup>131</sup>	48.7	32.0	22.5		22.0	54.0
Ce <sup>144</sup> -Pr <sup>144</sup>	99.9	99.5	99.9		99.9	99.8

accumulation of radioactivity in bone, flesh, and other tissues of the fish is much greater during the warm months than during the winter season.

A study has been initiated during this period to obtain data on the accumulation and distribution of radioactivity in waterfowl. The primary purpose at this time is to make a preliminary appraisal of the importance of this problem and to establish the proper procedures for a more systematic study of waterfowl on White Oak Lake if such further study is indicated. To date, a total of six specimens, four coots and two ducks, have been collected and analyzed. The preliminary data indicate that levels of radioactivity in the flesh and other tissues of the waterfowl examined are significant and are generally similar to those found in fish tissues. Present data are insufficient for definite conclusions, and work on this project is to be continued.

**Radioactivity in River-Bottom Sediments.** The results of a survey of the activity in river-bottom sediments, obtained by "flounder" measurements of cross sections of the river, are plotted in Fig. 1. These measurements were made by lowering from a boat the subsurface Geiger-Mueller-tube scanning instrument, "flounder," which has been discussed in previous reports. The readings at Tennessee Mile 575 and above are upstream from any possible influence from installations at Oak Ridge and fall generally within the normal range of background. Slight increases are noted in the Tennessee River below the junction with the Clinch River. These increases disappear directly below each of the dams because of the scouring action on the river bottom caused by increased velocity. Although these sections are shown as dotted lines in Fig. 1, a sufficient number of spot checks were made to establish the validity of the decreases in activity below the dams.

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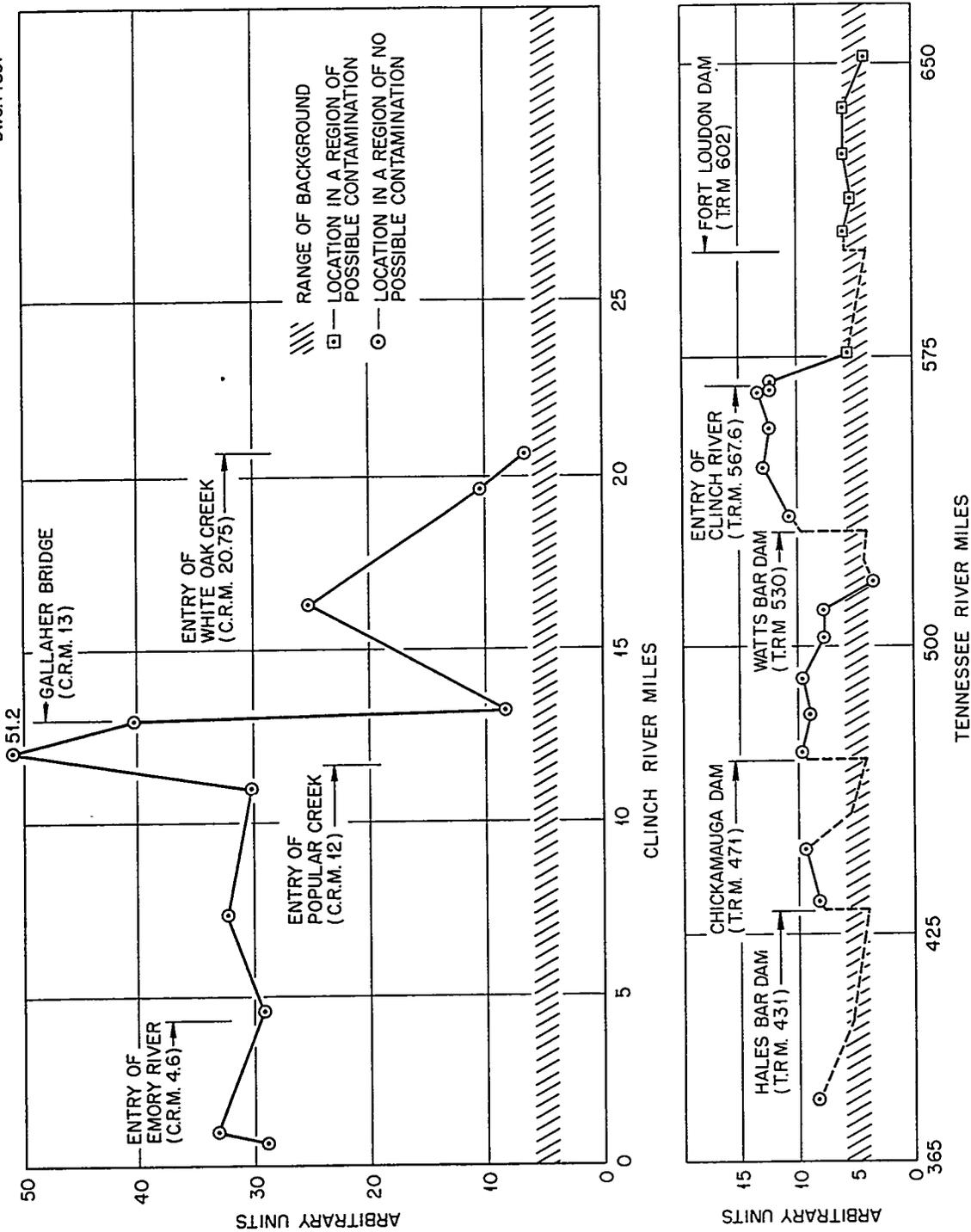


Fig. 1. Weighted Average Concentration of Radioactivity in River Sediments.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

The reading obtained at the point directly above Gallaher Bridge on the Clinch River appears to be too low. A higher value would normally be expected because the river narrows in this stretch, and the low value here is probably the result of increased velocity with consequent scouring and unfavorable conditions for the deposition of sediment.

### INSTRUMENTATION AND TECHNIQUES

J. M. Garner      O. W. Kochtitzky  
R. A. Lauderdale

Low-Level Measurements of Radioactivity in Water. The development

and use of a column type of water monitor that employs a 10-in. glass Geiger-Mueller tube surrounded by a bed of ion-exchange resin has been continued. This device is now being used to measure activity levels of natural ground and surface waters and of rain water collections in the vicinity of Oak Ridge. Experience with it has been amplified by the counting of more than 150 such water samples. It is capable of measuring activities in the order of  $10^{-7}$   $\mu\text{c/ml}$  in the absence of large quantities of non-radioactive soluble salts.

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## THEORETICAL PHYSICS

J. Neufeld      W. S. Snyder

### FAST-NEUTRON TOLERANCE CALCULATIONS

In the previous quarterly report the damage caused by energy losses of a beam of neutrons normally incident on a 30-cm slab of tissue has been reported for incident energies of 10, 5, 2.5, and 0.5 Mev. Since many of the neutrons thermalize in the slab, there is further damage resulting from the absorption of thermal neutrons. This damage has been calculated on the basis of the data of the Monte Carlo procedure. The thermal damage is quite negligible at high energies, being less than 1%, but it becomes appreciable at lower energies. To confirm this, an incident beam of 0.005 Mev was calculated, and the damage caused by thermal effects was

found to be about 60% of the total damage. The maximum permissible flux for neutrons of this energy is now being calculated and seems to be about 1500 neutrons/cm<sup>2</sup>/sec to give 0.3 rep in 40 hours. A detailed report on the problem is being written.

### DISTRIBUTION OF ENERGY LOSSES OF MOVING IONS

The density of energy loss as a function of distance from the track of a proton moving in tissue has been calculated for velocities of  $5w$ ,  $10w$ , and  $20w$  ( $w = e^2/\hbar$ ), where  $w$  is measured in centimeters per second. A report of these results is being prepared.

## PHYSICS OF NUCLEAR RADIATIONS

H. K. Richards

## FAST-NEUTRON POCKET METER INVESTIGATION

J. S. Cheka

A series of measurements has been made on a chamber lined with polyethylene and having a polyethylene central electrode (both Aquadag-coated) in order to compare this with the beryllium- and graphite-lined chambers that have been previously reported.

Table 2 shows some results of exposure to radium gamma and neutron radiation and to the associated gamma radiations from polonium-boron and polonium-beryllium sources. The chambers were charged to 250 v (zero on the minometer scale) and can be read down to 90 v (250 on the minometer scale). The figures given are the minometer scale readings that are the averages of several exposures. The chambers were filled with air at atmospheric pressure.

TABLE 2

Minometer Readings of Chambers Exposed to Indicated Radiation

EXPOSURE	CHAMBER WALL		
	BERYLLIUM	GRAPHITE	POLYETHYLENE
100 mr Ra $\gamma$	35.0	35.4	35.4
300 mr Ra $\gamma$	105	106.5	106.5
$10^7 n_f$ Po-B	5.07	4.25	15.48
$10^7 n_f$ Po-Be	8.45	6.08	20.58

In monitoring for neutrons, chambers that give an equal gamma-radiation response should be used in pairs: one of the least responsive to neutrons, the graphite-lined chamber, paired with one of the most responsive, the

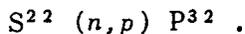
polyethylene chamber. The neutron exposure would be determined by the difference in response. Thus, in the case of polonium-boron neutrons, a week's permissible exposure of  $10^7 n_f$  would give a minometer reading of about 10% of that produced by a week's permissible exposure to radium gamma radiation, or its equivalent. In the field such exposures could easily occur simultaneously; thus, the neutron flux would have to be evaluated as a rather small difference in the total reading. Tests have shown that the ratio is improved to approximately 15% by the use of helium as the filling gas, but no study of the feasibility of using helium in pocket chambers has been made.

Another series of measurements was made at progressively lower air pressures, down to about 6 mm of Hg. As zero pressure was approached, both the graphite- and the polyethylene-lined chambers showed responses that approached zero in approximately a linear fashion. This would imply no measurable heavy-atom (carbon) ionic current. The response of the beryllium-lined chamber did not approach zero, but it approached a value between 1 and 2% of the response at normal pressure for both neutron sources. Since the neutron response of this chamber is more than 20% greater than that of the graphite-lined chamber at normal pressure, it appears that, although some beryllium atoms are given sufficient energy by fast-neutron collision to ionize, this effect is relatively small; and the major part of the added response is from the  $\text{Be}^9(n,\alpha)\text{He}^6$  reaction.

Test tubes containing 10 ml each of carbon disulphide were exposed to

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

polonium-boron neutrons. Sulfur in the compound reacted as follows:



The phosphorus so formed remained dissolved in carbon disulphide; the solution was transferred to counting dishes, evaporated, and then counted at 10% geometry. The results appear in Table 3.

This test is not sensitive enough for personnel monitoring, but it may serve for evaluation of exposure in an atomic disaster.

TABLE 3

Phosphorus<sup>32</sup> Formed by Neutron Bombardment of Carbon Disulphide

$n_f/cm^2$	TOTAL c/min* (above background)	c/min/ $10^7 n_f$
$9.19 \times 10^8$	32	0.35
$5.87 \times 10^8$	20	0.34
$2.61 \times 10^8$	12	0.46
$1.33 \times 10^8$	1	0.08

\* Dishes were counted for 5 minutes.

## MEASUREMENT OF IONIZING RADIATION BY FREQUENCY VARIATION OF AN RF OSCILLATOR

Experiments with a quartz fiber suspension for the electrometer leaf of the variable capacitance showed satisfactory results, but the mechanical vibrations of the system represent an undesirable interference; hence, new construction is under way to reduce these vibrations.

## BETA PARTICLES

T. E. Bortner

The range of beta particles of P<sup>32</sup> has been established in seven different

absorbers, including aluminum. This work was done with a standard thin-window counter, lead shielding, and a 1024 scaler. The results obtained, with a probable error of  $\pm 10$  mg/cm<sup>2</sup>, are as follows:

ABSORBER	RANGE (mg/cm <sup>2</sup> )
Beryllium	863
Carbon	800
Aluminum	800
Copper	700
Tin	660
Tantalum	630
Lead	620

## STRAGGLING OF CONVERSION ELECTRONS FROM BARIUM<sup>137</sup> AS MEASURED WITH THE SOLENOIDAL SPECTROMETER

R. D. Birkhoff      F. Kalil

Experimental work with the solenoidal beta spectrometer has been completed. The measurements that were made of straggling and absorption of 626 kev beta rays in foils of various thicknesses and atomic numbers have been used by an AEC fellow in radiological physics as a basis for his master's degree thesis at Vanderbilt University. Publication of a laboratory report is being delayed pending further analysis and interpretation of the data by several members of the Health Physics Division and the Mathematics Panel.

## CALIBRATION OF MONITORING EQUIPMENT

W. J. O'Brien

Another AEC fellow finished the installation and calibration of monitoring equipment in the State of Tennessee mobile radiological laboratory. This work also will be used to satisfy the thesis requirement for the master's degree at Vanderbilt University.

### SKIN FLUORESCENCE AFTER X AND GAMMA IRRADIATION

R. D. Birkhoff

A new project has been started by the Health Physics Division in co-operation with the University of Tennessee Physics Department. The fluorescence of human skin under ultraviolet light after exposure to x or gamma radiation is being studied with regard to application to dosage measurements.

### EXPERIMENTS ON BETA-RAY BACKSCATTERING

W. E. Moore

A  $2\pi$  beta proportional gas-flow counter is being used to study the backscattering of beta rays from several different materials. The chamber has been removed from the scalar, inverted, and the handle replaced by a  $0.6\text{-mg/cm}^2$  rubber hydrochloride window, coated with Aquadag. The source consists of a small spot of  $\text{P}^{32}$ , which is deposited on the upper side of this window and, therefore, outside the counting chamber. Backscattering materials are then placed above the source by using separation rings to vary the distance.

To study the variation of backscattering with thickness a series of measurements were taken by using thin leaves of gold and aluminum. The curves were plotted with the ratio of the backscattered radiation to the original radiation in percentage as the ordinate and the  $\text{mg/cm}^2$  of the backscatterer as the abscissa. Thin leaves of aluminum, weighing  $0.14\text{ mg/cm}^2$ , and of gold, weighing  $0.18\text{ mg/cm}^2$ ,

were used to study single scattering. When thicker pieces were used, multiple scattering resulted and the curves were made concave downward. Figure 2 shows that single scattering predominates to a thickness of  $1\text{ mg/cm}^2$  for gold and to a thickness of  $2.3\text{ mg/cm}^2$  for aluminum. As the thickness was increased further, the ratio of backscattered radiation to original radiation reached a constant value (saturation backscatter value). This value varied with the atomic number of the scatterer. Thick pieces of 18 elements were investigated, and saturation values were plotted against the atomic number of each.

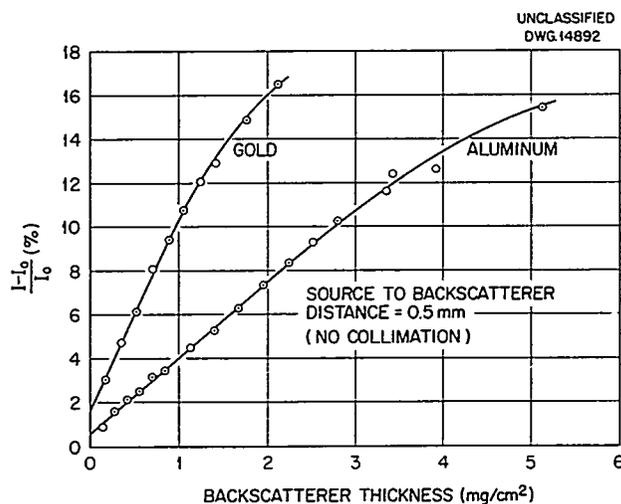


Fig. 2. Phosphorus<sup>32</sup> Backscattering Curves for Aluminum and Gold Leaf.

Collimators were constructed from polyethylene and aluminum so as to give "thickness" a more accurate meaning by limiting the maximum angle of backscattered radiation. The curves were repeated by using these collimated sources. Figures 3 and 4 are typical curves.

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

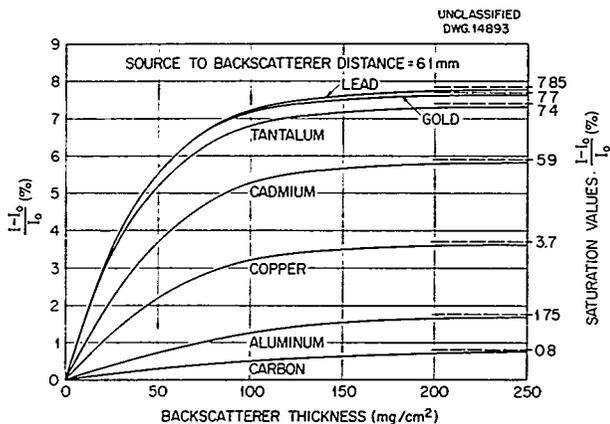


Fig. 3. Backscattering Curves for Phosphorus<sup>32</sup> with Collimation.

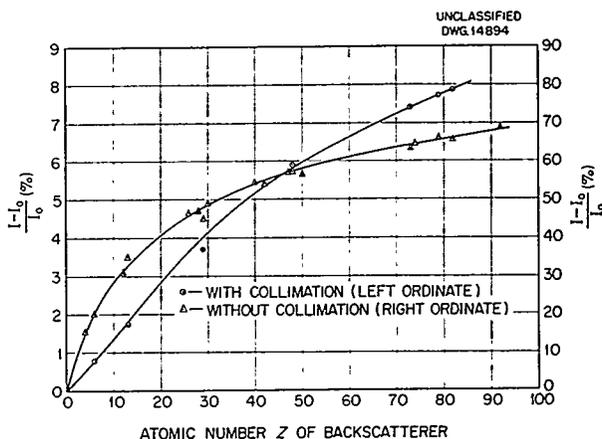


Fig. 4. Saturation Backscattering vs. Z for Phosphorus<sup>32</sup>.

## RADIOCHEMICAL ANALYSIS

L. B. Farabee

### ANALYTICAL PROCEDURE FOR DETECTING PLUTONIUM IN RIVER WATER

There exists a need of a procedure for the analysis of river and stream water for plutonium. This is of special interest to the Oak Ridge National Laboratory, since water from White Oak Lake is discharged into the Clinch River. The procedure now in use is unsatisfactory because of the difficulty of separating plutonium from iron and other inorganic constituents of the sample. Also, indeterminate self-absorption of alpha

radiation results from the plating of extraneous inorganic materials with plutonium. Some preliminary work has been done that was reported in ORNL-968.<sup>(1)</sup>

Recent exploratory tests have resulted in the development of an analytical procedure that is fairly quantitative and reproducible. In 14 determinations the average recovery was 92.0%, with a maximum deviation of  $\pm 4.7\%$ .

(1) Health Physics Division Quarterly Progress Report for Period Ending January 20, 1951, ORNL-968.

PHYSICS OF RADIATION DOSIMETRY

H. H. Hubbell

X-RAY DOSIMETRY

A project to determine the saturation effects of various x-ray dose rates on pocket ionization chambers at various charging voltages has been started.

Personnel monitoring film badges in current use are energy-dependent, and to determine their actual exposure, readings from them must be interpreted in relation to the energy of the radiation affecting them. In the hope of developing a film monitoring device that is not energy-dependent, preliminary exposures on a film badge having filters of iron, cadmium, and lead have been made by using a 250-kv x-ray machine.

One member of this section is representing the Laboratory on the subcommittee on x-ray sensitometry of the American Standards Association. This committee is attempting to standardize techniques for calibrating film used for personnel monitoring and is also writing a sensitometric standard for x-ray film.

TISSUE DEPTH DOSE FOR FAST NEUTRONS

G. S. Hurst

Apparatus has been designed and partly constructed for the purpose of measuring the dose resulting from fast neutrons at various depths in tissue. The neutron source will be the deuterium-deuteron reaction. Measurements will be made by using a tissue phantom consisting of water, urea, and sucrose. The small-diameter proportional counters to be used as dosimeters have been completed.

FAST-NEUTRON DOSIMETER

A contract has been let for the commercial production of fast-neutron count-rate dosimeters of the type previously described. The contractor reports satisfactory progress, and the first 26 instruments should be delivered about April 1, 1952.

PROPORTIONAL-COUNTER DEVELOPMENT

G. S. Hurst            R. H. Ritchie

The equation that describes the shape of a proportional-counter pulse arising from an extended track of ionization in the counter after the pulse has been amplified in a linear amplifier has been evaluated by the Mathematics Panel for various values of track extension and positive-ion collection time.

The results show that the maximum height of the output pulse is essentially independent of the length and position of the track in the counter as long as the ratio of the time of collection of the electrons from the track to the amplifier time constant is not greater than unity. This work will be described completely in a forthcoming paper.

PHYSICAL CALCULATIONS

R. H. Ritchie

A program of shield measurements and air-scattering calculations has been suggested and reported in CF-51-8-7.<sup>(2)</sup> Calculations have been made

<sup>(2)</sup>J. L. Meen and R. H. Ritchie, "Suggested Program for Divided Shield Measurements and Calculation of Air Scattering," CF-51-8-7 (August 1, 1951).

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

of the efficiency of a sodium iodide scintillation counter for a distributed source of beta and gamma rays. Comparisons have been made and reported in CF-51-10-203<sup>(3)</sup> of gamma-ray dosage measurements that were made with a standard gamma-ray chamber<sup>(4)</sup> and those that were made with a gamma-ray spectrometer.<sup>(5)</sup> Calculations are now in progress on the loss in pulse height in a scintillation crystal owing to the formation of Bremsstrahlung through the walls of the crystal.

Calculations are in progress on the effective radius of a beta source in the presence of a scattering foil in a beta spectrometer of the type used by Birkhoff.<sup>(6)</sup>

An expression has been derived for the temperature in a moving medium

---

<sup>(3)</sup>R. H. Ritchie, "Tentative Comparison of Ionization Chamber and Spectrometer Measurements at the Bulk Shielding Facility," CF-51-10-203 (October 31, 1951).

<sup>(4)</sup>L. H. Ballweg and J. L. Meem, "A Standard Gamma-Ray Ionization Chamber for Shielding Measurements," ORNL-1028 (July 9, 1951).

<sup>(5)</sup>J. K. Bair, F. Maienschein, and William Baker, "Multiple Crystal Gamma-Ray Spectroscopy Using NaI-ThI Crystals," NEPA-1701 (February 13, 1951).

<sup>(6)</sup>R. D. Birkhoff, "Distribution of Energy Loss of Electrons in Aluminum," *Phys. Rev.* **82**, 448 (1951).

owing to a stationary volume distribution of sources that vary in strength with time. This expression is a generalization of one given by Carslaw and Jaeger<sup>(7)</sup> and has been applied to a problem considered by Podolsky.<sup>(8,9)</sup>

### BIOPHYSICS

M. Slater

Preliminary work has been done toward setting up a project to study the direct action of charged particles on enzymes and other substances of biological interest. A literature survey has been made on the biological and chemical effects of ionizing radiation. An alpha-particle source and a bombardment chamber are being designed for experimental work. Also in the design stage is a tube for bombarding the substances mentioned with electrons of energies up to 250 kv, principally by using equipment already available in the division or the Laboratory.

---

<sup>(7)</sup>H. S. Carslaw and J. C. Jaeger, *Conduction of Heat in Solids* (Oxford: Clarendon Press, 1949), p. 223.

<sup>(8)</sup>Boris Podolsky, "A Problem of Heat Conduction," *J. Applied Phys.* **22**, 581 (May 1951).

<sup>(9)</sup>R. H. Ritchie, "The Temperature Function in a Moving Medium," *J. Applied Phys.* **22**, 1389 (November 1941).

**EDUCATION AND TRAINING**

E. E. Anderson

M. F. Fair      M. R. Ford

**AEC FELLOWSHIP PROGRAM**

The present group of 19 fellows in radiological physics began their academic work at Vanderbilt University September 24, 1951. Their records for the first quarter are highly satisfactory.

**TRAINING PROGRAM FOR AEC CONTRACTORS PERSONNEL**

Five employees of the DuPont Company have been with this section for training during this period, and four American Cyanamid employees have continued their training. One AEC employee spent two weeks with this section observing field practices in health physics.

**LECTURES AND SEMINARS**

One seminar on health physics was conducted for the Oak Ridge Institute of Nuclear Studies and one lecture on nuclear physics was given for

the Naval Reserve seminar. Lectures on radiation hazards were given at the following institutions as participation in the Traveling Lecture Program of ORNL: University of Mississippi, University of Arkansas, University of Oklahoma, Virginia Polytechnic Institute, and Radford College. An informal conference with science majors was held at Hollins College, Roanoke, Virginia.

**MISCELLANEOUS ACTIVITIES**

Members of the staff continue to assist in other teaching activities in the Laboratory by giving two courses in mathematics in the Apprentice Training School and a course in nuclear physics in the ORNL Staff Education Program.

Considerable time during this period has been devoted to reviewing reports written by members of the division and in writing the section on health physics for the textbook on reactor engineering.

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## EXPERIMENTAL RADIATION MEASUREMENTS

F. J. Davis

### VARIATIONS IN THE RADIUM AND RADON CONTENT OF THE CLINCH RIVER

L. F. Garcia

Measurements were made on the radon and radium content of water samples taken daily from a fixed point on the Clinch River, from October 30 through December 11, 1951. Briefly, the method consists in transferring the radon in a 1500-cc water sample to an evacuated ion chamber by boiling the water and bubbling nitrogen through it. The amount of radon is determined by counting the pulses produced in the chamber by the alpha particles of radon in equilibrium with radium A and radium C. The radium content is determined indirectly by measuring the amount of radon collected in the water sample during a period of approximately 12 days.

This investigation showed (see Fig. 5) that both the radon and radium content increase considerably after a local rainfall. The radon content was found to vary between  $0.73 \times 10^{-12}$  and  $7.75 \times 10^{-12}$  curie/liter, and the radium content varied between  $1.4 \times 10^{-14}$  and  $14.0 \times 10^{-14}$  curie/liter. A consistently high radon/radium ratio - as high as 153 in one day - was observed. There were several instances that seemed to indicate water temperature as an additional cause of the variations in the radon content; however, this was not conclusive.

### VARIATIONS IN THE NATURAL RADIOACTIVITY OF THE FREE ATMOSPHERE AT ORNL

W. C. King

A study of the meteorological influences on the radon and thoron concentrations in the air was made by counting with two scintillation detectors the radium C and C' and thorium C and C' alpha activity deposited on a moving filter. The measurements were separated by a 4-hr time interval. Plots of the diurnal variations of the data collected over several months show excellent correlation with temperature inversions, wind velocity, and relative humidity. Stable air near ground level that exists during a temperature inversion and low-wind velocity favors high concentrations of radon and thoron. Turbulent air, which is produced by high winds or which exists on clear sunny days, produces a minimum in the concentrations. The values may vary by a factor of 5 or 10 during the day. Prolonged dry spells are more favorable to higher peak concentrations than are wet periods. The values have been observed to vary by a factor of 22 between the maximum peaks obtained during a dry period and the minimum peaks obtained during a wet period. The average value found for the radon concentration in air during a two-month period was  $1.2 (10)^{-16}$  curies/cc, with the value of thoron averaging about 3% of that of the radon.

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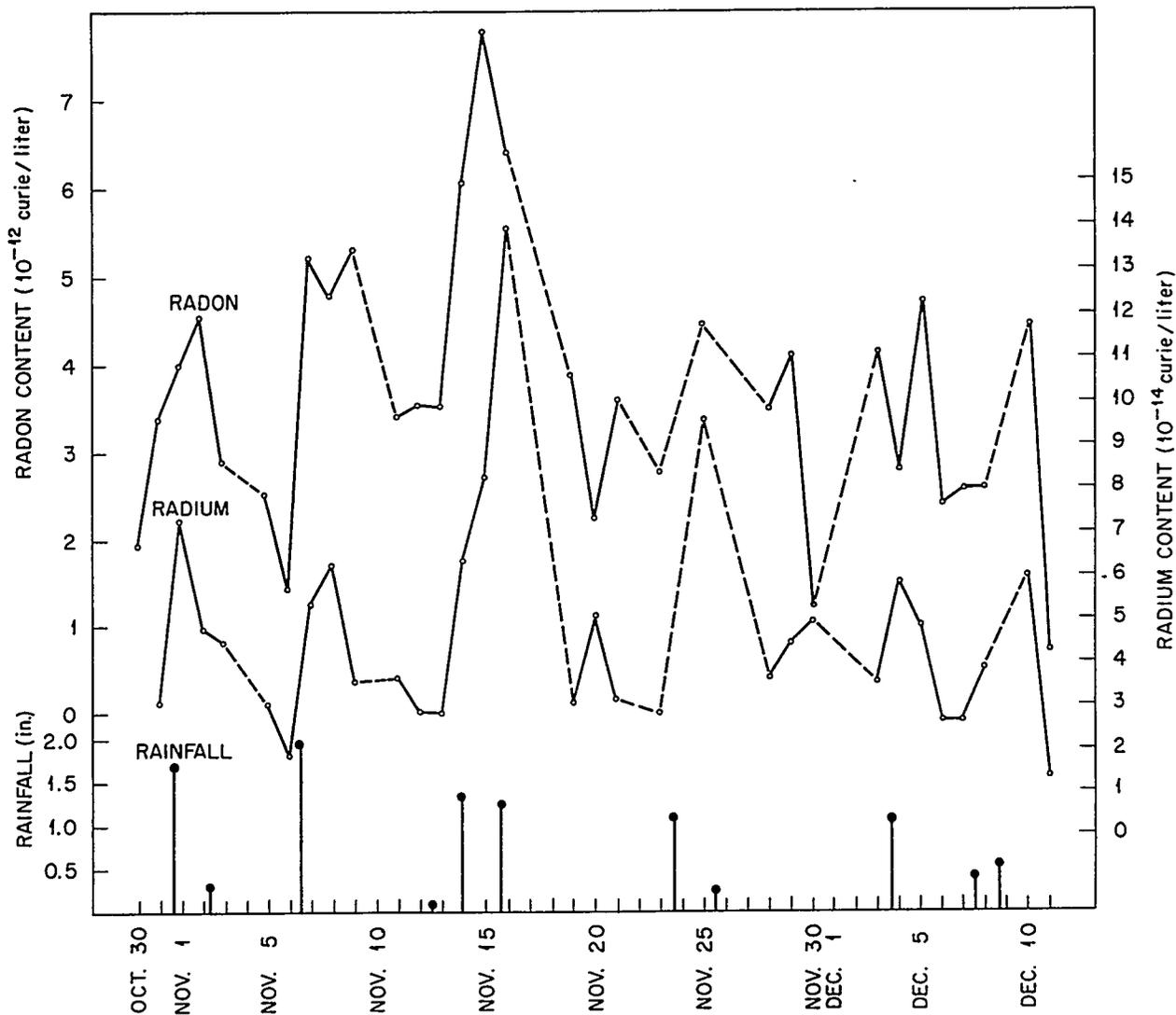


Fig. 5. Local Rainfall and the Radium and Radon Content of the Clinch River. From thesis by Luis F. Garcia, under the direction of Dr. Francis J. Davis - "Variations in the Radium and Radon Content of the Clinch River."

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## PERMISSIBLE INTERNAL DOSE - RADIOISOTOPES

K. Z. Morgan

### UNIVERSITY OF TENNESSEE RESEARCH AND DEVELOPMENT SUBCONTRACT

I. H. Tipton

Twenty-one samples each of human liver, kidney, heart, skeletal muscle, and bone (in most cases vertebra) have been received by the spectrographic laboratory at the University of Tennessee in Knoxville from the Deaconess Hospital pathology department, Boston, Massachusetts. One complete autopsy consisting of samples of human liver, kidney, heart, skeletal muscle, bone, brain, lung, pancreas, spleen, thyroid, gonads, stomach, and intestine have been received from the Ohio State pathology department, Columbus, Ohio. The pathology departments of the University of Alabama,

College of Medicine at Birmingham, Alabama, and the University of Tennessee College of Medicine, Memphis, Tennessee, are also cooperating with the program.

The present analytical technique employed in the program involves carbonizing the tissue samples on a hot plate and then ashing them in a muffle furnace at 500°C. A 20-mg aliquot of the ash is placed in a crater in a 1/4-in. pure spectrographic graphite electrode and burned in a 10-amp, d-c arc. Twenty different elements have been detected by this method. A more sensitive method that employs cathode layer techniques and a method for making quantitative estimates are under development.

---

## PUBLICATIONS AND SPECIAL REPORTS

### PUBLICATIONS

1. C. P. Straub, "Removal of Radioactive Waste," *Nucleonics*, 10, No. 1, 40-44 (1952).

2. O. W. Kochtitzky and O. R. Placak, "Radioactive Contamination as a Factor in Stream Sanitation Studies," *Public Works Journal* (in press).

3. V. I. Knobf, *Preparation of Biological Samples and Correction of Data*, ORNL-1048 (Aug. 3, 1951).

4. A. H. Emmons and R. A. Lauderdale, "A Method for the Detection and Estimation of Low Levels of Radioactive Contaminants in Water," *Nucleonics* (in press).

5. C. P. Straub, *Treatment and Disposal of Liquid Radioactive Wastes*,

American Chemical Society Monograph on Industrial Wastes (in press).

6. W. M. Hurst, *Monitoring of Liquids for Radioactivity*, ORNL-1155 (Feb. 26, 1952).

7. W. M. Hurst, *K<sup>40</sup> Measurements in Body Fluids*, ORNL-1165 (Jan. 4, 1952).

8. J. Neufeld and W. S. Snyder, *On the Energy Dissipation of Moving Ions in Tissue*, ORNL-1083 (Nov. 14, 1951).

9. R. H. Ritchie, "The Temperature Function in a Moving Medium," *J. Appl. Phys.*, 22, 1389 (1951).

10. G. S. Hurst, D. J. Knowles, and C. Yochem, *A Thermal Neutron*

FOR PERIOD ENDING JANUARY 20, 1952

*Survey Instrument*, ORNL-1134 (Jan. 2, 1952).

11. J. L. Meem and R. H. Ritchie, *Program of Shield Measurements and Air Scattering Calculations*, CF 51-8-7 (Aug. 1, 1951).

12. R. H. Ritchie, *Comparison Between Dosage Measurements Made with a Standard Gamma Ray Chamber and Those Made with a Gamma Ray Spectrometer*, CF 51-10-203 (Oct. 31, 1951).

SPECIAL REPORTS

1. C. P. Straub and D. A. Pecsok, *The Removal of Radioactive Materials*

*from Liquid Wastes by Water Supply Facilities*, 118th Meeting of the American Association for the Advancement of Science, Philadelphia, Pa., December 28, 1951.

2. L. A. Krumholz, *A Preliminary Study of the Fish Population of White Oak Lake, September - October, 1950* (February 28, 1951).

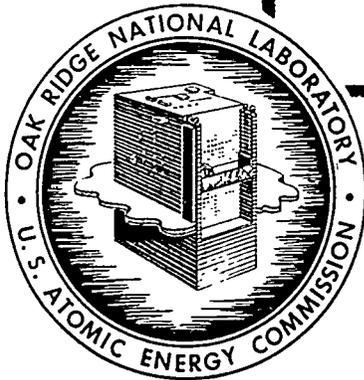
3. T. H. J. Burnett, *An Engineering View of the Hazards and Uses of Radioactivity*, presented at a meeting of the American Society of Heating and Ventilating Engineers, Memphis, Tenn., January 21, 1952.

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HEALTH PHYSICS DIVISION

PROGRESS REPORT

FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952



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**For Period January 20, 1952 to July 20, 1952**

K. Z. Morgan, Director

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## TABLE OF CONTENTS

	PAGE
RADIOACTIVE WASTE DISPOSAL RESEARCH	1
Water and Liquid-Waste Decontamination Processes	1
Survey Studies and Ecological Study of White Oak Creek Drainage Area	2
Instrumentation and Techniques	4
THEORETICAL PHYSICS	7
Fast-Neutron Tolerance Calculations	7
Distribution of Energy Losses of Moving Ions	7
Projects in Progress	8
PHYSICS OF NUCLEAR RADIATIONS	8
Fast-Neutron Monitoring	8
Measurement of Ionizing Radiation by High-Frequency Variation	8
Skin Fluorescence After X-Irradiation	9
New Beta Spectrometer	9
Beta Particles	9
RADIOCHEMICAL ANALYSIS	10
Analysis of Effluent Water for Plutonium	10
PHYSICS OF RADIATION DOSIMETRY	10
X-Ray Dosimetry	10
Beta-Ray Dosimetry	11
Fast-Neutron Dosimeter	11
Dosimetry of Fast Neutrons	11
Tissue Depth Dose for Fast Neutrons	11
Thermal Neutron Measurements	11
Neutron-Scattering Calculations	12
Radiation Dosimetry Using Complex Molecules	12
EDUCATION AND TRAINING	12
AEC Fellowship Program	12
Training Program for AEC Contractors' Personnel	12
Military Training Program	13
Lectures and Seminars	13
Miscellaneous Activities	13
EXPERIMENTAL RADIATION MEASUREMENTS	13
Portable Recording Scintillometer	13
Uranium Prospecting	13

PERMISSIBLE INTERNAL DOSE - RADIOISOTOPES	15
Spectrographic Analysis of Human Tissue	15
Maximum Permissible Concentrations	15
RADIOACTIVE PARTICLE PROGRAM AND PEEP PROGRAM	20
EXPOSURE EXPERIMENT WITH MIXED GAMMA AND NEUTRON RADIATIONS	21
MEASUREMENTS OF THE VALUE OF W FOR ALPHA PARTICLES IN VARIOUS GASES	22
PUBLICATIONS AND SPECIAL REPORTS	23
Publications	23
Special Reports	24

# HEALTH PHYSICS DIVISION PROGRESS REPORT

## RADIOACTIVE WASTE DISPOSAL RESEARCH

R. J. Morton

The organization of the cooperative program of research on water decontamination and other radioactive waste problems by the U. S. Public Health Service and the Oak Ridge National Laboratory was completed during the period covered by this report. This included the assignment of two Public Health Service chemists, which makes a total of seven on-loan employees who are integrated into this joint program.

The project of the Engineer Research and Development Laboratories has been planned in detail for the next fiscal year. In addition to the radiochemist assigned from the Corps of Engineers to this project about a year ago, two technician-operators joined the group about March 1, and on June 24 the transfer of a fourth worker completed the on-loan staff of this project.

Three graduate students have completed their research problems on radioactive waste. These projects are in fulfillment of the thesis requirement in sanitary engineering for master of science degrees to be granted by North Carolina State College, Virginia Polytechnic Institute, and the University of Tennessee.

The Tennessee Valley Authority found it necessary to discontinue the loan of a full-time sanitary engineer to the Health Physics waste research group effective at the end of February. Cooperation of the TVA is being continued through part-time consultation, by the provision of data that are essential to the waste disposal studies at the Laboratory, and by assistance in the conduct of river

survey studies. The TVA continues primary responsibility for the ecological studies of the White Oak drainage area; the first phase of these studies has been completed.

### WATER AND LIQUID-WASTE DECONTAMINATION PROCESSES

T. W. Brockett	D. A. Pecsok
H. E. Butcher	O. R. Placak
M. W. Carter	M. S. Seal
A. G. Friend	C. P. Straub
W. J. Lacy	E. C. Tabor
H. J. Wyrick	

**Removal of Iodine-131 and Strontium-89 from Tap Water by Ion Exchange.** The purpose of this investigation, conducted as a graduate thesis project by A. G. Friend, was to determine the efficiency of ion-exchange resins in the removal of carrier-free radioiodine ( $I^{131}$ ) and carrier-free radiostrontium ( $Sr^{89}$ ) from tap water. The data that were collected indicated excellent positive results.

The concentration of the radioisotopes used in this series of tests was approximately  $1.7 \times 10^{-2} \mu\text{c/ml}$ . The resins employed were a strongly basic type of anion resin (Amberlite IRA-400) and a strongly acid type of cation resin (Amberlite IR-120). The anion resin was used on the chloride and the hydroxide cycles, and the cation resin was used on the hydrogen, sodium, and calcium cycles.

The investigation was conducted in three parts: (1) the removal of  $I^{131}$  by an anion resin bed and a mixed resin bed, (2) the removal of  $Sr^{89}$  by a

## HEALTH PHYSICS DIVISION PROGRESS REPORT

cation resin bed and a mixed resin bed, and (3) the removal of a mixture of  $I^{131}$  and  $Sr^{89}$  by a mixed resin bed. The results showed wide variations in removals, but in all instances superior removals were obtained with the mixed resin bed.

**Evaluation of Water Purification Equipment for the Removal of Fission Products.** Personnel of the Engineer and Research Laboratories have evaluated some water purification equipment to determine the reduction of radioactivity in water that can be obtained. This equipment consists of a standard diatomite filter outfit in a portable 1-man pack that has a capacity of 15 gal/min. The process is discontinuous and treats 500 gal of water per batch. The contaminant used was a 3-year-old fission-product mixture. The constituents of the mixture and their approximate contributions to the activity are given in Table 1. It is presumed that greater removals could be expected on a fresh fission-product mixture containing many easy-to-remove radioisotopes of short half life.

Table 1

CONTAMINANT MIXTURE USED IN EVALUATING WATER-PURIFICATION EQUIPMENT

NUCLIDE	CONTRIBUTION TO TOTAL ACTIVITY (%)
$Ce^{144}-Pr^{144}$	40
$Pm^{147}$	20
$Sr^{90}-Y^{90}$	18
$Ce^{137}-Ba^{137}$	14
$Ru^{106}-Rh^{106}$	6
Others	2
Total	100

The water contaminated with mixed fission products was pretreated either with powdered iron, a local clay slurry, or ferric chloride-limestone coagulation and was then allowed to settle. The supernatant liquid was coagulated by using ferric chloride and calcium carbonate. After it had settled, the supernatant liquid was filtered through the diatomite filter in accordance with standard practice. Figure 1 is a diagrammatic sketch of the procedure used. Samples were taken before and after each treatment and tested for pH, alkalinity (methyl orange), and radioactivity. The results are given in Table 2.

### SURVEY STUDIES AND ECOLOGICAL STUDY OF WHITE OAK CREEK DRAINAGE AREA

T. W. Brockett	V. I. Knobf
M. J. Cook	L. A. Krumholz
E. R. Eastwood	W. T. Miller
J. M. Garner	R. J. Morton
W. T. Helm	F. R. Nease
R. L. Nichols	

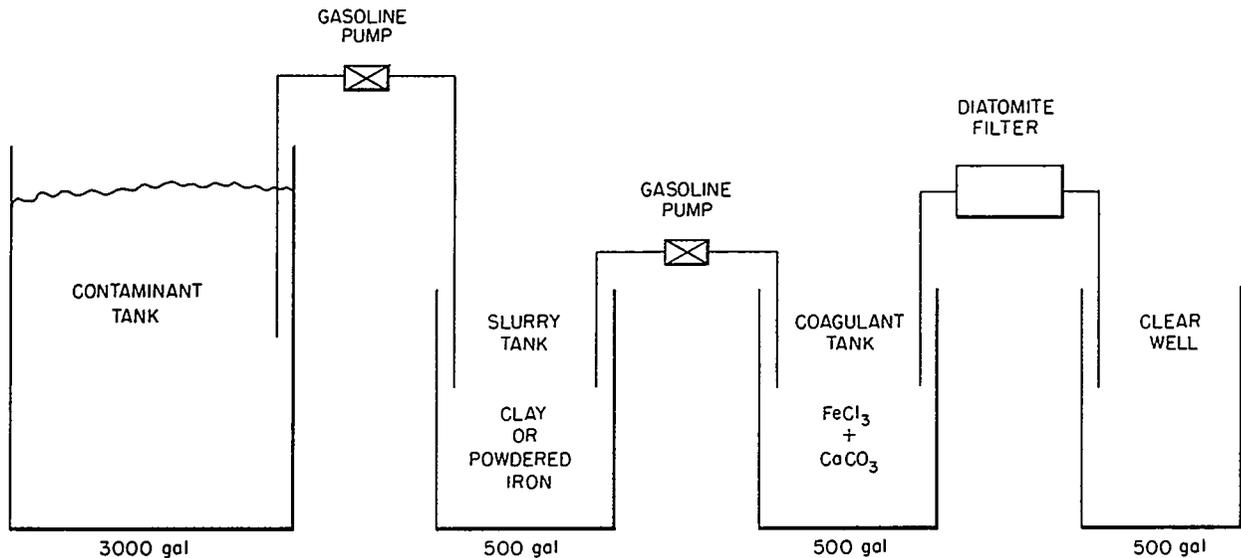
**Ecological Survey of White Oak Creek.** In cooperation with the Department of Botany of the University of Tennessee, specimens of plants collected from the White Oak Creek area have been prepared as permanent collections. Complete reference collections will be maintained at that institution, at the National Herbarium, and at Duke University.

Stomach contents of bluegills and black crappies are being identified and analyzed. The findings are being correlated with the relative abundance of the various organisms taken in the limnological collections.

The field work for the second spring estimate (the fourth in a series of six semiannual estimates) of the fish population of White Oak Lake has been completed. The report for the

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Fig. 1. Diagram of Treatment Procedure.

Table 2

EVALUATION OF DIATOMITE FILTER SET NO. 2

RUN NO.	INITIAL CONDITIONS			TREATMENT		FINAL CONDITIONS			ACTIVITY REMOVED (%)
	pH	Alkalinity (ppm)	Activity* (c/m/ml)	Pretreatment**	Coagulation and Filtration	pH	Alkalinity (ppm)	Activity* (c/m/ml)	
1	7.6	80	2780	335 g of powdered iron	335 g of FeCl <sub>3</sub> 450 g of CaCO <sub>3</sub>	5.6	15	1079	60
2	7.4	82	2781	1890 g of powdered clay	335 g of FeCl <sub>3</sub> 900 g of CaCO <sub>3</sub>	6.2	32	810	71
3	7.8	81	2722	First coagulation 335 g of FeCl <sub>3</sub> 900 g of CaCO <sub>3</sub>	Second coagulation 335 g of FeCl <sub>3</sub> 1350 g of CaCO <sub>3</sub>	5.7	21	1060	61

\*Uncorrected for geometry and coincidence.

\*\*Pretreatment with powdered iron removed 55% of activity.  
Pretreatment with powdered clay removed 60% of activity.  
Pretreatment by coagulation removed 53% of activity.

## HEALTH PHYSICS DIVISION PROGRESS REPORT

third semiannual estimate (September-October, 1951) was released in February. The radioassay of bluegill and black crappie tissues is continuing in order to ascertain what seasonal changes may take place in the amount of radioactive materials accumulated in the various tissues.

A population of *Gambusia affinis affinis*, which originated from the fish introduced into the settling basin in May 1951, has become well established in White Oak Lake. Within 30 days after their introduction into the settling basin more than 50 of these fish and/or their offspring were found in White Oak Lake. In an earlier report<sup>(1)</sup> the population of *Gambusia* in the settling basin was reported as destroyed, presumably by some toxic chemical waste. Such a statement is misleading, inasmuch as a portion of the group obviously migrated downstream into White Oak Lake.

**Location and Studies of Chemical Waste Storage Pits.** The second of two unlined pits for the storage of liquid chemical wastes was constructed during this period. The first pit was installed in July 1951 and was partly filled with wastes during the period August 1 to October 5, 1951. Both pits are located in a deep shale formation on the water shed of White Oak Lake and within the controlled area of the Laboratory. Information obtained from the consulting geologist of the AEC and from the Ground Water Branch of the U. S. Geological Survey indicates that the shale formation is deep and relatively impervious and that seepage of the wastes through the shale away from the pit should be at a very slow rate and in the direction of White Oak Lake. The storage of liquid wastes in these pits is being accepted on an experimental basis.

After preliminary observations on the first pit, the second pit (pit number 2) has been so designed and equipped that extensive studies can be made. Wells 93 ft deep have been dug, one on each of three sides of this pit, and, before any waste was deposited in the pit, records of the ground water elevations in the wells, logging of the wells for natural radioactivity, and chemical analysis of a sample of water from each well were made. A record is made of the volume of each portion of liquid waste that is added to the pit, and a sample of the liquid is taken for analysis and study of its decay rate. The following observations in the pit area are made (some on a continuous basis, others periodically): determination of the liquid level in the pit, logging of the wells for radioactivity, analysis of the water in the wells (chemical and radioassay), determination of ground-water elevation in the wells, scanning of the surrounding ground and vegetation for any evidence of an increase in radioactivity owing to seepage, and estimation of the radioactivity in the pit. The Knoxville office of the U. S. Geological Survey is cooperating in these studies, particularly in the ground water measurements and in the analysis of the water and shale samples. Collateral studies including percolation and contact tests of the shale material to determine the capacity of this material for absorbing and holding radioactive constituents of waste are being made.

### INSTRUMENTATION AND TECHNIQUES

R. H. Dean	F. Kalil
J. M. Garner	B. Kahn
C. E. Graham	W. J. Lacy
R. L. Nichols	

**Evaluation of Commercially Available Instruments for the Measurement of Radioactivity in Water.** Several types

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<sup>(1)</sup>Health Physics Division Quarterly Progress for Period Ending October 20, 1951, ORNL-1174.

FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952

of commercial, portable instruments are being studied to determine how useful and effective they are for the measurement of radioactive contamination in water, particularly for the routine monitoring of water supplies as well as for the detection of emergency levels of contamination that might result from laboratory accidents or atomic explosions. Electroscopes and G-M survey meters have been tested to date.

The responses of several types of portable G-M survey meters to various radioisotopes and to mixtures of fission products in water were observed by using volumes of standard solutions between 0.15 and 7.0 liters with concentrations of radioactivity between  $10^{-4}$  and  $10^{-1}$   $\mu\text{c/ml}$ . Landsverk and Lauritzen electroscopes were investigated by using volumes of less than

0.5 liters and the same range of concentration. The responses of the instruments were obtained for the different standards and likewise for various energies of beta and gamma radiation. Knowledge of the range and sensitivity of the instruments studied will make possible recommendations concerning their use in water monitoring. In connection with this work a series of beta-emitting radioisotopes was studied to select standards covering a wide range of energies.<sup>(2)</sup>

*Electroscopes.* The electroscope may be read over a range of about 10,000 times the lowest detectable concentrations. As indicated in Fig. 2, for representative alpha-, beta-, and gamma-radiation emitters

(2) W. S. Lyon and B. Kahn, *Analytical Chemistry Division Quarterly Progress Report for Period Ending March 26, 1952*, ORNL-1276, p. 21 and 23.

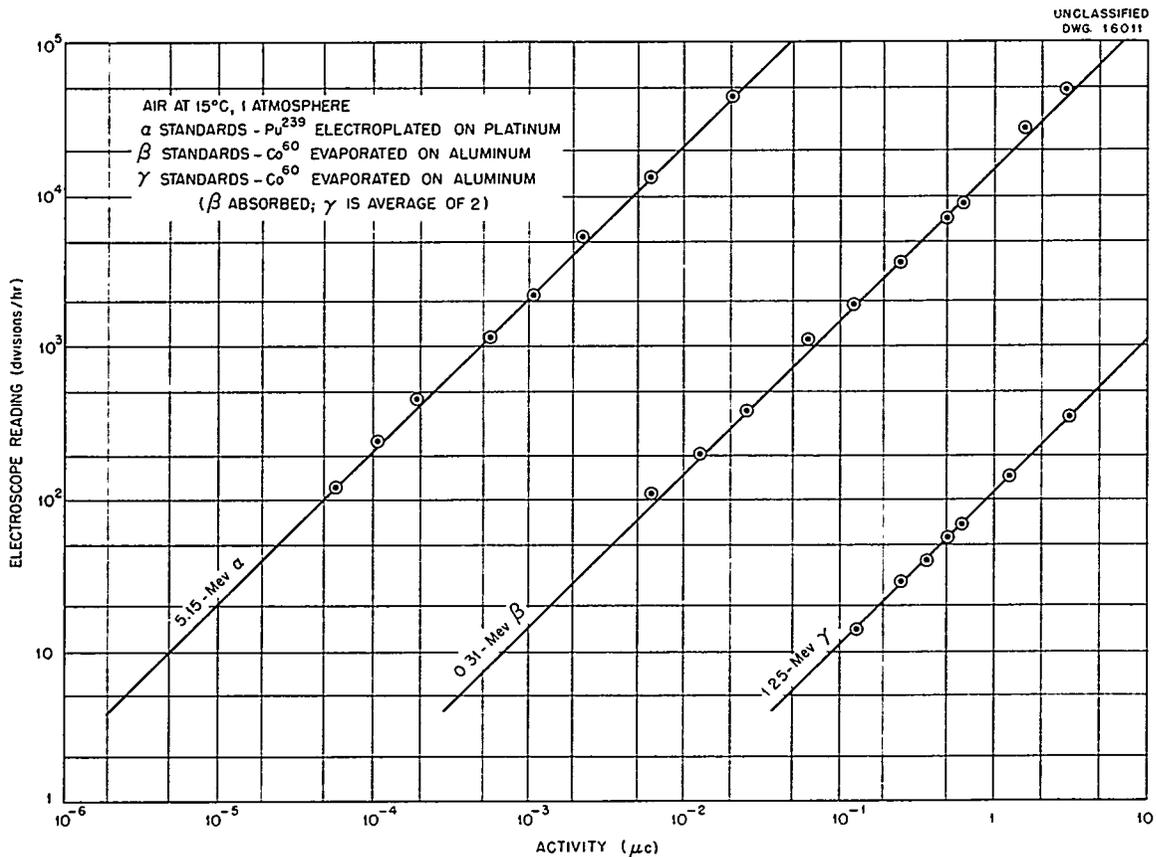
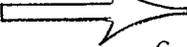


Fig. 2. Sensitivity of Landsverk Electroscope L-75.

NOTE

## HEALTH PHYSICS DIVISION PROGRESS REPORT

that had been deposited upon planchets, alpha radiation was detectable at an activity as low as  $10^{-6} \mu\text{c}$ , beta radiation at  $10^{-4} \mu\text{c}$ , and gamma radiation at approximately  $10^{-2} \mu\text{c}$ . The concentrations in  $\mu\text{c/ml}$  can be calculated from the activity and volume of solution evaporated. Whether these sensitivities are sufficient for routine use may be determined by comparison with the accepted values for the maximum permissible concentration of the various radioisotopes in water (cf., "Maximum Permissible Concentrations," this report). The response of the electroscope is sufficient for determining the concentrations of fission products in drinking water that may be deemed safe for emergency use after an atomic explosion.



*G-M Survey Meters.* The use of sensitive beta-gamma G-M survey meters for the detection of emergency levels of radioactivity in drinking water has been suggested by various workers. The meter readings may be obtained by holding the probe of the instrument above the surface of the sample to be tested or by submerging it. A sample of unknown concentration of radioactive constituents can be monitored in terms of milliroentgens per hour, and such readings can then be converted by means of a calibration curve to concentrations in microcuries per milliliter. In these studies a variety of tests were made with three types of survey meters and with five interchangeable probes by using water solutions of various radioisotopes and of mixed fission products.

It was found that the response of different types of survey meters to

the same solution varied considerably. There was a wide range in the response of any given meter to the solution of different radioisotopes. This range is indicated by the curves shown in Fig. 3. All the radioisotopes studied gave curves falling between those for  $\text{Ru}^{106}$ - $\text{Rh}^{106}$  and  $\text{Tl}^{204}$  (see Fig. 3). It would be expected that a sample containing the usual diverse mixture of unknown radioisotopes probably would fall on a line in the central portion of the range and certainly between the extreme high and low values that are shown. The fission-product curve shown in Fig. 3 was obtained with a three-year-old fission product mixture.

**Monitoring and Telemetering at White Oak Dam.** The installation of equipment for the measuring and recording water elevations and levels of radioactivity at White Oak Dam and telemetering the measurements to the X-10 area has been completed. Preliminary tests have been made and modifications are in progress. After calibration, this system will provide continuous records at the dam and at the Laboratory of the volume of water and the concentration of radioactivity in the water discharged from White Oak Lake.

**Well-logging Equipment.** Two new assemblies of equipment for making logs of the radioactivity in wells have been completed and put into service. Three of these trailer-mounted units are now available for routine observations and for special studies of the 55 test wells that have been drilled in the X-10 area.

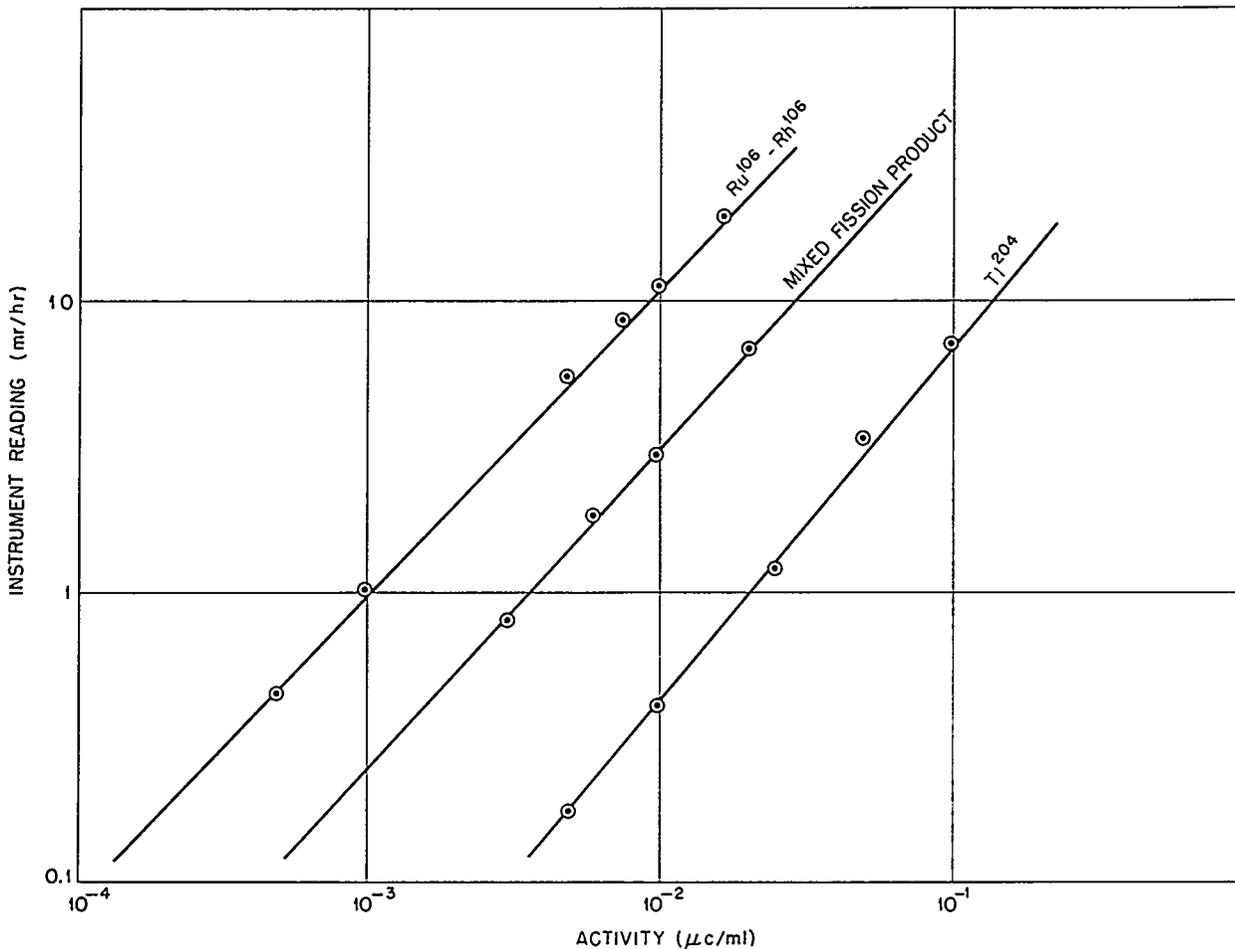


Fig. 3. Typical Readings of a Beta-Gamma Survey Meter with Probe Submerged in Radioactive Solutions of Known Concentrations.

## THEORETICAL PHYSICS

J. Neufeld      W. S. Snyder

### FAST-NEUTRON TOLERANCE CALCULATIONS

The results of the Monte Carlo study of fast-neutron irradiation of tissue have been prepared for publication and a report describing them is being written.

### DISTRIBUTION OF ENERGY LOSSES OF MOVING IONS

Additional evaluations have been made of the fractions of the total energy that are absorbed within portions of various widths in the

## HEALTH PHYSICS DIVISION PROGRESS REPORT

track of a heavy, ionizing particle. These widths have been compared with the size of cells, viruses, etc. in order to estimate the biological effectiveness of the particles. A report comprising these data, together with the graphs representing the energy loss distributions at various distances from the track, has been completed.

### PROJECTS IN PROGRESS

Calculations of maximum permissible exposures for fast and thermal neutrons distributed isotropically, and for beams entering a tissue slab at various angles, are being studied to determine the most efficient program for their computation.

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## PHYSICS OF NUCLEAR RADIATIONS

H. K. Richards

### FAST-NEUTRON MONITORING

J. S. Cheka

A pair of ionization chambers to measure fast neutrons in the presence of gamma radiation is being constructed. Both chambers will be adjusted to give equal response to gamma radiation. The chamber lined with graphite will record gamma-ray ionization only, whereas the other one, which contains a polyethylene lining, will produce, in addition, recoil protons. The difference in ionization will be read by means of an electrometer. Since the permissible exposure of fast neutrons produces only 10% of the ionization of the permissible gamma-ray dose, the calibration will have to be very exact.

An improvement was made in the microscopy of nuclear track film. The current procedure, employed here and elsewhere, consists in the scanning of a number of microscope fields at approximately 900X by using dark-field illumination. Since a field has an area of  $2 \times 10^{-4}$  cm<sup>2</sup>, and a week's permissible exposure produces about  $2 \times 10^3$  recognizable proton tracks per cm<sup>2</sup>, the reliability of the track count in 12, or even 24, fields is low, and the estimate of a fraction

of a week's permissible fast-neutron exposure is meaningless. If the 90X objective is replaced by a 44X objective and 10X-wide field eyepieces are used, the field diameter increases from 0.016 to 0.045 cm and the area increases from 0.0002 to 0.0016 cm<sup>2</sup>, a factor of 8. If stops are set so that the mechanical stage can travel 1.11 cm laterally, a traverse can be made instead of scanning individual fields. With such a traverse 0.050 cm<sup>2</sup> can be scanned in little more time than it takes to read 12 fields (0.0024 cm<sup>2</sup>) at 900X. Thus, exposure to the maximum permissible fast-neutron flux is estimated on the basis of 100 tracks in the scanned area rather than on the basis of five tracks.

### MEASUREMENT OF IONIZING RADIATION BY HIGH-FREQUENCY VARIATION

H. K. Richards

A new electrometer, with a quartz fiber of  $6 \times 10^{-4}$  in. in diameter, was constructed and tested for the measurement of ionizing radiation by high-frequency variation. At the region of maximum sensitivity the frequency variation was about 160 cycles per volt. The carrier frequency was

## FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952

2300 kilocycles. Since the electrostatic capacitance of the electrometer was approximately 4 cm, the variation of the electrostatic charge,  $q$ , per volt is given by:

$$\frac{dq}{dV} = 1.33 \times 10^{-2} \text{ esu/v}$$
$$\text{or } 2.77 \times 10^7 \text{ electrons/v .}$$

By dividing by 160, the charge variation per cycle is given by:

$$\frac{dq}{\text{cycle}} = 8.3 \times 10^{-5} \text{ esu/cycle}$$
$$= 1.73 \times 10^5 \text{ electrons/cycle .}$$

By comparing this order of magnitude with the experimental data, the following result was obtained: A radium-gamma source producing 1.4 mr/hr at the center of the electrometer corresponds to  $2.33 \times 10^{-5}$  esu/min/cc or  $4.85 \times 10^4$  electrons/min/cc. Since the frequency variation amounted to 32 cycles/min the number of electrons or ion pairs/cycle/cc was  $1.52 \times 10^3$ . The total volume was somewhat above 100 cc and the total number of electron pairs was  $1.52 \times 10^5$ , a figure that agrees with the estimated value given above in its order of magnitude.

In addition to the exposure to gamma radiation, neutrons from a polonium-boron source have been used to produce recoil protons from polyethylene inside the electrometer. The number of neutrons was about  $4.7 \times 10^4/\text{min}\cdot\text{cm}^2$ . Since the target area of the polyethylene was about  $25 \text{ cm}^2$ ,  $1.17 \times 10^6$  neutrons were available for proton production. The gamma effect of the polonium-boron source was known by a previous measurement without the polyethylene. A 1-in. bismuth shield reduced the gamma-ray effect to a minimum. The frequency change caused by the recoil protons was measured as 17 cycles per minute.

A new electrometer with quartz crystals as frequency stabilizers has been completed. At frequencies between 15 and 30 megacycles, the frequency can be varied within 10 to 20 kilocycles by adding parallel reactances to the crystal circuit. It is intended that the electrometer capacitances be used to produce these variations.

### SKIN FLUORESCENCE AFTER X-IRRADIATION

R. D. Birkhoff

The fluorescence of human skin under ultraviolet light after exposure to x radiation was studied with regard to its application to dosage measurements in a preliminary survey started by the Health Physics Division in cooperation with the University of Tennessee Physics Department. Fluorescence for some persons was observed, but variation in light output for an individual and also between individuals was so great that dosage measurements by this method were not deemed practical.

### NEW BETA SPECTROMETER

R. D. Birkhoff      A. W. Smith

Plans for the new beta spectrometer and associated control circuits are nearing completion. Much of this work is under the direction of A. W. Smith, a temporary summer employee, from Baylor University. Actual construction has been started at K-25 after several delays owing to difficulties in obtaining material and to schedule conflicts.

### BETA PARTICLES

T. E. Bortner

The range of beta particles of  $P^{32}$  has been established in seven different

## HEALTH PHYSICS DIVISION PROGRESS REPORT

absorbers, including aluminum. This work was done with a standard thin-window counter inside a lead shield. Full details are given in another report. <sup>(1)</sup>

During the work previously described it was found that the beryllium absorbers were emitting ionizing particles. It was shown that the source of radiation was not surface

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<sup>(1)</sup>T. E. Bortner, *The Range of Beta Particles of P<sup>32</sup> in Different Atomic Number Absorbers*, CF 52-2-81 (February 14, 1952).

contamination. The beta-ray energy appeared to be about 1 Mev. Spectrographic analysis gave no hint as to the identity of the radioactive element.

The power supply on the magnetic separator has been changed so that its output is about 3 amp instead of 10. This current is ample for the contemplated beta-ray work and is more easily controlled than the higher current. The magnetic field has been measured and plotted for various sizes and shapes of pole faces.

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## RADIOCHEMICAL ANALYSIS

L. B. Farabee

### ANALYSIS OF EFFLUENT WATER FOR PLUTONIUM

Recently, revisions were made in the analytical procedures for the assay of plutonium in the effluents discharged from the settling basin into the White Oak Creek and from the White Oak Dam into the Clinch River. The procedure for the analysis of water taken at the White Oak Dam was reported previously. <sup>(1)</sup> During the last several

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<sup>(1)</sup>*Health Physics Division Quarterly Progress Report for Period Ending January 20, 1952*, ORNL-1277.

months, work has been conducted in selecting and testing a suitable procedure for the analysis of plutonium in the effluent water discharged from the settling basin. The procedure selected was fairly quantitative and reproducible, and with it an average recovery of 89.4% (with a maximum deviation of 5.3%) was achieved in 15 experimental runs. As of July 1, 1952 these new procedures were put into use for the routine analyses of composite water samples by the Chemical Analysis Unit of the Applied Health Physics Sections.

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## PHYSICS OF RADIATION DOSIMETRY

H. H. Hubbell

### X-RAY DOSIMETRY

H. H. Hubbell      F. H. W. Noll

Design has been completed and construction begun on the apparatus to measure the saturation effects in pocket ionization chambers at different dose rates.

The standard air-ionization chamber in the Division has been modified with an improved voltage divider, insulators, connectors, and carefully measured window diaphragms. Sets of aluminum, copper, and lead filters have been made for the x-ray machine for standardization of the effective energy of the x radiation for any

## FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952

setting of the controls. The x-ray machine will then be used for a re-determination of the energy dependence of the sensitivity of all readily available types of commercial x-ray and personnel monitoring film.

### BETA-RAY DOSIMETRY

H. H. Hubbell

Work has been resumed on a pocket chamber designed to have the usual sensitivity to gamma rays and also to be sensitive to any beta rays that have sufficient energy to penetrate the dead layer of the human epidermis. A sample chamber is being tested. A hollow uranium cylinder has been constructed as a standard exposure source; it gives dose values that agree with the values calculated from results obtained with the extrapolation chamber on plane sources.

### FAST-NEUTRON DOSIMETER

H. H. Hubbell

Satisfactory models of the portable, fast-neutron, count-rate dosimeter previously described are now being delivered under contract by a commercial manufacturer. The instruments made under this contract are checked and calibrated at ORNL and then distributed to various AEC sites as requested by the AEC Radiation Instruments Branch.

### DOSIMETRY OF FAST NEUTRONS

G. S. Hurst

Work has continued on the development of a nondirectional fast-neutron detector that may be calibrated by means of an alpha-particle source contained within the counter. It

should be possible to measure with this detector in absolute units the energy absorbed from a fast-neutron beam per gram of ethylene, which approximates soft tissue in composition. It was previously found that the energy absorbed from fast neutrons was a factor of 2 or 3 less than the calculated values. A reason for this factor was thought to be the capture of most of the free electrons by oxygen atoms; consequently a purifier containing hot calcium was added to the counter, and agreement within about 5% is now obtained between the measured and computed values of the energy absorption.

### TISSUE DEPTH DOSE FOR FAST NEUTRONS

G. S. Hurst      T. A. Barr, Jr.

The apparatus for measuring the tissue depth dose from fast neutrons has been completed. The phantom consists of a cylindrical tank 30 cm in height and 200 cm in diameter, filled with a mixture of urea, sugar, and water in such proportions as to duplicate average soft tissue. The dosimeters are small proportional counters lined with polyethylene and filled with ethylene in order to approximate a Bragg-Gray cavity. The dose value will be obtained from these counters by integrating the heights of the pulses with the apparatus described by Glass and Hurst.<sup>(1)</sup> Calibration of the electronic instruments and the neutron counter is nearly completed.

### THERMAL-NEUTRON MEASUREMENTS

R. H. Ritchie

An ORNL report on the determination of the diffusion length in graphite

<sup>(1)</sup>F. M. Glass and G. S. Hurst, *Rev. Sci. Instruments* (February 1952), p. 67.

## HEALTH PHYSICS DIVISION PROGRESS REPORT

is complete and in the process of declassification.

A restandardization of the thermal flux in the X-10 sigma pile is nearly complete and will be written up as an ORNL report.

A letter has been submitted to the editor of the *Physical Review* on "Thermal Neutron Measurements in Graphite Using Gold and Indium Foils," by E. D. Klema and R. H. Ritchie.

### NEUTRON-SCATTERING CALCULATIONS

R. H. Ritchie

Extensive calculations have been made on the scattering of fast neutrons from the ground and from various structures, and results are given in several classified reports. <sup>(2,3)</sup>

Two chapters are being prepared for the shielding section of the *Reactor Handbook*, one on the maximum permissible exposure for various radiations and the other on the scattering of gamma

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<sup>(2)</sup>E. P. Blizard, C. E. Clifford, J. L. Meem, R. H. Ritchie, and A. Simon, *Proposal for a Divided Shield for Testing Facility*, CF 52-4-85 (April 4, 1952).

<sup>(3)</sup>A. Simon and R. H. Ritchie, *Background Calculations for the Proposed Tower Shielding Facility*, ORNL-1273 (to be issued).

and neutron radiations from various shielding structures, etc.

### RADIATION DOSIMETRY USING COMPLEX MOLECULES

M. Slater

Equipment and materials have been collected for the study of the inactivation of complex molecules, such as enzymes, by heat and by ionizing radiations. This work is envisaged as the first step in a larger program of studying the basic problems of dosimetry in tissue. As a source of electrons for this work, a small accelerator has been designed through the extensive cooperation of the High Voltage Section of the Physics Division. Its main components are now being fabricated.

Assay methods and techniques have been studied, and the properties of a commercially prepared sample of the enzyme catalase, which catalyzes the decomposition of hydrogen peroxide, have been investigated. The properties, such as reaction velocity, optical absorption spectrum, effects of concentration, pH, and reaction temperature, etc., agree reasonably well with those reported in the literature. They will be compared with those found for dry and wet samples inactivated by heat or radiation or both.

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### EDUCATION AND TRAINING

E. E. Anderson      M. F. Fair  
M. R. Ford

#### AEC FELLOWSHIP PROGRAM

The graduate course in radiological physics taught by members of the Health Physics Division at Vanderbilt University began February 4 and continued, during the remainder of the school year, through May 26. The Fellows began their field-training program at

the Oak Ridge National Laboratory on June 11.

#### TRAINING PROGRAM FOR AEC CONTRACTORS' PERSONNEL

Four employees of the DuPont Company have been associated with this section for training during this

## FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952

period, and one employee of the Dow Chemical Company received training for a period of one week. Four American Cyanamid Company employees completed their assignment at the Laboratory and left for Idaho in May.

### MILITARY TRAINING PROGRAM

Pfc. Prestele from Camp Detrick, Maryland, spent three and one-half weeks at the Laboratory observing Health Physics practices in the field.

Ten medical officers from Duke University and five from Reed College spent eight weeks during this period in lectures, classroom work, and field training.

### LECTURES AND SEMINARS

Four seminars on health physics were conducted for ORINS. As participation

in the Travel Lecture Program of ORNL, lectures on radiation hazards were given as follows: single lectures at Alabama Polytechnic Institute, the University of Georgia, Meharry Medical College, Quartermaster's School at Fort Lee, Virginia, and at Chattanooga; two at Vanderbilt University; and two at the University of Tennessee, Memphis.

### MISCELLANEOUS ACTIVITIES

Members of the staff continued to assist in other teaching activities of the Laboratory, which consisted of giving two courses in mathematics in the Apprentice Training School and of presenting the lectures on health physics in the Orientation Program.

The first draft of the section on health physics for the textbook on reactor engineering has been completed.

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## EXPERIMENTAL RADIATION MEASUREMENTS

F. J. Davis

### PORTABLE RECORDING SCINTILLOMETER

C. F. Harris            J. A. Harter

A project for the development of a portable recording scintillometer weighing approximately 25 lb for use in light aircraft has been initiated. In case of a disaster, this instrument can be used for making a rapid survey to determine the radiation hazard of a contaminated area. Other possible uses for it are uranium prospecting, determining the extent of accumulated contamination in areas that surround industries which use or process radioactive material, or determining the fall-out from atom bomb explosions.

### URANIUM PROSPECTING<sup>(1)</sup>

F. J. Davis            P. W. Reinhardt

Surveys of areas in Wyoming and Colorado were made during the month of May; however, further work was halted owing to contamination of areas by the recent atomic tests. In the neighborhood of Casper, Wyoming, on May 24, the background was found to be 4 to 5 times normal (normal being that at the Knoxville, Tennessee, airport). After the atomic blast on May 25, the radiation was found to be 18 to 20 times normal near Denver on May 27. Figure 4

(1) In cooperation with the U. S. Geological Survey.

# HEALTH PHYSICS DIVISION PROGRESS REPORT

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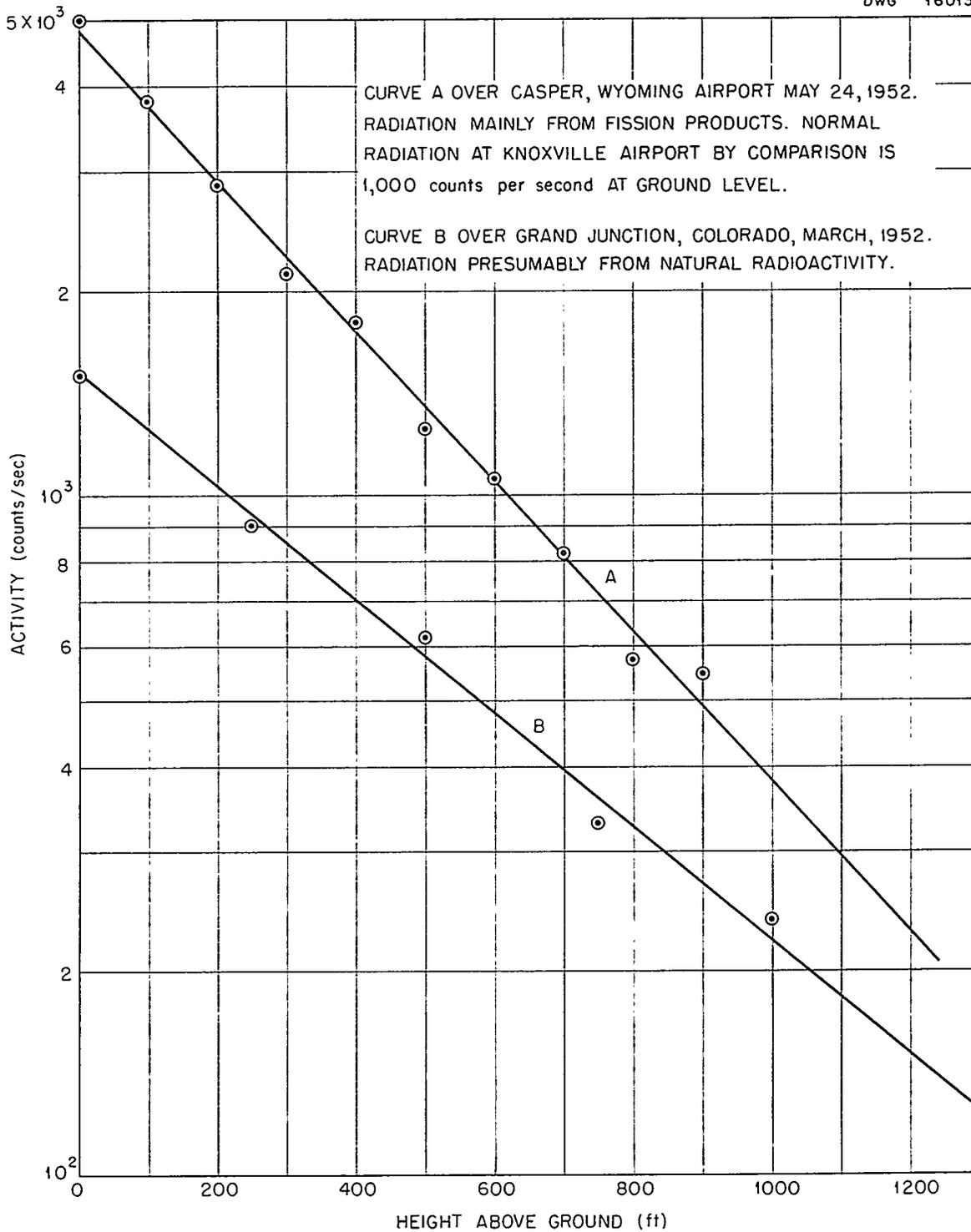


Fig. 4. Variation of Radiation with Height.

shows the variation of radiation intensity with height. Curve A in this figure represents data taken on May 24 at the Casper, Wyoming, airport, where the bulk of the radiation was from fission products. For comparison purposes, curve B represents data taken in March 1952 at the Grand Junction, Colorado, airport, where the radiation was presumably from natural sources. Both curves are nearly straight-line on semilog coordinates, which indicates that the radiation as a function of height can be expressed as a simple exponential function. This exponential function can be derived theoretically

by assuming a buildup from scattered radiation that is proportional to the height, as suggested in an earlier progress report.<sup>(2)</sup> It is to be noted that the slope of curve A is greater than that of curve B. The half thickness of air for curve A is 260 ft; for curve B it is 370 feet. This can be explained by assuming that the gamma rays from the fission products have a different energy distribution than those from natural radioactivity.

<sup>(2)</sup>Health Physics Division Quarterly Progress Report for Period Ending July 15, 1950, ORNL-786.

## PERMISSIBLE INTERNAL DOSE - RADIOISOTOPES

K. Z. Morgan

### SPECTROGRAPHIC ANALYSIS OF HUMAN TISSUE<sup>(1)</sup>

I. H. Tipton

Since January 20, 56 tissues from Deaconess Hospital in Boston, 15 from Alabama Medical College in Birmingham, 36 from the University of Tennessee Medical College in Memphis, and 15 from Ohio State University Medical School in Columbus have been received for spectrographic analysis.

The tissues are carbonized on a hot plate and ashed in a muffle furnace at 500°C. Three milligram samples of ash are mixed with the same amount of pure powdered graphite and loaded into a crater 1/4 in. deep and 1/16 in. in diameter in a 1/8-in. pure-graphite electrode. This electrode is made the cathode in a 10-amp d-c arc, and the cathode layer is focused on the slit of a Bausch and Lomb Littrow spectrograph. The region 2488 Å to 3474 Å is photographed on Eastman Spectrum Analysis No. 2 plate, and quartz

<sup>(1)</sup>University of Tennessee Research and Development Subcontract.

optics are used. Glass optics are used for the region 3900 Å to 5300 Å.

All the tissues received to date have been ashed and their spectra recorded. The plates are being examined qualitatively. Ash standards are being prepared for quantitative estimations for 23 elements.

### MAXIMUM PERMISSIBLE CONCENTRATIONS

K. Z. Morgan            M. J. Cook  
M. R. Ford

Calculations have been made for the maximum permissible amounts of certain radioisotopes in the human body, in water, and in air. In Table 3 are listed the data that have already been approved by the Subcommittee on Internal Dose of the National Committee on Radiation Protection.

Table 4 gives data on supplementary isotopes. This information has been submitted to the Subcommittee and tentatively approved.

The data in Table 5 were calculated recently and will be submitted to the Subcommittee.

# HEALTH PHYSICS DIVISION PROGRESS REPORT

Table 3

APPROVED MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN AIR AND WATER FOR CONTINUOUS EXPOSURE

ELEMENT	ORGAN	TOTAL BODY ( $\mu\text{c}$ )	WATER ( $\mu\text{c}/\text{cc}$ )	AIR ( $\mu\text{c}/\text{cc}$ )
Natural U (soluble)	Kidneys	0.02	$7 \times 10^{-5}$	$1.7 \times 10^{-11}$
Natural U (insoluble)	Lungs	0.009		$1.7 \times 10^{-11}$
U <sup>233</sup> (soluble)	Bone	0.04	$1.5 \times 10^{-4}$	$1 \times 10^{-10}$
U <sup>233</sup> (insoluble)	Lungs	0.008		$1.6 \times 10^{-11}$
Ra <sup>226</sup>	Bone	0.1	$4 \times 10^{-8}$	$8 \times 10^{-12}$
Rn <sup>222</sup>	Body		$2 \times 10^{-6}$	$10^{-8}$
Pu <sup>239</sup> (soluble)	Bone	0.04	$1.5 \times 10^{-6}$	$2 \times 10^{-12}$
Pu <sup>239</sup> (insoluble)	Lungs	0.008		$2 \times 10^{-12}$
Po <sup>210</sup> (soluble)	Spleen	0.02	$3 \times 10^{-5}$	$2 \times 10^{-10}$
Po <sup>210</sup> (insoluble)	Lungs	$7 \times 10^{-3}$		$7 \times 10^{-11}$
C <sup>14</sup> (CO <sub>2</sub> )	Fat	250	$3 \times 10^{-3}$	$10^{-6}$
C <sup>14</sup> (CO <sub>2</sub> )	Bone	1500	$4 \times 10^{-3}$	$5 \times 10^{-7}$
H <sup>3</sup> (HTO or H <sub>2</sub> O)	Total body	$10^4$	0.2	$2 \times 10^{-5}$
Ca <sup>45</sup>	Bone	65	$5 \times 10^{-4}$	$3 \times 10^{-8}$
P <sup>32</sup>	Bone	10	$2 \times 10^{-4}$	$1 \times 10^{-7}$
K <sup>42</sup>	Muscle	20	$1 \times 10^{-2}$	$2 \times 10^{-6}$
S <sup>35</sup>	Skin	100	$5 \times 10^{-3}$	$10^{-6}$
Na <sup>24</sup>	Total body	15	$8 \times 10^{-3}$	$2 \times 10^{-6}$
Cl <sup>36</sup>	Total body	200	$2 \times 10^{-3}$	$4 \times 10^{-7}$
Fe <sup>55</sup>	Blood	$1 \times 10^3$	$4 \times 10^{-3}$	$6 \times 10^{-7}$
Fe <sup>59</sup>	Blood	11	$1 \times 10^{-4}$	$1.5 \times 10^{-8}$
Mn <sup>56</sup>	Kidneys	2	0.15	$3 \times 10^{-6}$
Mn <sup>56</sup>	Liver	7.5	0.2	$4 \times 10^{-6}$

FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952

Table 3 (continued)

ELEMENT	ORGAN	TOTAL BODY ( $\mu\text{c}$ )	WATER ( $\mu\text{c}/\text{cc}$ )	AIR ( $\mu\text{c}/\text{cc}$ )
$\text{Cu}^{64}$	Liver	$1.5 \times 10^2$	$8 \times 10^{-2}$	$6 \times 10^{-6}$
$\text{I}^{131}$	Thyroid	0.3	$3 \times 10^{-5}$	$3 \times 10^{-9}$
$\text{Zn}^{65}$	Bone	430	$6 \times 10^{-2}$	$2 \times 10^{-6}$
$\text{Sr}^{89}$	Bone	2	$7 \times 10^{-5}$	$2 \times 10^{-8}$
$\text{Sr}^{90}\text{-Y}^{90}$	Bone	1	$8 \times 10^{-7}$	$2 \times 10^{-10}$
$\text{A}^{41}$	Total body	30	$5 \times 10^{-4}$	$5 \times 10^{-7}$
$\text{Xe}^{133}$	Total body	300	$4 \times 10^{-3}$	$4 \times 10^{-6}$
$\text{Xe}^{135}$	Total body	100	$1 \times 10^{-3}$	$2 \times 10^{-6}$
$\text{Co}^{60}$	Liver	3	$2 \times 10^{-2}$	$10^{-6}$
$\text{Au}^{198}$	Kidneys	10	$3 \times 10^{-3}$	$1 \times 10^{-7}$
$\text{Au}^{199}$	Kidneys	28	$7 \times 10^{-3}$	$2.5 \times 10^{-7}$
$\text{Cr}^{51}$	Kidneys	390	0.5	$8 \times 10^{-6}$
$\text{Ni}^{59}$	Liver	39	0.25	$2 \times 10^{-5}$
$\text{Mo}^{99}$	Bone	50	14	$2 \times 10^{-3}$
$\text{Th}^{234}$	Bone	120	3	$6 \times 10^{-7}$
$\text{As}^{76}$	Kidneys	10	0.2	$2 \times 10^{-6}$
$\text{Ga}^{72}$	Bone	8	9	$3 \times 10^{-6}$
$\text{Ba}^{140}\text{-La}^{140}$	Bone	5	$2 \times 10^{-3}$	$6 \times 10^{-8}$

# HEALTH PHYSICS DIVISION PROGRESS REPORT

Table 4

TENTATIVELY APPROVED MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN  
TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN  
AIR AND WATER FOR CONTINUOUS EXPOSURE

ELEMENT	ORGAN	TOTAL BODY ( $\mu\text{c}$ )	WATER ( $\mu\text{c}/\text{cc}$ )	AIR ( $\mu\text{c}/\text{cc}$ )
F <sup>18</sup>	Bone	24	0.9	10 <sup>-4</sup>
F <sup>18</sup>	Teeth	0.07	2.5 × 10 <sup>-3</sup>	3 × 10 <sup>-7</sup>
Be <sup>7</sup>	Bone	670	1	4 × 10 <sup>-6</sup>
Sc <sup>46</sup>	Spleen	6	0.4	7 × 10 <sup>-8</sup>
V <sup>48</sup>	Bone	20	0.5	10 <sup>-6</sup>
Ge <sup>71</sup>	Kidneys	67	9	4 × 10 <sup>-5</sup>
Rb <sup>86</sup>	Muscle	60	3 × 10 <sup>-3</sup>	4 × 10 <sup>-7</sup>
Y <sup>91</sup>	Bone	15	0.2	4 × 10 <sup>-8</sup>
Nb <sup>95</sup>	Bone	90	4 × 10 <sup>-3</sup>	4 × 10 <sup>-7</sup>
Tc <sup>96</sup>	Kidneys	5	3 × 10 <sup>-2</sup>	3 × 10 <sup>-6</sup>
Ru <sup>106</sup> -Rh <sup>106</sup>	Kidneys	4	0.1	3 × 10 <sup>-8</sup>
Rh <sup>105</sup>	Kidneys	9	1.5 × 10 <sup>-2</sup>	8.5 × 10 <sup>-7</sup>
Pd <sup>103</sup>	Kidneys	6	1 × 10 <sup>-2</sup>	6 × 10 <sup>-7</sup>
Cd <sup>109</sup> -Ag <sup>109m</sup>	Liver	40	7 × 10 <sup>-2</sup>	7 × 10 <sup>-8</sup>
Sn <sup>113</sup>	Bone	80	0.2	6 × 10 <sup>-7</sup>
Te <sup>127</sup>	Kidneys	4	3 × 10 <sup>-2</sup>	10 <sup>-7</sup>
Te <sup>129</sup>	Kidneys	1.3	10 <sup>-2</sup>	4 × 10 <sup>-8</sup>
Cs <sup>137</sup> -Ba <sup>137m</sup>	Muscle	90	1.5 × 10 <sup>-3</sup>	2 × 10 <sup>-7</sup>
La <sup>140</sup>	Bone	24	1	10 <sup>-6</sup>
Re <sup>183</sup>	Thyroid	35	8 × 10 <sup>-2</sup>	8 × 10 <sup>-6</sup>
Re <sup>183</sup>	Skin	600	0.2	2 × 10 <sup>-5</sup>
Ir <sup>190</sup>	Kidneys	21	10 <sup>-2</sup>	7 × 10 <sup>-7</sup>
Ir <sup>192</sup>	Kidneys	3.4	9 × 10 <sup>-4</sup>	5 × 10 <sup>-8</sup>

FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952

Table 4 (continued)

ELEMENT	ORGAN	TOTAL BODY ( $\mu\text{c}$ )	WATER ( $\mu\text{c}/\text{cc}$ )	AIR ( $\mu\text{c}/\text{cc}$ )
Pb <sup>203</sup>	Bone	57	0.1	$6.5 \times 10^{-6}$
At <sup>211</sup>	Thyroid	$6 \times 10^{-4}$	$2 \times 10^{-6}$	$2 \times 10^{-10}$
Am <sup>241</sup>	Bone	0.056	$10^{-4}$	$3 \times 10^{-11}$
Cm <sup>242</sup>	Bone	0.05	$9 \times 10^{-4}$	$2 \times 10^{-10}$
Ce <sup>144</sup> -Pr <sup>144</sup>	Bone	5	$4 \times 10^{-2}$	$7 \times 10^{-9}$
Pr <sup>143</sup>	Bone	29	$4 \times 10^{-1}$	$7.5 \times 10^{-7}$
Pm <sup>147</sup>	Bone	120	1	$2 \times 10^{-7}$
Sm <sup>151</sup>	Bone	420	$5 \times 10^{-1}$	$3 \times 10^{-8}$
Eu <sup>154</sup>	Bone	22	$3 \times 10^{-2}$	$6 \times 10^{-9}$
Ho <sup>166</sup>	Bone	17	23	$3 \times 10^{-6}$
Tm <sup>170</sup>	Bone	19	$2.5 \times 10^{-1}$	$5 \times 10^{-8}$
Lu <sup>177</sup>	Bone	78	24	$5 \times 10^{-6}$
Ag <sup>111</sup>	Liver	36	4	$3 \times 10^{-5}$
Ag <sup>105</sup>	Liver	18	2	$10^{-5}$

# HEALTH PHYSICS DIVISION PROGRESS REPORT

Table 5

MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN AIR AND WATER FOR CONTINUOUS EXPOSURE (to be submitted for approval)

ELEMENT	ORGAN	TOTAL BODY ( $\mu\text{c}$ )	WATER ( $\mu\text{c}/\text{cc}$ )	AIR ( $\mu\text{c}/\text{cc}$ )
W <sup>181</sup>	Bone	32	$1.6 \times 10^{-1}$	$5.4 \times 10^{-6}$
Au <sup>196</sup>	Liver	8	$4.8 \times 10^{-2}$	$1.9 \times 10^{-7}$
Sc <sup>46</sup>	Liver	4.4	$2.6 \times 10^{-1}$	$5.1 \times 10^{-8}$
Sc <sup>47</sup>	Liver	11	2.9	$5.6 \times 10^{-7}$
Sc <sup>48</sup>	Liver	2.8	1.3	$2.6 \times 10^{-7}$
Tl <sup>200</sup>	Muscle	37	$2.2 \times 10^{-2}$	$2.1 \times 10^{-6}$
Tl <sup>201</sup>	Muscle	287	$7.2 \times 10^{-2}$	$6.6 \times 10^{-6}$
Tl <sup>202</sup>	Muscle	218	$2.0 \times 10^{-2}$	$1.9 \times 10^{-6}$
Pt <sup>191</sup>	Kidneys	2.3	$5.6 \times 10^{-3}$	$1.9 \times 10^{-7}$
Pt <sup>193</sup>	Kidneys	2.6	$4.6 \times 10^{-3}$	$1.5 \times 10^{-7}$
Ir <sup>192</sup>	Spleen	3.2	$5.7 \times 10^{-3}$	$2.8 \times 10^{-8}$
Rh <sup>105</sup>	Kidneys	8.9	$3.6 \times 10^{-1}$	$1.4 \times 10^{-6}$
Am <sup>241</sup>	Bone	0.074	$6.9 \times 10^{-5}$	$1.4 \times 10^{-11}$

## RADIOACTIVE PARTICLE PROGRAM AND PEEP PROGRAM

E. G. Struxness

Effective with the start of fiscal year 1953, a new program, the Radioactive Particle Program, was inaugurated, and the Protective Equipment Evaluation Program (PEEP), formerly under the supervision of E. D. Shipley, ORNL associate research director, was transferred to the Health Physics Division. Personnel comprising the PEEP group were reassigned, although

actual transfers are not yet effective.

The laboratory facilities, located in Building 2001, X-10 area, are being modified and it is expected that they will be sufficiently complete to permit occupancy by September 1. Meanwhile the investigations are being carried on in the present location, Building 9733-4 at the Y-12 area.

FOR PERIOD JANUARY 20, 1952 TO JULY 20, 1952

## EXPOSURE EXPERIMENT WITH MIXED GAMMA AND NEUTRON RADIATIONS

W. T. Ham      G. S. Hurst  
M. Slater

The following is a summary of the dosimetry measurements proposed for use in Phase I of an experiment involving exposure of animals to a mixed gamma and neutron radiation field at ORNL. The purpose of these measurements is to determine the integral dose to the whole body and to specific organs (lens of eye, testes) with an accuracy commensurate with the biological effects under investigation. Surface dose and depth dose measurements for both neutrons and gamma rays will be made in suitable phantoms. The dosimetry methods proposed can also be used for comparison of the exposure facilities and for more detailed studies in Phase II of this project. The following dosimetry program was proposed after careful consideration had been given to such factors as accuracy, exposure facility time, sensitivity, reproducibility, cost and availability of instruments, fabrication costs, and the use of materials, methods, and geometries that permit theoretical calculations.

The instruments to be used for the gamma-ray measurements are the pocket chamber and film meters presently used for personnel monitoring at ORNL. These will be calibrated under actual exposure conditions with a carbon-wall, CO<sub>2</sub>-gas, ionization chamber available at the exposure

facility. Since the exposure gamma-to-neutron dose ratio (physical units) is to be 10:1, the contribution of the relatively small neutron responses of the pocket chamber and gamma-ray film will be practically negligible and will be automatically taken into account during the calibration under actual exposure conditions.

Fast-neutron dosimetry will be done principally with a polyethylene-wall, ethylene-gas, proportional chamber connected to a pulse-height integrator. This system is insensitive to gamma rays and gives a reading proportional to dose for neutrons above 200 kev. It will be calibrated with a polonium-beryllium source and compared with a similar but larger chamber with a built-in alpha source. Thermal- and fast-neutron dosimetry will be done with neutron-sensitive personnel-monitoring films calibrated by standard sources.

A Failla-Rossi "tissue-equivalent" chamber for measuring the total dose will be borrowed. Subtracting the gamma ray, the fast-, and the thermal-neutron doses from this total dose will give the intermediate (or epithermal) neutron contribution to the dose. Unfortunately no instrumentation is available for measuring energy loss in tissue other than that which results in ionization.

# HEALTH PHYSICS DIVISION PROGRESS REPORT

## MEASUREMENTS OF THE VALUE OF $W$ FOR ALPHA PARTICLES IN VARIOUS GASES

T. E. Bortner      G. S. Hurst

An experiment for the determination of the value of  $W$  (the number of electron volts required to produce an ion pair) for alpha particles in various gases has been started. The alpha particles of known energy are allowed to expend their energy between parallel plates of an ionization chamber. The source placed directly on one of the electrodes is of such a strength that the charge liberated can produce a voltage drop of 0.1 v on a  $0.1073 \pm 0.0002\text{-}\mu\text{f}$  fast condenser in about 10 minutes. The actual change in voltage is determined by means of an electrometer,<sup>(1)</sup> which is used in conjunction with a Rubicon potentiometer as a null indicator. The value of  $W$  can be computed from the known source strength (particles per minute).

The gas-filling and purification apparatus is shown schematically in Fig. 5. The test gas is admitted into the system through a cold trap and a hot copper purifier. The ionization chamber is closed from the manifold, and continuous purification is achieved by convection over hot calcium.

The results in Table 6 have been obtained for alpha particles from

<sup>(1)</sup>F. M. Glass, *Nucleonics* (February 1952), p. 36.

$\text{Pu}^{239}$ . These results are preliminary and subject to revision as the work progresses.

Table 6

MEASUREMENTS OF THE VALUE OF  $W$  FOR  
ALPHA PARTICLES IN VARIOUS GASES  
AND GAS MIXTURES

GAS	$W(\text{ev/ion pair})$
Argon	26.2*
Nitrogen	36.3
Methane	29.6
Butane	25.9
Ethylene	28.0
10% argon-90% helium	30.2
30% argon-70% helium	29.8
50% argon-50% helium	20.3
70% argon-30% helium	28.5
90% argon-10% helium	27.3
10% argon-90% nitrogen	35.7
30% argon-70% nitrogen	33.7
50% argon-50% nitrogen	31.5
70% argon-30% nitrogen	29.5
90% argon-10% nitrogen	27.5

\*Jesse reports a value of 26.4 for alpha particles in Argon, ANL-4778.

Work is in progress on the determination of  $W$  for helium and other gases and mixtures of gases.

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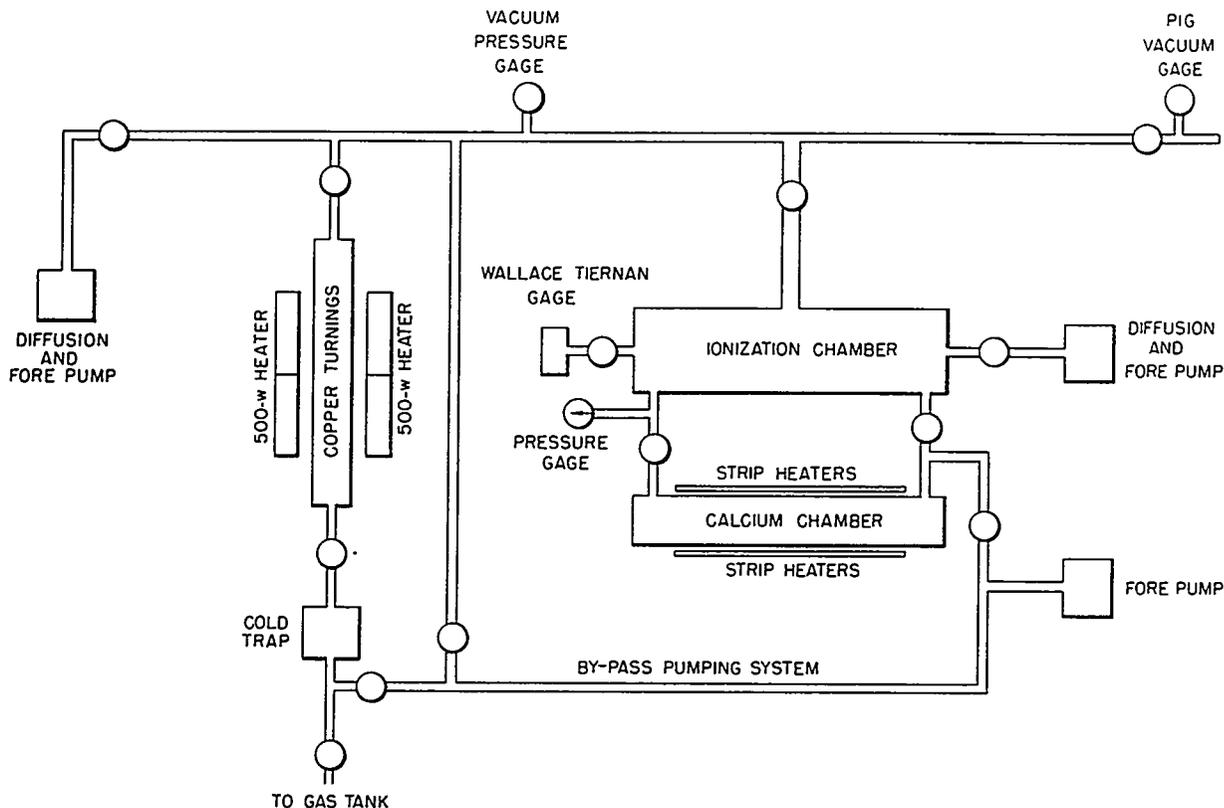


Fig. 5. Block Diagram of Gas-filling Apparatus Used for the Determination of  $W$ . All circles, unless otherwise designated, are cut-off valves.

## PUBLICATIONS AND SPECIAL REPORTS

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2. C. P. Straub, *Public Health Reports* 67, 298-305 (March 1952).

3. O. W. Kochtitzky and O. R. Placak, *Public Works* 83, 76 (June 1952).

4. F. P. Cowan, R. A. Love (BNL), and L. B. Farabee, *Am. J. Roentgenol.*,

*Radium Therapy, and Nuclear Medicine* 67, 805-816 (May 1952). (Previously published as AECU-1169.)

5. F. M. Glass and G. S. Hurst, *Rev. Sci. Instruments* 23, 67 (Feb. 1952).

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7. A. Simon and R. H. Ritchie, *Background Calculations for the Proposed Tower Shielding Facility*, ORNL-1273 (in publication).

## HEALTH PHYSICS DIVISION PROGRESS REPORT

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9. R. L. Heath and P. R. Bell, *Phys. Rev.* **87**, 176 (July 1952).
10. J. R. Horan and G. A. Boyd, *Phys. Rev.* **87**, 177 (July, 1952).
11. K. Z. Morgan and C. P. Straub, *Phys. Rev.* **87**, 178 (July 1952).
12. I. H. Tipton, *Phys. Rev.* **87**, 179 (July 1952).
13. E. D. Klema, R. H. Ritchie, and T. Arnette, *A Determination of the Diffusion Length of Thermal Neutrons in the X-10 Standard Graphite Pile*, ORNL-1340 (July 30, 1952).
5. L. Krumholz and W. T. Miller, *The Second Fall Estimate of the Size of the Fish Population of White Oak Lake, September - October, 1951* (Feb. 5, 1952).
6. L. A. Krumholz and W. T. Miller, *The Second Spring Estimate of the Size of the Fish Population of White Oak Lake, March - April, 1952* (July 29, 1952).
7. F. W. Stead, *Progress in Airborne Radioactivity Surveying* (April 1952). Preliminary report for the U. S. Department of the Interior, Geological Survey.
8. L. F. Garcia, W. C. King, and F. J. Davis, *Variation in the Natural Radioactivity of Air and Water in the Oak Ridge Area*. Paper delivered April 25, 1952 at the USAEC Meeting on Industrial Health.

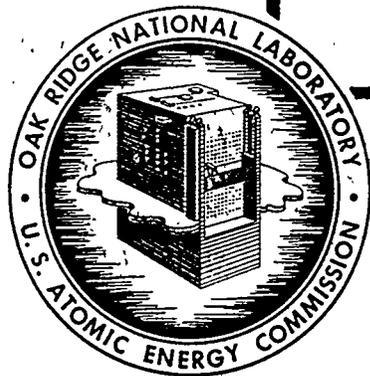
### SPECIAL REPORTS

1. M. W. Carter, *Results of an Investigation on the Removal of a Radioactive Isotope ( $I^{131}$ ) from Sewage by Laboratory Trickling Filters*. (A thesis presented to the Georgia School of Technology in June 1951 and issued as a special report May 1, 1952.)
2. A. G. Friend, *Report on the Investigation of the Removal of Iodine ( $I^{131}$ ) and Strontium ( $Sr^{89}$ ) from Water by Ion Exchange Resins*. (A thesis submitted to the Virginia Polytechnic Institute June 8, 1952 and issued as a special report May 19, 1952.)
3. W. J. Lacy, R. H. Dean, and C. E. Graham, *Use of G.M. Survey Meters for Radioactive Water Monitoring* (April 28, 1952). Work performed at ORNL for the Engineer and Research Laboratories, U. S. Corps of Engineers, Ft. Belvoir, Va.
4. O. R. Placak, *Recommendations for the Disposal of Carbon-14 Wastes* (July 12, 1952). Report for the Subcommittee on Waste Disposal and Decontamination, to be published.
9. A. D. Warden, *Instrumentation for Monitoring Airborne Activity*. Paper delivered April 25, 1952 in Cincinnati, Ohio, at the USAEC Meeting on Industrial Health.
10. D. M. Davis, J. C. Hart, and K. Z. Morgan, *Aerial Surveying with Light Aircraft for the Detection of Radioactive Contamination on the Ground*. Paper delivered April 25, 1952 in Cincinnati, Ohio, at the USAEC Meeting on Industrial Health.
11. G. S. Hurst and R. H. Ritchie, *Fast Neutron Dosimetry*. Paper presented at the Symposium on the Biophysical and Biological Effects of Neutrons, AEC Division of Biology and Medicine, Washington, D.C., March 17-18, 1952.
12. W. S. Snyder and J. Neufeld, *Maximum Permissible Neutron Flux for Fast and Thermal Neutrons*. Paper presented at the Symposium on the Biophysical and Biological Effects of Neutrons, AEC Division of Biology and Medicine, Washington, D.C., March 17-18, 1952.

HEALTH PHYSICS DIVISION

QUARTERLY PROGRESS REPORT

FOR PERIOD ENDING OCTOBER 20, 1952



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**QUARTERLY PROGRESS REPORT**  
**For Period Ending October 20, 1952**

K. Z. Morgan, Director

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# CONTENTS

	Page
RADIOACTIVE-WASTE DISPOSAL RESEARCH .....	1
Water and Liquid-Waste Decontamination Processes .....	1
Surveys and Evaluations – Field and Laboratory .....	1
ECOLOGICAL STUDY .....	4
THEORETICAL PHYSICS .....	5
Fast-Neutron Tolerance Calculations .....	5
Thermal-Neutron Tolerance Calculations .....	5
Stopping Power of Fission Fragments in Light Gases .....	5
Energy Distribution of Multiple-scattered Electrons in Foils .....	5
RADIATION DOSE .....	6
Internal Radiation Dose .....	6
Radiochemical analysis .....	6
Spectrographic analysis of human tissue .....	6
External Radiation Dose .....	6
Backscattering of beta particles .....	6
Measurement of ionizing radiation by high-frequency variation .....	6
X-ray dosimetry .....	6
Tissue depth dose for fast neutrons .....	7
Shielding .....	7
Film monitoring for fast neutrons .....	7
Energy losses of electrons in foils .....	7
PHYSICS OF NUCLEAR RADIATION .....	7
Ionization by Alpha Particles .....	7
Measurement of the Electron-Attachment Coefficient for Various Gases .....	8
Dosimetry for Animal Exposures .....	8
EDUCATION, TRAINING, AND CONSULTATION .....	9
AEC Fellowship Program .....	9
Training Program for AEC Contractors' Personnel .....	9
Consultation .....	9
EXPERIMENTAL RADIATION MEASUREMENTS .....	9
Uranium Prospecting .....	9
AIRBORNE RADIOPARTICULATE CONTAMINATION .....	10
Radioactive-Particle Program and PEEP .....	10
PUBLICATIONS .....	10

Reports previously issued in this series are as follows:

ORNL-166	Period Ending August 31, 1948
ORNL-227	Period Ending November 30, 1948
ORNL-346	Period Ending February 28, 1949
ORNL-375	Period Ending July 15, 1949
ORNL-495	Period Ending October 15, 1949
ORNL-596	Period Ending January 15, 1950
ORNL-695	Period Ending April 15, 1950
ORNL-786	Period Ending July 15, 1950
ORNL-877	Period Ending October 20, 1950
ORNL-968	Period Ending January 20, 1951
ORNL-1086	Period Ending July 20, 1951
ORNL-1174	Period Ending October 20, 1951
ORNL-1277	Period Ending January 20, 1952
ORNL-1353	Period January 20 to July 20, 1952

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## RADIOACTIVE-WASTE DISPOSAL RESEARCH

R. J. Morton

### WATER AND LIQUID-WASTE DECONTAMINATION PROCESSES

M. W. Carter	W. J. Lacy
F. L. Cobler	D. A. Pecsok
R. H. Dean	O. R. Placak
C. E. Graham	M. S. Seal
H. L. Krieger	C. P. Straub

**Experimental Study of Commercial Water-Purification Devices.** Two types of commercial water-purification units were evaluated with respect to their effectiveness in removing the radioactive components from a solution of fission products. Twelve units were tested of which four units were provided gratis by the manufacturer and eight units were purchased by the Laboratory. All units contained 36 g of a mixture of diatomaceous earth and activated carbon, 22 g of Nalcite SAR resin, and 22 g of Nalcite HCR resin; and 9 of the 12 units contained, in addition, 42 g of powdered iron. The solution used had an activity of approximately 10,000 c/m/ml (at 10% geometry) and was of the following approximate composition: strontium-yttrium 27.6%, cerium-praseodymium 17.4%, ruthenium-rhodium 3.9%, promethium 22.1%, samarium 1.4%, cesium 27.2%, and other radioisotopes 0.4%. Six series were run and the results are summarized in Table 1. It will be noted that the percentages of removal were quite variable even under similar test conditions. When tap water was used as the diluent, the highest removal observed was 98%. With distilled water, initial removals of 99% were obtained.

### SURVEYS AND EVALUATIONS - FIELD AND LABORATORY

T. W. Brockett	F. Kalil
M. J. Cook	R. J. Morton
J. M. Garner	R. L. Nichols
B. Kahn	O. R. Placak
H. J. Wyrick	

**Ground-Water Conditions at Waste-Storage Pit No. 2.** Studies of ground water and other conditions in the vicinity of pit No. 2 have been

continued as outlined in a previous report.<sup>(1)</sup> With cooperation and assistance from the U. S. Geological Survey, the two test wells nearest the pit have been equipped with continuously recording water-level gages and the water level in a third well has been measured periodically. Three water samples from each of the three wells have been collected for chemical analysis and radioassay. Frequent radiologging measurements in the wells have been made before and after radioactive wastes were transferred to the pit.

Relatively small quantities of liquid radioactive wastes (a total of 16,200 gal) were transferred and deposited in the pit on June 20 and 27 and during the period September 12 to 19, 1952. Until about August 1 all three wells were uncontaminated. On August 12 radiologging indicated a considerable amount of radioactive contamination in one test well and a small amount in another. These two wells are on opposite sides of the pit and approximately 80 ft from the waste pool at the bottom of the pit. The third well, which is 200 ft from one end of the waste pool, was still uncontaminated on October 1. Radiochemical analyses of two samples of water from the more heavily contaminated well indicated that the radioactive material reaching this well from the pit was entirely Ru<sup>106</sup>. The water table underneath the pit is approximately 6 ft lower than the bottom of the pit and has fluctuated less than 2 ft during the entire period of observation.

The data obtained thus far from the ground-water studies indicate that the shale formation is quite uniform and impermeable, a high degree of adsorption of the radioisotopes contained in the wastes occurs (with the exception of ruthenium), and the ground-water level is relatively stable with small, lateral flow rates.

The more rapid and far-reaching migration of ruthenium through the shale formation is of particular interest considering the eight valence states and the various chemical forms in which

<sup>(1)</sup>T. W. Brockett et al., *H-P Prog. Rep. Jan. 20, 1952 to July 20, 1952*, ORNL-1353, p. 4.

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

**TABLE 1. SUMMARY OF RESULTS**

SERIES	INFLUENT ACTIVITY (c/m/ml)	REMOVAL FOR VARIOUS VOLUMES OF THROUGHPUT (%)				AVERAGE REMOVAL IN FIRST 40 LITERS OF THROUGHPUT (%)	FLOW RATE*	pH OF INFLUENT	pH RANGE OF EFFLUENT	PRESENCE OF VISIBLE IRON FLOC	REMARKS
		20 liters	40 liters	60 liters	80 liters						
A	10,970	38	39	39	54	40	0.28 liter/min	7.8	8.9 to 10.0	None	Distilled water flushed through unit for first 20 liters at 3.78 liters/min
B	12,260	95	92	77	60	94.8	20 liters at 3.78 liters/min 2 liters at 0.014 liter/min 54 liters at 0.43 liter/min	7.7	7.3 to 7.7	Much	Spiked solution flushed through units for initial 5-min period at 3.78 liters/min
C-1	11,540	98	95	90	84	98.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	7.4	6.8 to 7.6	Much	Spiked solution flushed through units for initial 5-min period at 3.78 liters/min
C-2	9,100	94	88	82	82	93.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	7.4	7.0 to 7.6	Much	Spiked solution flushed through units for initial 5-min period at 3.78 liters/min
C-3	9,100	87	76	76	76	85.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	7.4	6.5 to 7.1	Much	Spiked solution flushed through units for initial 5-min period at 3.78 liters/min
D-1	9,100	75	51	51	51	66.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	7.4	6.0 to 7.2	None	Unit does not contain powdered iron
D-2	9,100	84	49	49	49	76.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	7.4	6.0 to 7.2	None	Unit does not contain powdered iron
D-3	5,380	84	48	43	43	75.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	7.4	6.2 to 7.1	None	Unit does not contain powdered iron
E-1	10,380	54	42	42	42	58.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	10.0	8.2 to 9.4	Little	Influent pretreated by alum coagulation and sand filtration
E-2	10,380	62	47	47	47	64.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	10.0	7.6 to 8.6	Little	Influent pretreated by alum coagulation and sand filtration
E-3	10,380	54	38	38	38	56.0	20 liters at 3.78 liters/min Balance at 0.47 liter/min	7.4	6.2 to 7.4	Little	Influent pretreated by alum coagulation and sand filtration
F	1,790	99	99	99	43	98.8	20 liters at 3.78 liters/min Balance at 0.47 liter/min	4.4	4.9 to 6.0	Dissolved iron present	Radioactive material diluted with distilled water

\*Manufacturer's operating instructions are in terms of gallons and of pints per minute: 3.785 liters/min = 1 gal/min; 0.473 liter/min = 1 pt/min.

this element may occur. This emphasizes the importance of information concerning the variations in behavior of the different chemical forms of the same element. In some situations the environmental hazards from liquid wastes may depend largely upon the chemical forms in which the radioactive materials are present. For example, the data in Table 2 (next section) show that Ru<sup>106</sup>, which was in the form of ruthenium chloride, was almost completely removed in experiments using shale taken from the site of pit No. 2. In contrast, analyses from the test wells showed that ruthenium passed through more than 80 ft of the shale formation. It is probable, although not confirmed, that this contaminant was present in the wastes as a ruthenate or in other forms that do not interact with the shale material in the same manner as does ruthenium chloride.

**Adsorption of Radioisotopes by Natural Soils.** The study, initiated about six months ago, of the adsorption of radioisotopes from liquid wastes by natural soil materials is being continued. The purpose is to obtain more specific information than is now available regarding the removal and fixation of certain isotopes and mixtures of isotopes by the soil whenever radioactive materials

are released or deposited, for example, in burial grounds, lagoons for sludge or liquid wastes, or from a more widespread dispersion of radioactive contaminants resulting from emergency conditions. Such information is of general interest wherever radioactive contamination of surface or underground soils may occur and is of particular interest to the Laboratory in relation to liquid-waste disposal.

Shale samples obtained from the site of waste storage pit No. 2 have been used in a series of tests to determine the adsorption capacities of the shale for certain radioactive isotopes and mixtures of isotopes. Two methods of testing were used, namely, jar tests and columns.

In the case of the jar-test studies, a range of pulverized shale samples (0.5 to 20.0 g) was placed in a series of one-liter beakers, each beaker containing 500 ml of tap water contaminated with the radioactive isotope or mixture of isotopes to be tested. The contents of the beakers were mixed rapidly (216 rpm) for various intervals (30 min, 1 hr, 2 hr), allowed to settle, and then were sampled for counting. The results obtained are shown in Table 2.

TABLE 2. REMOVAL OF RADIOACTIVE ISOTOPES BY SHALE<sup>(a)</sup>

(Jar-Stirring Method)

JAR NO.	SHALE (g)	OVER-ALL REMOVAL AFTER STIRRING FOR 2 hr (%)									
		Ba <sup>140</sup>	Ce <sup>144</sup>	Cs <sup>137</sup>	I <sup>131</sup>	P <sup>32</sup>	Ru <sup>106</sup>	Sr <sup>90</sup>	Zr <sup>95</sup>	MFP <sup>(b)</sup>	W-8 <sup>(b)</sup>
1	0.5	91.8	98.0	98.2	8.6	48.6	93.0	39.8	98.4	83.5	71.6 <sup>(c)</sup>
2	1.0	94.7	98.3	98.6	22.2	75.2	97.8	40.7	99.0	87.7	74.6
3	2.0	96.4	97.2	98.4	21.8	87.1	98.3	45.1	99.0	90.3	73.4
4	3.0	97.5	99.7	99.2	24.0	82.4	99.5	54.4	99.1		79.5
5	5.0	98.2	98.9	99.2	35.7	88.3	99.5	64.1	99.3	94.7	81.0
6	10.0	99.3	99.9	99.2	39.5	88.2	99.5	73.6	99.4	96.6	83.9
7	12.0	99.5	99.9	99.2	49.2	98.2	99.6	71.9	99.3		81.4
8	15.0	99.7	99.9	99.5	56.8	95.8	99.5	76.9	99.2		84.0
9	18.0	99.8	100.0	99.5	56.1	99.3	99.7	78.0	99.7		82.4
10	20.0	99.8	100.0	99.7	66.9	99.2	99.8	76.8	99.6	98.2	85.2

(a) Level of activity used averaged  $3.24 \times 10^{-2}$   $\mu\text{c/ml}$  or 7200 c/m/ml.

(b) Three-year-old mixed fission-product solution containing approximately 16% Cs, 20% trivalent rare earths, 2% Ru, 20% Sr, 21% Ce, and 21% unknown.

(c) Waste from W-8 waste-storage tank.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

For the column studies, a series of lusteroid columns,  $1\frac{1}{4}$  in. in diameter and 6 in. long, were set up and 75 g of shale sieved to 60 to 70 mesh was placed in each column. Two thousand milliliters of tap water containing the radioactive isotope to be studied was allowed to flow by gravity through each column at a rate of about 20 ml/hour. The effluent was sampled after approximately every 100 ml of flow. Under these conditions 100% removal was obtained for the following isotopes: Ba<sup>140</sup>-La<sup>140</sup>, Ce<sup>144</sup>-Pr<sup>144</sup>, Cs<sup>137</sup>, P<sup>32</sup>, Ru<sup>106</sup>-Rh<sup>106</sup>, and Zr<sup>95</sup>-Nb<sup>95</sup>. However, a maximum removal of 87.3% (at 100 ml of flow) and a minimum of 65.3% (at 1900 ml of flow)

were obtained for I<sup>131</sup>. For Sr<sup>90</sup>-Y<sup>90</sup> a maximum removal of 98.2% (at 100 ml of flow) and a minimum of 79.6% (at 2000 ml of flow) were obtained. A maximum removal of 99.9% (at 100 ml of flow) and a minimum removal of 93.2% (at 2000 ml of flow) were obtained for the fission-product mixture (same as used in jar tests). A maximum of 98.5% (at 50 ml of flow) and a minimum of 85.7% (at 1800 ml of flow) were removed from the waste from tank W-8. The level of activity used in the column tests averaged approximately  $3 \times 10^{-2}$   $\mu\text{c/ml}$ .

A mathematical correlation of the results from the two methods has not been possible because of insufficient data. The work is being continued.

---

### ECOLOGICAL STUDY<sup>(1)</sup>

L. A. Krumholz      W. T. Helm  
E. R. Eastwood     W. T. Miller  
W. A. Mills

Work on the fifth semiannual estimate of the fish population of White Oak Lake was begun on September 22 and will continue for approximately five weeks. The report for the fourth such study was distributed on July 29.

Research has continued on the accumulation of radioactive materials in different tissues of various fish, amphibious reptiles, and birds from White Oak Lake, along with similar studies on plankton organisms and bottom fauna.

A year-round study on the accumulation of long-lived fission products in bluegills and black crappies from White Oak Lake, begun in the summer of 1951, indicates that there is a definite seasonal variation in the amount of such materials accumulated in the different tissues. Although different tissues have an affinity for different chemical elements, the pattern of seasonal variation appears to be the same for all tissues. All tissues accumulated a minimum of radioactive materials during the winter months (December to

March, inclusive). In the spring, as the water temperature rose, the metabolic rate of the fish increased and was accompanied by an increase in accumulation of radioisotopes. Although the warm months of the year extended from May through September, the accumulation of fission products in the fish tissues continued to rise until late July, and then began to diminish. By mid-October 1952, the amount of radioactive materials in the various tissues was approximately the same as it had been at that time the previous year. Apparently the accumulation of radioactive materials in the various fish tissues depends primarily on three factors: (1) the temperature of the water, which largely controls the metabolic rate of the fish living therein, (2) the presence of an ample food supply containing the radioactive materials, and (3) the availability of that food supply to sight-feeding fishes, as controlled by the turbidity of the water.

The field work in the botany section of the biological survey has been terminated and the preparation of the final report is now in progress.

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<sup>(1)</sup>In cooperation with the Tennessee Valley Authority.

## THEORETICAL PHYSICS

J. Neufeld            W. S. Snyder  
R. H. Ritchie

## FAST-NEUTRON TOLERANCE CALCULATIONS

A program for the calculation of the energy dissipation of fast neutrons in tissue is being prepared for the UNIVAC and the ORACLE. The Monte Carlo method will be employed, using point sources of isotropically distributed neutrons. The anisotropy of the scattering is being studied, using recent results of NDA, and it is hoped to take it into account in future programs. For the present, the source energies to be used will be between 5 kev and 1 Mev, where most of the rise in the dosage curve occurs.

The correlation of the experimental data of G. S. Hurst and T. A. Barr with the previous Monte Carlo study at 2.5 Mev seems excellent, although the present data are scanty.

## THERMAL-NEUTRON TOLERANCE CALCULATIONS

A program has been prepared for use on the NEPA machine to calculate a variety of thermal-neutron dosage curves for slab and sphere geometries. The scattering is assumed to be isotropic in the laboratory coordinates and the neutrons are considered to be monoenergetic. The bodies of interest will be of intermediate size, ranging from 1 to 10 cm in radius or thickness, so they will approximate the conditions of many animal experiments.

## STOPPING POWER OF FISSION FRAGMENTS IN LIGHT GASES

The energy loss resulting from atomic collisions has been calculated by Bohr<sup>(1)</sup> on the basis of statistical models both for the moving atom and

<sup>(1)</sup>N. Bohr, *Phys. Rev.* 59, 270 (1941).

the stopping atom. The statistical model is not very applicable to light gases; therefore modified calculations will be made to estimate the stopping power of heavy ions in light gases.

## ENERGY DISTRIBUTION OF MULTIPLE-SCATTERED ELECTRONS IN FOILS

Landau<sup>(2)</sup> has studied the effect of straggling on the energy distribution of electrons in thin foils. Angular deflections, which are mainly due to elastic scattering, give rise to greater energy losses and more energy straggling than predicted by Landau's theory.

To include the effect of these angular deviations, it may be assumed that energy loss and deflection occur independently and that boundary effects may be neglected. The Boltzmann equation for the one-dimensional problem is written and the small-angle approximation is made;<sup>(3)</sup>  $\cos \theta$  is replaced by  $1 - \theta^2/2$  throughout. The angle  $\theta$  is that between the X axis and the direction of electron travel. Laplace transformations are applied to this equation in the energy-loss variable and in the spatial coordinate, X.

The solution of the transformed equation may be written in terms of the Whittaker function.<sup>(4)</sup> The resulting distribution function for the electrons that are proceeding parallel to the X axis at position X may be written as a power series in X, which involves successive derivatives of the Landau function.

Further work is being done on extending the results and evaluating certain of the functions.

<sup>(2)</sup>L. Landau, *J. Phys. (U. S. S. R.)* 8, 201 (1944).

<sup>(3)</sup>N. C. Wang and E. Guth, *Phys. Rev.* 84, 1092 (1951), Eq. 16 and 17.

<sup>(4)</sup>E. T. Whittaker and G. N. Watson, Chap. XVI in *A Course of Modern Analysis*, Macmillan, New York, 1943.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

### RADIATION DOSE

H. H. Hubbell

#### INTERNAL RADIATION DOSE

K. Z. Morgan

**Radiochemical Analysis** (L. B. Farabee). Long-lived alpha activity adhering to filterable airborne particulate matter can be collected on Whatman No. 41 filter disks. Since a chemical assay for the alpha activity on each filter is not practical, a study was made to determine the feasibility of counting the alpha activity directly on the filter. In this study a long-lived alpha-emitting radioisotope on particulate matter was collected on a filter disk and a direct count was made in an alpha proportional counter. The organic constituent of the filter was then destroyed and a chemical assay of the radioisotope was done on the residue. The recovered alpha activity was then counted under standard conditions of known self-absorption.

Nineteen individual samples were determined. The efficiency of counting alpha activity on the paper ranged from 36.0 to 75.0%, with an average of 58.6%. The results showed considerable fluctuation which may be due to varying amounts of carbon and silicates collected on the filters. At present it seems practical to estimate the counting efficiency at approximately 60%.

**Spectrographic Analysis of Human Tissue**<sup>(1)</sup> (I. H. Tipton). More than 200 tissues have been analyzed semiquantitatively for B, Co, Au, Mn, Mo, Pb, Cr, Sn, Si, Ni, Bi, Ba, Al, Be, V, Ti, Cu, Cd, Ag, Zn, and Nb. Some 55 bone and cartilage samples (included in the above number) were also analyzed for Fe.

Samples have been submitted to the neutron-activation analysis group for elements where the sensitivity in the spectrographic method is not satisfactory. Test samples indicate about 38 ppm of strontium in bone ash but no detectable strontium in soft-tissue ash. Thirty-one samples of bone ash have been submitted for neutron-activation analysis. Because of the presence of a high concentration of sodium chloride in soft tissue, the spectrographic sensitivity for zinc is very poor. The tissues will be analyzed for zinc by neutron activation.

<sup>(1)</sup>University of Tennessee research and development contract.

#### EXTERNAL RADIATION DOSE

H. K. Richards

**Backscattering of Beta Particles.** The experimental results of T. E. Bortner and W. E. Moore are being used to develop a semiempirical theory for the backscattering of beta particles of a number of different maximum energies from scatterers of a wide range of atomic numbers. A comprehensive report concerning the work on this problem during the last two years is in preparation.

**Measurement of Ionizing Radiation by High-Frequency Variation.** Experiments mentioned in the previous quarterly report<sup>(2)</sup> were continued and the ratio of neutron to gamma response of the instrument for a polonium-boron source was found to be 1.21. A calculation of the order of magnitude showed that one-cycle variation in frequency corresponded to 34 recoil protons.

In addition to experiments with gamma intensities of about 1 to 2 mr/hr, gamma radiation of several hundred milliroentgens per hour was measured by connecting the quartz fiber of the electrometer to a capacitance of 5000  $\mu\mu\text{f}$  through a 10 megohm resistance. This resistance effectively decoupled the R-F system from the capacitance but permitted the extension of the range for the radiation measurement by the electrostatic coupling.

Investigations have been started with a quartz-crystal-controlled oscillator operated at series resonance. Frequency variations can be produced, as previously mentioned, within a range determined by the ratio of the equivalent series capacitance to the parallel capacitance of the crystal. The variation is produced by the variable capacitance of an electrometer.

Experiments are in preparation that will use ferroelectric materials to replace the electrometer.

**X-Ray Dosimetry** (H. H. Hubbell, F. H. W. Noll). The project of redetermining the energy dependence of all readily available types of commercial x-ray and personnel-monitoring film has continued. Preliminary runs on four types show a sensitivity that varies by a factor of about 18 as the effective energy of the heavily filtered x radiation is varied

<sup>(2)</sup>H. K. Richards, *H-P Prog. Rep. Jan. 20, 1952 to July 20, 1952*, ORNL-1353, p. 8.

from about 25 to 190 kev. This factor appears to be about the same for the four types of film tried, although their absolute sensitivities are quite different.

**Tissue Depth Dose for Fast Neutrons** (G. S. Hurst, T. A. Barr, Jr.). The measurements of the dose resulting from fast neutrons in a large, cylindrical tank, 30 cm thick and 200 cm in diameter, filled with tissue-equivalent solution, have been practically completed and a report is being prepared. The results show good agreement with the Monte Carlo calculations of W. S. Snyder and indicate a relaxation length of about 7 cm for polonium-boron neutrons in tissue. The ratio of total dose to first-collision dose in tissue is about 2, which is in agreement with the calculations.

**Shielding** (R. H. Ritchie). The preparation of two chapters on maximum permissible exposures and on the scattering of gamma and neutron radiations from various shielding structures, etc. for the "Reactor Handbook" has continued.

**Film Monitoring for Fast Neutrons** (J. S. Cheka). Work has been done on the modification of the NTA film packet to make it a fast-neutron dose meter. NTA emulsion is rather insensitive to gamma radiation but records the passage of heavy ionizing particles such as recoil protons. A minimum proton energy of 0.25 Mev is required to form a recognizable tract of three grains. In its present state, the film measures neither flux nor dose accurately. After a calibration is made on a batch of film, neutron exposure can be evaluated by that batch only if the energy spectrum of neutrons is the same as that of the source used for the calibration.

The fast-neutron response of the film consists of three parts: (1) protons with energies greater

than 0.25 Mev that are formed in the emulsion, (2) protons formed in the cellulose acetate base of the film that reach the emulsion with energies greater than 0.25 Mev, and (3) protons formed in the film wrapper or other extraneous hydrogenous material that reach the emulsion with residual energies greater than 0.25 Mev.

The tissue-dose curve to be fitted is based on W. S. Snyder's calculations of fast-neutron energy loss in tissue. When the resultant curves from parts (1) and (2) of the fast-neutron response are added, they fit the tissue-dose curve fairly closely up to 5 Mev. Beyond this point the sum falls below the dose curve. Calculations are being made on a proton radiator that corresponds to part (3) of the fast-neutron response. It will consist of a plastic and a nonhydrogenous filler selected to give a rate of proton production and proton range that will permit just sufficient protons with energies greater than 0.25 Mev to reach the emulsion to make up the deficiency at higher energies.

**Energy Losses of Electrons in Foils** (R. D. Birkhoff, A. W. Smith, J. Bergstein). A small accelerator has been designed and constructed for use in measuring the energy losses, in foils, of electrons with energies up to 250 kev and for the program of radiation dosimetry using complex molecules. Extensive help has been given by R. W. Bennett and R. F. King of the High-Voltage Laboratory.

A stopping-potential type of energy analyzer is being designed that will permit the study of the particle energy distribution resulting from the passage of the beam through thin layers of absorbing gases and solids. Preliminary performance data indicate a probable energy resolution in the analyzer of 5 ppm.

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## PHYSICS OF NUCLEAR RADIATION

G. S. Hurst

### IONIZATION BY ALPHA PARTICLES

T. E. Bortner

The  $W$  value for helium of extremely high purity is approximately 42 ev per ion pair. This value, as well as the values for helium and argon,<sup>(1)</sup> must be considered as preliminary until further experi-

<sup>(1)</sup>T. E. Bortner and G. S. Hurst, *H-P Prog. Rep.* Jan. 20, 1952 to July 20, 1952, ORNL-1353, p. 22.

mental work is completed. A heating unit has been placed on one chamber port (between the calcium trap and the ion chamber) and a liquid-nitrogen trap on the other. In this way a temperature differential of about 500°C is attained that substantially aids the convection of gas through the calcium chamber.

A slyphon pump has been designed and placed on the calcium trap to pump gas through the ion chamber. The pump is now being tested.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

### MEASUREMENT OF THE ELECTRON- ATTACHMENT COEFFICIENT FOR VARIOUS GASES

W. G. Stone

A knowledge of the probability of an electron attaching itself to a neutral heavy atom is of considerable importance in the prediction of the behavior of ionization chambers and counters. The quantity that is most easily measured is the probability of an electron becoming attached while moving a distance of 1 cm in a gas under a known electric field. This also is the quantity needed for ionization-chamber work, but in order to make certain theoretical deductions the probability of attachment per collision is needed. In order to know the coefficient (probability) per collision, the drift velocity of electrons under the same conditions must be measured.

An ionization chamber and associated purification chamber for making this measurement is being designed and built by Abele and Knowles of the Instrument Department. The design is 80% complete and the construction is 10% complete. The chamber is designed to measure both electron-attachment coefficient and electron-drift velocity. Where the nature of the gas permits, the two measurements can be made simultaneously.

The chamber and all associated equipment with which the gas under measurement will come in

contact will be constructed of stainless steel, Teflon, and Fluorothene. The only exception will be the material in the purification chamber that will be used to remove traces of impurities from the gas under test. When testing the noble gases and most organic gases, the purifying medium will be metallic calcium.

R. Baldock advised against the use of available stainless steel valves because they have cast bodies that are difficult to outgas, so special valves are being designed and built by Hensley of the Engineering Department. The design is 98% complete and construction is scheduled to begin soon.

The special preamplifier that is required for the equipment is being designed and built by Adams of the Instrument Department. The design is 75% complete.

### DOSIMETRY FOR ANIMAL EXPOSURE

W. T. Ham  
G. S. Hurst

M. Slater  
J. A. Auxier<sup>(2)</sup>

All the dosimetry measurements indicated in the previous quarterly report for animal exposures have been completed. A detailed report of the results is in preparation.

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<sup>(2)</sup>In cooperation with the University of Texas, Austin, Texas.

## EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson  
M. F. Fair

M. R. Ford  
T. H. J. Burnett

### AEC FELLOWSHIP PROGRAM

The 1951-52 group of AEC Fellows in radiological physics completed their field training at the Oak Ridge National Laboratory on August 30. Nine of the Fellows were granted six-month extensions of their fellowships to complete a research problem in fulfillment of the requirements for a Master's degree from Vanderbilt University. One Fellow was granted a 12-month extension for study at Harvard University in the field of industrial hygiene. The remainder of the Fellows accepted jobs in the field of health physics with the exception of two who are continuing their graduate work.

The new group of AEC radiological Fellows (22 in number) began work at Vanderbilt University on September 22.

### TRAINING PROGRAM FOR AEC CONTRACTORS' PERSONNEL

Three of the four DuPont employees completed their training and have been transferred to Aiken, South Carolina. The other employee, who is a sanitary engineer, has completed the routine field training and is working in the waste-disposal section. One employee of ORINS Medical Division spent a month with the section for training in routine survey work.

### CONSULTATION

One member of the section has been on loan to the University of Pittsburgh to make a survey of current practices in the monitoring and control of airborne radioactive particles.

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## EXPERIMENTAL RADIATION MEASUREMENTS

F. J. Davis  
C. F. Harris

J. A. Harter  
P. W. Reinhardt

### URANIUM PROSPECTING<sup>(1)</sup>

A scintillation counter that is designed to be mounted on an automobile luggage rack has been developed for use in uranium prospecting and radiation surveys. The 1 by 2½ in. sodium iodide crystal used is shielded against radiation from the road but is sensitive to radiation sources on both sides of the road. The chart-drive mechanism of an Esterline-Angus recorder has been coupled to the speedometer shaft of the automobile so that the travel of the chart is proportional to the travel of the car, and is independent of speed. Also, an edge marker is connected to the odometer so that a single edge mark occurs each mile, a double edge mark every ten miles, and a triple edge mark every one hundred miles. There is an additional edge marker on the opposite edge of the chart that

can be operated by a hand switch to record the chart positions of reference land marks. The circuits are powered by dry batteries that have a service life of approximately 1000 hours. The apparatus has been operated in Colorado and Wyoming areas by the U. S. Geological Survey and has proved to be superior to the Geiger-counter apparatus previously used. Improvements being developed by the U. S. Geological Survey include a two-channel system that gives independent records from two crystals, each responding to radiation from only one side of the road.

An additional aircraft of the C-47 class has been allocated and is awaiting delivery to the U. S. Geological Survey for use in uranium prospecting. Conversion of the plane is expected to be complete early in the spring of 1953. The radiation equipment will be essentially the same as that in the present DC-3 aircraft. The aircraft will be used part time for radiation surveys at the Oak Ridge National Laboratory.

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<sup>(1)</sup>In cooperation with the U. S. Geological Survey.

## AIRBORNE RADIOPARTICULATE CONTAMINATION

E. G. Struxness  
W. D. Cottrell  
R. L. Bradshaw

J. W. Thomas  
B. G. Saunders  
E. E. Grassell

### RADIOACTIVE-PARTICLE PROGRAM AND PEEP

The physical transfer of personnel and equipment, formerly associated with PEEP under the direction of E. D. Shipley, to ORNL Health Physics Division at X-10 is essentially complete. A few minor alterations and additions to the present laboratories remain to be accomplished.

The continuous-action Wilson apparatus, on loan from H. L. Green of the Chemical Defense Experimental Establishment at Porton, Down, England, has been received. The apparatus, together with the associated photographic equipment, is being assembled and adapted for use in counting small particles, particularly those that may penetrate highly efficient particulate filters. Other equipment for penetration studies has been reassembled in the laboratory and the preliminary operational adjustments are in the process of completion.

A study of all the available data, published and unpublished, pertaining to the so-called "particle" problem at ORNL has been initiated and a proposal for further evaluation of this problem will be submitted.

A device that measures and records particle size, based on the light scattering properties of small aerosol particles, has been developed. Although the device is usable at the present time, other improvements are planned. A servo controller for maintaining constant particle size in the DOP aerosol generator is also under development.

An investigation of the variables affecting operation of the DOP aerosol generator is now under way. Another diffusion battery, shorter in length, has been fabricated. It will be used in conjunction with the longer battery previously tested and will give information on the discrepancies that may possibly result from end-effects.

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Hart, *Personnel Monitoring Operating Techniques*, ORNL-1411, October 1952.

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HEALTH PHYSICS DIVISION  
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FOR PERIOD ENDING JANUARY 20, 1953



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K. Z. Morgan, Director

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# CONTENTS

	Page
THEORETICAL PHYSICS .....	1
Fast-Neutron Tolerance Calculations .....	1
Thermal-Neutron Tolerance Calculations .....	1
Stopping Power of Fission Fragments in Light Gases .....	1
Cooperative Program with Shielding Group .....	1
PHYSICS OF NUCLEAR RADIATION .....	1
Ionization by Alpha Particles .....	1
Electron Attachment Coefficient Measurement .....	1
Ionization Produced by Recoil Particles .....	1
RADIATION DOSE .....	2
Internal Radiation Dose .....	2
Radiochemical analysis .....	2
Spectrographic analysis of human tissue .....	2
External Radiation Dose .....	2
Backscattering of beta particles .....	2
Measurement of ionizing radiation by high-frequency variation .....	2
X-ray dosimetry .....	3
Film monitoring for fast neutrons .....	3
Energy losses of electrons in foils .....	4
Special tests .....	4
AIRBORNE RADIOPARTICULATE CONTAMINATION .....	4
Radioactive-Dust Studies and PEEP .....	4
RADIOACTIVE-WASTE DISPOSAL RESEARCH .....	5
Water and Liquid-Waste Decontamination Processes .....	5
Water decontamination studies .....	5
Surveys and Evaluations – Field and Laboratory .....	5
Radioactivity in river bottom sediments .....	5
Accumulation of Cs <sup>137</sup> and Sr <sup>89</sup> in small fishes .....	6
Instrumentation and Techniques .....	10
Counting response of crystal spectrometer .....	10
ECOLOGICAL STUDY .....	11
EDUCATION, TRAINING, AND CONSULTATION .....	12
AEC Fellowship Program .....	12
Training Program for AEC Contractors' Personnel .....	12
Lectures .....	12
Consultation .....	12
PUBLICATIONS .....	12
LECTURES AND PAPERS .....	13

Reports previously issued in this series are as follows:

ORNL-166	Period Ending August 31, 1948
ORNL-227	Period Ending November 30, 1948
ORNL-346	Period Ending February 28, 1949
ORNL-375	Period Ending July 15, 1949
ORNL-495	Period Ending October 15, 1949
ORNL-596	Period Ending January 15, 1950
ORNL-695	Period Ending April 15, 1950
ORNL-786	Period Ending July 15, 1950
ORNL-877	Period Ending October 20, 1950
ORNL-968	Period Ending January 20, 1951
ORNL-1086	Period Ending July 20, 1951
ORNL-1174	Period Ending October 20, 1951
ORNL-1277	Period Ending January 20, 1952
ORNL-1353	Period January 20 to July 20, 1952
ORNL-1420	Period Ending October 20, 1952

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

## THEORETICAL PHYSICS

J. Neufeld

W. S. Snyder

R. H. Ritchie

### FAST-NEUTRON TOLERANCE CALCULATIONS

A program for calculating the energy deposition by fast neutrons in a tissue phantom has been prepared for use on the ORACLE. The running of these problems awaits the completion of the machine.

### THERMAL-NEUTRON TOLERANCE CALCULATIONS

Preliminary results that show dose curves for thermal neutrons incident on small spheres and slabs have been obtained by using the NEPA machine. The curves are being studied to determine their accuracy before additional problems are submitted.

### STOPPING POWER OF FISSION FRAGMENTS IN LIGHT GASES

A formula for the stopping power of heavy ions moving in light gases has been developed and is under study. The formula requires a numerical integration, which is being programmed.

### COOPERATIVE PROGRAM WITH SHIELDING GROUP

A chapter has been written for the shielding section of the classified *Reactor Handbook*. Further work has been done on multiple scattering effects, which are reported in memorandum CF-53-1-102.<sup>(1)</sup>

<sup>(1)</sup>R. H. Ritchie, ORNL CF-53-1-102 (classified).

## PHYSICS OF NUCLEAR RADIATION

G. S. Hurst

### IONIZATION BY ALPHA PARTICLES

T. E. Bortner

Helium of a high degree of purity has been prepared by use of activated charcoal at the temperature of liquid nitrogen and a mechanical pump to circulate the helium over hot calcium and through the ionization chamber. With this means of purification, the  $w^{(1)}$  value for helium has been determined to be 46 ev. This same value was also obtained by allowing helium to flow from the tank through activated charcoal at the temperature of liquid nitrogen and then through the ionization chamber at a rate of about 15 liters/min. In the latter method, the readings were taken while the helium was flowing through the chamber and also immediately after the flow was stopped.

The  $w$  values for hydrogen (37 ev) and carbon dioxide (34.3 ev) have also been determined.

<sup>(1)</sup>Average number of electron volts necessary to form an ion pair.

Further determinations of the  $w$  value of percentage mixtures of hydrogen and nitrogen are under way. Some work on electronegative gases is to be done in the near future.

### ELECTRON ATTACHMENT COEFFICIENT MEASUREMENT

W. G. Stone

Engineering and drafting work for the chamber and associated equipment for measuring the electron attachment coefficient and the electron drift velocity has been completed, and the shop work is 46% complete. The preamplifier to be used with this chamber has been completed.

### IONIZATION PRODUCED BY RECOIL PARTICLES

W. G. Stone

Equipment for the measurement of the ionization produced by  $U^{235}$  recoils has been designed and

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

is now 75% complete. This measurement will be made at gas pressures of 3 to 10 cm Hg in a specially designed counter chamber with a constant flow of gas. The control of pressure is by means of a Cartesian manostat, and measurement of pressure is by use of a manometer referred to

a high-vacuum chamber. Short-time variations of pressure owing to the operation of the Cartesian manostat will be reduced by means of storage chambers and valves. Calibration of the chamber will be done by the use of alpha particles from a separate source.

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### RADIATION DOSE

H. H. Hubbell

#### INTERNAL RADIATION DOSE

K. Z. Morgan

**Radiochemical Analysis** (L. B. Farabee). The procedure presently used for the analyses of urine specimens for certain beta-gamma emitting radioisotopes requires numerous chemical precipitations that are time consuming. A revised method, with specific emphasis on the determination of radioactive strontium, is desirable.

Some preliminary investigation has been done on the use of IRC-50, a carboxylic acid type of cation-exchange resin with a high exchange capacity, in selectively removing strontium (along with the calcium and magnesium normally present) from a large-volume urine specimen. The resin has a high capacity for polyvalent cations over sodium, and this makes it adaptable for removing an alkaline earth from urine, which normally contains bulky amounts of sodium and potassium. Dilute acids can be employed to remove the cations from the resin.

**Spectrographic Analysis of Human Tissue**<sup>(1)</sup> (I. H. Tipton). The program at the University of Tennessee for spectrographic determination of trace elements in normal human tissue is in full operation. During the past quarter, specimens of 15 different tissues from each of 12 victims of sudden accidental death<sup>(2)</sup> have been received from the coroner's pathologist in New York City through the office of H. J. Koch of the Sloan-Kettering Institute. Nine autopsies have been received from the University of Tennessee Medical College in Memphis. Human tissue is needed from

<sup>(1)</sup>University of Tennessee research and development contract.

<sup>(2)</sup>Tissue from accident victims is preferred because the chemical balance of elements in the body is not disturbed by drugs administered during a period of hospitalization.

additional cooperative agencies in other geographical areas in order to obtain a more accurate representation of the variation of elements in human tissue as influenced by the environment.

Studies with moving plates are in progress to work out methods for increasing the accuracy and sensitivity of the analysis. Treatment of the tissue ash and synthetic standard ash with hydrochloric acid, with sulfuric acid, and with nitric acid indicates that the nitric acid gives the most reproducible results.

The data from the quantitative estimation of 19 elements in over 200 tissues that were measured in the last quarter are being analyzed by the ORNL Mathematics Panel.

#### EXTERNAL RADIATION DOSE

H. K. Richards

**Backscattering of Beta Particles.** A semi-empirical theory is being developed to account for the backscattering from materials of finite thickness with different atomic numbers.

**Measurement of Ionizing Radiation by High-Frequency Variation.**<sup>(3)</sup> In the measurement of ionizing radiation by high-frequency variation, a new electrometer design was used in which quartz fibers of 0.001-in. thickness and a reduced distance between the electrodes increased the sensitivity and greatly reduced the mechanical fluctuations of the system. The center frequency was stabilized by a quartz crystal and an inductance in series. The variable frequency range was 15 to 20 kc/sec. A radium-gamma dose rate of 1 mr/hr produced a frequency variation of about 30 to 35 cps in 1 min at a center frequency of 4.9 megacycles/sec. At constant ambient temperature,

<sup>(3)</sup>H. K. Richards, *H-P Prog. Rep. Jan. 20, 1952 to July 20, 1952*, ORNL-1353, p. 8; H. K. Richards, *H-P Quar. Prog. Rep. Oct. 20, 1952*, ORNL-1420, p. 6.

the drift of the frequency was reduced to about 2 cps in 1 minute.

Experiments with ferroelectric materials for the replacement of the moving parts of the electrometer for high-level radiation are under way.

**X-Ray Dosimetry** (H. H. Hubbell). In the project of redetermining the energy dependence of the sensitivity of x-ray film, preliminary calculations have been made, and a program of further calculation has been laid out to determine the maximum reasonable amount of filtration of the x-ray beam to be used at each applied kilovoltage. Too little filtration gives a beam of such a wide distribution of wave lengths that to speak of its effective wave length has no meaning, whereas too much filtration reduces the intensity so far that unreasonably long exposures are required. Since spectrometers for this wave-length range are complex and expensive, the simplest way to determine the spectral distribution in the beam is by calculation. By using Kramers' theoretical result,<sup>(4)</sup> which has been well verified experimentally,<sup>(5)</sup> and by using the Bureau of Standards values of mass attenuation coefficients,<sup>(6)</sup> it is a matter of simple but time-consuming calculation to determine the spectral energy distribution for an x-ray beam passed through any given set of filters. From the air absorption coefficients,<sup>(6)</sup> the response of an air-equivalent ion chamber is found, and this curve is multiplied by the spectral energy distribution to get the spectral distribution of air dose.

The "effective voltage" of such a distribution, as observed with an air-equivalent chamber, may be defined as the voltage equivalent to a monochromatic x-ray beam having the same attenuation as the given beam in an incremental thickness of a standard absorber, such as copper. Therefore, a distribution curve for a given set of filters is taken, and a new curve for a small added thickness of copper is then calculated. By assuming exponential attenuation, the attenuation coefficient from the ratio of the areas under these two curves can be found. The effective voltage, therefore, is the voltage in the NBS table corresponding to the calculated attenuation coefficient.

(4) H. A. Kramers, *Phil. Mag.* 46, 836 (1923).

(5) W. W. Nicholas, *J. Research Natl. Bur. Standards* 2, 837 (1929); H. Kulenkampff, *Ann. Physik* 69, 548 (1922).

(6) G. R. White, "X-Ray Attenuation Coefficients from 10 kev to 100 Mev," NBS-1003 (May 13, 1952).

The effective voltage can be measured experimentally by an exactly analogous procedure. For one set of filters, with 200 kv applied to the tube, the calculated effective kilovoltage was 153, whereas the observed kilovoltage was 149. The agreement is good, since the theory takes no account of the characteristic emission lines of the target. Another possible parameter of the spectral distribution would be the center of gravity of the area under the curve. The center of gravity falls close to the same effective voltage.

The aim is to determine by calculation the filters to be used at each applied kilovoltage in order to have a beam of useful intensity, reasonably well defined effective voltage, and constant energy spread. A point to be especially noted – and one frequently not realized – is that spectral distribution curves such as these apply only to detection by an air-equivalent chamber. Somewhat different distributions would apply if the detector is tissue-equivalent, and quite different distributions apply for a detector that measures total energy in the beam. It follows that the "effective voltage" is dependent on the device used to measure the radiation.

**Film Monitoring for Fast Neutrons** (J. S. Cheka). Work on a modified pocket film dosimeter to render the currently used NTA film a fast-neutron dosimeter has been previously reported.<sup>(7)</sup>

To make a shield for the film, the loading of plastic with metallic dust was attempted by the method of stirring the dust into the melted plastic. Two faults appeared in the method: the metal settled before the plastic hardened, and bubbles appeared in the layer. Both these phenomena render the plastic nonuniform and, therefore, ineffective as a proton radiator of predetermined yield. These faults could probably be eliminated through the cooperation of a plastic manufacturer.

Meanwhile, a modification in the radiator design was made. The new radiator consists of layers of aluminum foil and paper. The paper supplies the hydrogen for the generation of recoil protons, and the aluminum limits the fraction of generated protons that reaches the emulsion and is recorded.

Several laminated radiators were assembled, which were based on calculations to compensate the response of the present film; the hydrogen content of the film base was obtained from Eastman Kodak. Exposures were made to the weekly

(7) J. S. Cheka, *H-P Quar. Prog. Rep.* Oct. 20, 1952, ORNL-1420, p. 7.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

maximum permissible dose of neutrons from a polonium-boron and a polonium-beryllium source. These doses were  $5.33 \times 10^6$  and  $4.46 \times 10^6$  neutrons/cm<sup>2</sup>, respectively. The films were read under the microscope at a magnification of 440x and showed 14% more tracks per traverse from the polonium-beryllium (higher energy) source. This difference was greater than the probable error. The films were then reread at 900x, 50 fields per film. These readings differed by about 8%, or less than the probable error.

From these results, it appears that the lower magnification fails to show all three-grain tracks, of which there are probably more from the lower energy spectrum of the polonium-boron source. Based on the assumption that 0.35 Mev (four-grain track) rather than 0.25 Mev (three-grain track) is the threshold of recognizability, a rough calculation of the response of the constructed radiator indicated that the polonium-boron spectrum (narrowly centered about 2.5 Mev) would give a reading about 9% low, and the polonium-beryllium spectrum would give a reading a few per cent high.

The method of altering NTA response to make the track count proportional to tissue dose by means of a compensating radiator is being reported at the Cambridge meeting of the American Physical Society.

Since a film badge is worn next to the body, the question arises as to whether the first collision

dose curve should be used or the multiple collision curve given by Snyder. This aspect is being investigated.

**Energy Losses of Electrons in Foils** (R. D. Birkhoff, J. Bergstein, M. Slater, H. H. Hubbell). Preliminary experiments on the accelerator using the stopping-potential type of energy analyzer have been successfully completed. The necessary modifications of the controls, safety devices, and measurement systems for more permanent use are in progress. A major problem of secondary emission from the collector, which completely falsified the current readings, was solved by the proper design and placement of suppressor grids. A promising technique of varying the analyzing voltage at an audio frequency and viewing the electron current with an oscilloscope was developed, thus permitting the use of a-c instead of d-c amplification, and presenting the entire energy loss curve on the oscilloscope at one time, instead of laboriously taking it point by point. The design of new controls to operate the x-ray high-voltage supply for either the x-ray tube or the accelerator is about half complete.

**Special Tests.** At the request of the Radiation Instruments Branch of the AEC in Washington, the Radiation Dose section, in cooperation with the Physics of Nuclear Radiations section, has undertaken a classified project involving special radiation dose measurements.

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## AIRBORNE RADIOPARTICULATE CONTAMINATION

E. G. Struxness

W. D. Cottrell

B. G. Saunders

R. L. Bradshaw

E. E. Grassel

J. W. Thomas

### RADIOACTIVE-DUST STUDIES AND PEEP

A few minor alterations and additions to the laboratories remain to be accomplished. Additional laboratory space has been obtained in Building 2005 for use in connection with the synthesis of radioactive smokes.

The Green continuous-action cloud chamber was put into operation and calibrated. A thorough study was made of all errors attendant to making a count of particles in a given volume of air. An accuracy within  $\pm 5\%$  can be expected when 500 droplets on the photographic film are counted.

The optical system itself contributes 2.6% of the error. Other optical systems were investigated for reducing this error. A device for measuring the fall rate of droplets in the cloud chamber was developed and calibrated. It utilizes a rotating 12-sided prism.

The Green cloud chamber depends on the action of a piston for achieving an adiabatic expansion of air and is classed as a *volume-defined* cloud chamber. A volume-defined cloud chamber using a slyphon bellows actuated by vacuum or compressed air was developed and tested. A *pressure-defined* cloud chamber actuated by vacuum was

also developed and tested. The virtues of these chambers are their low cost, compactness, and simplicity.

A Hilsch vortex tube that separates an air stream into hot and cold components was fabricated. By using the principle of the Hilsch tube, it may be possible to build a device for fractionating aerosols according to particle size.

A plan for the study of radioparticulate air contamination at ORNL has been established. The initial phase of this study, which includes the evaluation of existing data, will require several months for completion.

A modified method of controlling particle size in the DOP generator has been developed to overcome the difficulties experienced with the original design. Circuits for this servo controller are now being designed.

Several minor modifications for better operation of the Servo Owl (an instrument for automatically indicating particle size, based on the light-

scattering properties of small particles) have been made.

An experimental model of a high-speed air top for the production of solid homogeneous aerosols was completed and tested. The top, 1 in. in diameter and made of aluminum alloy, was stable up to 81,000 rpm. When driven by air at a pressure of 15 psi, droplets of dioctyl phthalate as small as 15  $\mu$  in diameter and having a uniformity of  $\pm 10\%$  were produced. Below this drop size, the projection distance of the drops was not sufficient to clear the stator housing, and hence they could not be caught and measured satisfactorily. An improved top and stator housing have been designed and are now being constructed.

Preliminary experiments concerning streamline flow for a proposed new type of continuous air monitor were made.

Laboratory apparatus is being calibrated with a view to determining turbulence end-effects of the diffusion battery.

## RADIOACTIVE-WASTE DISPOSAL RESEARCH

R. J. Morton

### WATER AND LIQUID-WASTE DECONTAMINATION PROCESSES

M. W. Carter	D. A. Pecsok
F. L. Cobler	O. R. Placak
H. L. Krieger	M. S. Seal
W. J. Lacy	C. P. Straub

**Water Decontamination Studies.** During this period, preliminary laboratory studies were carried through on the removal of  $Ba^{140}$ - $La^{140}$ ,  $Cr^{51}$ ,  $Sr^{89}$ ,  $Y^{91}$ ,  $Sc^{46}$  (all in chloride form in weak HCl), and  $W^{185}$  (as  $K_2WO_4$  in KOH), each diluted in tap water. These studies include determinations of the percentages of: removal by coagulation at three levels of activity (20,000, 2,000, and 200 c/m/ml) by using three dosages each (1, 2, and 6 grains per gallon - gpg) of  $FeSO_4$ ,  $FeCl_3$ , and alum; take-up on natural clays; removal by water softening procedures; removal by phosphate coagulation; and removal by various materials in small glass columns. The results are summarized in Table 1, along with previous findings.

### SURVEYS AND EVALUATIONS - FIELD AND LABORATORY

T. W. Brockett	F. Kalil
M. J. Cook	R. J. Morton
J. M. Garner	R. L. Nichols
B. Kahn	O. R. Placak
H. J. Wyrick	

**Radioactivity in River Bottom Sediments.** A second survey of the gamma activity in bottom deposits in the Clinch and Tennessee Rivers has been completed. This survey covered 627 miles of the Tennessee River, about 60 miles of the Clinch River, and portions of all major streams feeding into these rivers. Direct readings were made by lowering a Flounder to the bottom of the stream. Data are being tabulated and a report is in progress.

Samples of bottom deposits were collected for laboratory study. Beta and gamma counts were taken on these samples with G-M counters and anthracene crystal counters, respectively. A fairly uniform counting rate was found in the samples

# HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

taken in the Tennessee River below Chickamauga Reservoir. The activity above this point increases as the mouth of the Clinch River is approached and reaches a maximum at Clinch River mile 13. Beta activity at this point is about six times the background activity. The beta-gamma ratio in-

creases as the activity of the mud decreases. The statistics are not sufficiently good to give a value for this ratio.

**Accumulation of Cs<sup>137</sup> and Sr<sup>89</sup> in Small Fishes.**  
It was reported in a recent Health Physics quar-

TABLE 1. REMOVAL OF RADIOISOTOPES FROM WATER

PROCESS	AMOUNT OF RADIOISOTOPE REMOVED (%)*											
	Radioisotope Removed											
	Ba-La	Cd	Ce	Cr	Cs	Sb	Sc	Sr	W	Y	Zn	Zr-Nb
Columns												
IR-120(H)	99+						95-99	99+	0-25	90-95		
IR-120(Na)	95-99						95-99	99+	0-25	75-90		
Dowex-1(OH)	25-75						95-99	0-25	99+	95-99		
Dowex-1(Cl)	25-75						95-99	0-25	95-99	90-95		
IR-120(H) + Dowex-1(OH)	99+						95-99	99+	95-99	95-99		
IR-120(Na)+Dowex-1(Cl)	99+						95-99	99+	95-99	95-99		
Green sand(Na)	95-99						95-99	99+	0-25	25-75		
Filter sand	0-25						95-99	0-25	0-25	75-90		
Anthrafilt	25-75						90-95	0-25	0-25	75-90		
Zorbball	95-99						90-95	99+	0-25	90-95		
Synthad	95-99						95-99	99+	25-75	75-90		
Fluorex	99+			99+			95-99	99+	99+	95-99		
Turbidity (ppm)												
100	25-75	0-25			25-75	0-25	25-75	0-25	0-25	25-75		95-99
750	25-75	25-75			75-90	0-25	90-95	0-25	0-25	25-75		99+
5000	90-95	25-75			95-99	0-25	95-99	25-75	25-75	90-95		95-99
Softening												
Lime, 2 gpg Soda, 2 gpg	25-75	25-75			0-25		25-75	0-25	0-25	25-75		25-75
Lime, 4 gpg Soda, 4 gpg	75-90	90-95			0-25		75-90	25-75	0-25	75-90		25-75
Lime, 8 gpg Soda, 8 gpg					0-25			75-90	0-25			75-90
Phosphate Coagulation												
50 ppm PO <sub>4</sub> ----			99+				99+	25-75	0-25	99+	99+	
100 ppm PO <sub>4</sub> ----						75-90	99+	95-99	0-25	99+		99+
Coagulation												
FeSO <sub>4</sub> , 1 gpg	25-75						90-95	0-25	25-75	75-90		
2 gpg	25-75						95-99	25-75	25-75	95-99		
6 gpg	75-90						95-99	25-75	25-75	95-99		
FeCl <sub>3</sub> , 1 gpg	25-75						25-75	0-25	25-75	75-90		
2 gpg	25-75						75-90	0-25	25-75	75-90		
6 gpg	75-90						90-95	25-75	25-75	90-95		
Alum, 1 gpg	25-75	25-75			0-25		90-95	0-25	0-25	75-90		25-75
2 gpg	25-75	75-90					95-99	0-25	0-25	90-95		75-90
6 gpg	25-75	75-90					95-99	0-25	25-75	95-99		95-99

\*Removals are indicated in the following class intervals: 0 to 25, 25 to 75, 75 to 90, 90 to 95, 95 to 99, and 99+.

terly<sup>(1)</sup> that a controlled fish experiment in the laboratory had been started. This experiment has now been completed and the data have been submitted to the ORNL Mathematics Panel for statistical analysis. In this experiment, there were three temperature levels (4, 22, and 29°C); three isotopic concentration levels of each radioisotope studied (approximately 4,000, 20,000, and 90,000 c/m/ml); three isotopes (Cs<sup>137</sup>, Sr<sup>89</sup>, and a combination of Cs<sup>137</sup> + Sr<sup>89</sup>); and three exposure times

(1, 2, and 6 days). Each fish was kept individually in a fruit jar containing 600 ml of solution. It was originally planned that 18 fish be used for the testing of each combination of factors, but owing to conditions beyond control, a few series were completed with only ten fish. Throughout this experiment, the fish were not fed. Table 2 presents the data as arithmetic averages of the counts per minute per gram of fish. A few preliminary generalizations may be made prior to completion of the statistical analysis:

1. As the temperature increased, the concentration of radioactivity in the fish increased.

(1) M. J. Cook et al., *H-P Quar. Prog. Rep. Oct. 20, 1951*, ORNL-1174, p. 3.

TABLE 2. DATA FROM CONTROLLED FISH EXPERIMENT

ISOTOPE	CONCENTRATION (c/m/ml)	CONCENTRATION OF RADIOACTIVITY IN FISH (c/m/g)		
		Time in Solution		
		1 day	2 days	6 days
Temperature, 4°C (40°F)				
Sr <sup>89</sup>	50,606	11,105 (6,167 to 16,492)*	10,637 (6,203 to 14,638)	35,104 (25,902 to 50,727)
Cs <sup>137</sup>	87,767	8,066 (5,471 to 12,899)	12,571 (8,221 to 20,839)	29,436 (16,833 to 44,328)
Cs <sup>137</sup> + Sr <sup>89</sup>	121,580	22,599 (14,543 to 44,838)	25,541 (14,316 to 47,267)	71,830 (25,520 to 225,305)
Sr <sup>89</sup>	20,206	6,089 (3,574 to 9,708)	7,149 (3,132 to 10,747)	16,189 (12,131 to 28,653)
Cs <sup>137</sup>	24,922	3,779 (1,619 to 6,300)	3,068 (2,003 to 4,367)	7,527 (3,801 to 12,520)
Cs <sup>137</sup> + Sr <sup>89</sup>	40,173	4,884 (2,066 to 11,388)	5,496 (1,834 to 10,884)	9,076 (5,240 to 16,056)
Sr <sup>89</sup>	3,918	1,174 (574 to 1,733)	1,158 (664 to 1,834)	2,873 (1,151 to 4,383)
Cs <sup>137</sup>	5,164	936 (455 to 1,220)	1,073 (759 to 1,680)	2,930 (1,646 to 4,200)
Cs <sup>137</sup> + Sr <sup>89</sup>	9,084	2,009 (1,257 to 2,885)	3,255 (1,506 to 7,213)	3,280 (1,079 to 7,642)

\*Numbers in parenthesis indicate the range of counts per minute per gram of all fish treated identically.

**HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT**

**TABLE 2. (continued)**

ISOTOPE	CONCENTRATION (c/m/ml)	CONCENTRATION OF RADIOACTIVITY IN FISH (c/m/g)		
		Time in Solution		
		1 day	2 days	6 days
Temperature, 22°C (70°F)				
Sr <sup>89</sup>	63,402	17,280 (13,030 to 28,766)*	26,421 (18,271 to 37,390)	56,888 (37,498 to 85,676)
Cs <sup>137</sup>	88,564	25,073 (11,097 to 57,514)	57,947 (15,825 to 255,221)	146,549 (91,759 to 240,513)
Cs <sup>137</sup> + Sr <sup>89</sup>	127,882	63,385 (20,079 to 126,293)	91,778 (52,789 to 159,674)	451,642 (207,185 to 808,752)
Sr <sup>89</sup>	20,201	5,548 (2,344 to 9,748)	11,979 (6,997 to 19,534)	26,149 (8,767 to 63,436)
Cs <sup>137</sup>	25,561	7,396 (5,114 to 14,158)	22,386 (9,452 to 65,784)	40,635 (14,420 to 77,900)
Cs <sup>137</sup> + Sr <sup>89</sup>	37,420	15,304 (5,740 to 31,956)	38,256 (11,565 to 80,600)	175,662 (50,470 to 680,304)
Sr <sup>89</sup>	3,936	1,131 (221 to 2,580)	3,314 (1,923 to 7,045)	6,399 (2,372 to 12,689)
Cs <sup>137</sup>	4,953	3,362 (952 to 6,937)	4,080 (1,295 to 10,594)	6,389 (2,511 to 11,264)
Cs <sup>137</sup> + Sr <sup>89</sup>	8,035	8,069 (2,145 to 14,197)	8,455 (2,172 to 17,887)	36,082 (12,036 to 74,000)

\*Numbers in parenthesis indicate the range of counts per minute per gram of all fish treated identically.

TABLE 2. (continued)

ISOTOPE	CONCENTRATION (c/m/ml)	CONCENTRATION OF RADIOACTIVITY IN FISH (c/m/g)		
		Time in Solution		
		1 day	2 days	6 days
Temperature 29°C (84°F)				
Sr <sup>89</sup>	52,826	25,964 (20,215 to 39,071)*	46,207 (4,601 to 73,709)	128,992 (66,564 to 247,431)
Cs <sup>137</sup>	49,123	111,585 (8,361 to 224,257)	183,452 (75,870 to 380,332)	365,916 (137,420 to 616,560)
Cs <sup>137</sup> + Sr <sup>89</sup>	130,569	105,096 (71,806 to 155,692)	151,491 (31,353 to 826,061)	612,119 (99,045 to 1,273,190)
Sr <sup>89</sup>	15,328	11,002 (4,151 to 22,662)	22,321 (7,669 to 60,129)	51,625 (23,651 to 115,253)
Cs <sup>137</sup>	21,173	5,839 (2,119 to 16,002)	12,264 (4,585 to 37,716)	80,106 (13,736 to 167,478)
Cs <sup>137</sup> + Sr <sup>89</sup>	44,668	15,389 (6,755 to 33,505)	71,803 (19,795 to 365,756)	107,799 (44,867 to 213,782)
Sr <sup>89</sup>	3,015	1,786 (530 to 4,236)	3,570 (1,622 to 6,856)	13,586 (4,903 to 26,667)
Cs <sup>137</sup>	4,909	7,363 (1,267 to 24,336)	16,298 (2,162 to 53,788)	16,854 (4,584 to 36,168)
Cs <sup>137</sup> + Sr <sup>89</sup>	9,624	5,721 (1,381 to 13,169)	17,455 (2,593 to 64,383)	21,599 (5,987 to 81,937)

\*Numbers in parenthesis indicate the range of counts per minute per gram of all fish treated identically.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

2. As the time of exposure increased, the concentration of radioactivity in the fish increased.

3. As the concentration of the isotopes increased, the concentration of radioactivity in the fish increased.

4. Among the fish that were treated identically, there was a very wide variation in the concentration of the radioactivity.

### INSTRUMENTATION AND TECHNIQUES

J. M. Garner                      F. Kalil  
B. Kahn                              W. J. Lacy  
   R. L. Nichols

**Counting Response of Crystal Spectrometer.** The counting response of a crystal spectrometer was determined for gamma rays having energies be-

tween 280 and 2760 keV. The work is being continued to determine the response at lower energies and is being done by B. Kahn in cooperation with W. S. Lyon of the Analytical Chemistry Division; they are using a spectrometer belonging to that Division.

The spectrometer consists of a thallium-activated sodium iodide crystal, a type 5819 photomultiplier tube, a linear amplifier equipped with a differential pulse-height selector, and a scaler. It has been adjusted to detect pulses with a spectrum width of 10 keV at a pulse-height setting that has been calibrated so that 1 volt equals 1 keV of energy. A curve such as that in Fig. 1 is obtained by plotting the count rate at several pulse-height settings. The abscissa reading at the peak corresponds to the energy of the gamma

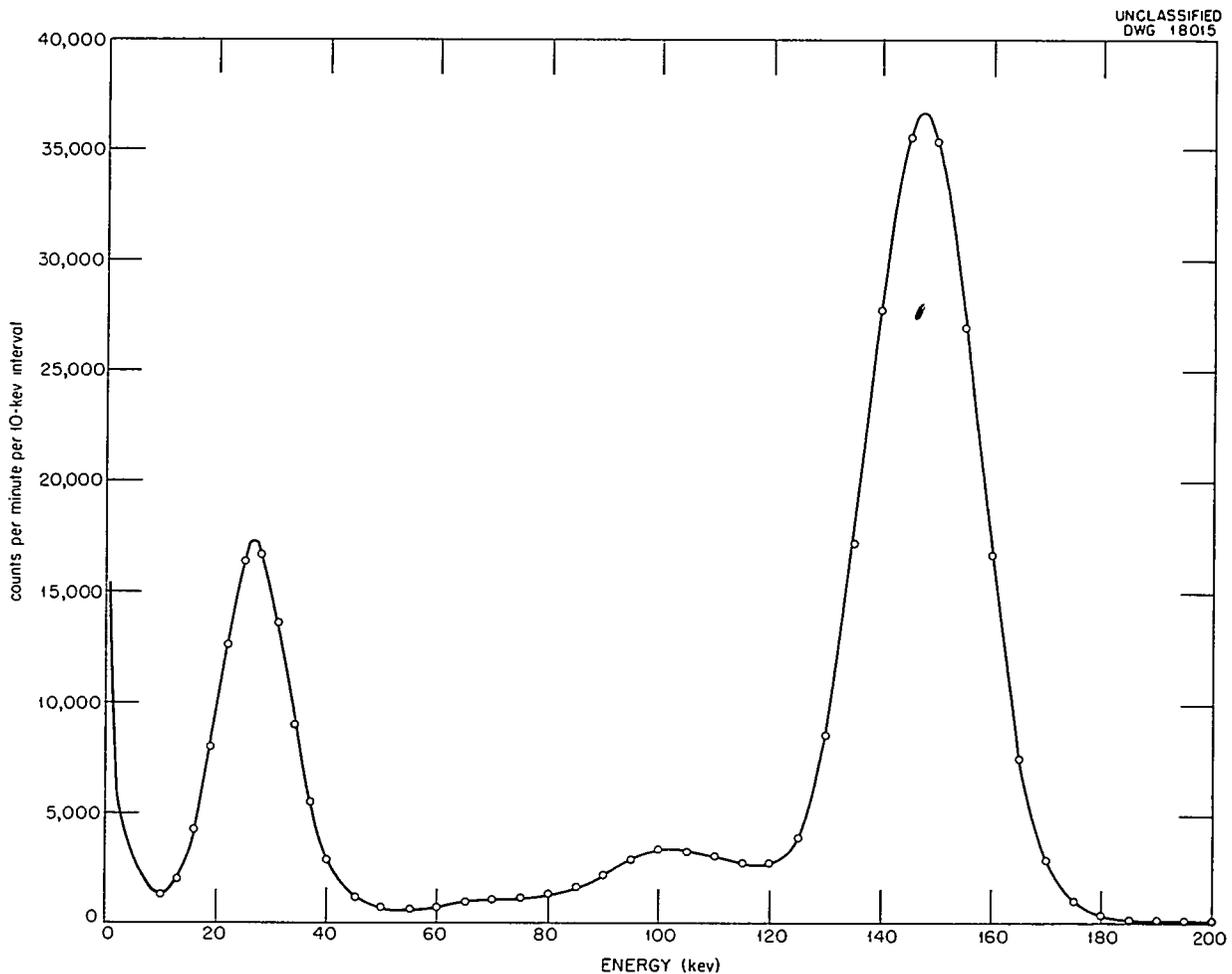


Fig. 1. Gamma-Ray Spectrum of  $Ce^{141}$ .

or x ray emitted by the radioisotope, and the area under the peak (with background subtracted) is the counting rate caused by photoelectrons produced by these quanta in the crystal. Radioisotopes with known rates of photon emission have been used to obtain the ratio of disintegration rate to area under peak (counting rate) given in Fig. 2.

The spectrometer will be used as an analytical instrument,<sup>(2)</sup> specifically to identify the gamma-emitting radioisotopes and to determine the amount of each of such radioisotope in samples of the water discharged at White Oak Dam. In relation to the evaluation and control of releases from White Oak Lake to the Clinch River, these quantitative determinations will: (1) allow more accurate estimates than are now available of the radioactive material that is released; and (2) provide a basis for calibration of the continuous gamma monitor installed at the dam. Calibration of the monitoring instrument and periodic determination of the gamma spectrum will facilitate interpretation of the continuous record and calculation of the total releases of radioactive material. It is planned to use

(2)W. S. Lyon and B. Kahn, *Anal. Chem. Quar. Prog. Rep.* Jan. 10, 1953, ORNL-1474 (to be published).

similar procedures at a later time to determine the activity discharged to White Oak Creek from the ORNL liquid waste stream.

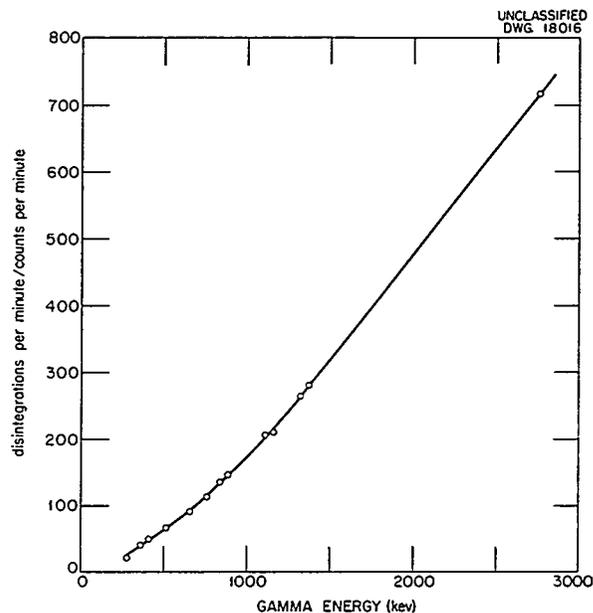


Fig. 2. Variation of Response of Thallium-activated Sodium Iodide Spectrometer with Gamma Energy.

## ECOLOGICAL STUDY

L. A. Krumholz

E. R. Eastwood  
W. T. Helm

W. T. Miller  
W. A. Mills

Research has continued on the accumulation of radioactive materials in the different tissues of various fishes, birds, and mammals from the White Oak Lake area, along with similar studies on plankton organisms and bottom fauna.

The year-round study on the accumulation of long-lived fission products in bluegills and black crappies has largely been completed. Weekly samples were taken from three bluegills and three black crappies for a period of 17 months. An analysis of the data will be forthcoming in the final report.

The extent to which migratory waterfowl have

been using White Oak Lake as a resting area has been under study during the period. A total of more than 550 waterfowl, including wood duck, mallard, black duck, green-winged teal, pintail, gadwall, and also American coot, has been banded in cooperation with the U. S. Fish and Wildlife Service. Specimens of these waterfowl are being assayed for deposition of radioactive materials. Of the birds assayed, the coot appear to accumulate considerably greater amounts than any of the other birds. Such an accumulation is probably traceable to the peculiar feeding habits of that species.

## HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

### EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson

M. F. Fair

M. R. Ford

T. H. J. Burnett

K. Z. Morgan

#### AEC FELLOWSHIP PROGRAM

The 1952-53 group of AEC Fellows in Radiological Physics completed the first quarter of graduate work at Vanderbilt University with good records.

One of the 1952-53 Fellows has been working on a research problem for a thesis under the supervision of R. D. Birkhoff in the Health Physics Division. The experimental work has been completed, and the Fellow has accepted a position in the Los Alamos Laboratory.

#### TRAINING PROGRAM FOR AEC CONTRACTORS' PERSONNEL

Two DuPont employees have been with this section during portions of this period.

#### LECTURES

Papers on the training and education of health physicists were given at the Health Physics Con-

ference at Idaho Falls, at the annual meeting of the Radiological Society of North America at Cincinnati, and at the AAAS meeting in St. Louis.

Lectures on current practices in radiation protection have been given at four colleges and universities in Texas, in conjunction with the ORINS-ORNL Traveling Lecture Program.

Two seminars on nuclear and health physics were given for R. T. Overman's groups at ORINS, two for the Naval Reserve group, and one for officers in training at the Navy Medical School at Bethesda, Maryland. In addition, seminars were held with various health physics groups at Harwell, England, and a paper was given at the Radiological Conference, Stockholm, Sweden.

#### CONSULTATION

A final report on the survey of current practices in the monitoring and control of airborne radioactive particles has been completed in cooperation with T. F. Hatch of the University of Pittsburgh.

---

### PUBLICATIONS

W. DeMarcus and J. W. Thomas, "Theory of a Diffusion Battery," ORNL-1413 (Nov. 19, 1952).

C. P. Straub and D. A. Pecsok, Discussion of "Longitudinal Mixing Measured by Radioactive Tracers," by H. A. Thomas, Jr. and R. S. Archibald, *Trans. Am. Soc. Civil Engrs.* 117, 851 (1952).

R. J. Morton, "Radioactive Contamination, Continuing Problem in Water Supply Engineering," *Civil Eng.* 22, 138 (Sept. 1952).

H. A. Butcher, "A Study of the Removal of Radioactive Iodine from Hospital Waste by Laboratory Trickling Filters" (thesis submitted to the Graduate Council of the University of Tennessee

in partial fulfillment of the requirement of the degree of Master of Science, Dec. 1952).

D. M. Davis, J. C. Hart, and K. Z. Morgan, *Nucleonics* 10, No. 11, 75 (1952).

W. K. Eister and K. Z. Morgan, TID-5109 (classified).

H. R. Craft, J. C. Ledbetter, and J. C. Hart, "Personnel Monitoring Operating Techniques," ORNL-1411 (Jan. 21, 1953).

T. J. Burnett, "Sampling Methods and Requirements for Estimating Airborne Radioparticulate Hazards," ORNL CF-52-11-1 (Nov. 21, 1952).

A. Simon and R. H. Ritchie, ORNL-1273 (classified).

J. W. Thomas, ORNL-1378 (classified).

LECTURES AND PAPERS

G. S. Hurst, "Fast Neutron Dosimetry," Annual Meeting of Radiological Society of North America, December 11, 1952, Cincinnati, Ohio.

G. S. Hurst, "Fast Neutron Instrumentation," Instrument Conference, Brookhaven National Laboratory, December 3, 1952.

E. E. Anderson, "Education and Training of Health Physicists," Annual Meeting of Radiological Society of North America, December 11, 1952, Cincinnati, Ohio.

E. E. Anderson, "The Need for and Training of Health Physicists," Annual Meeting of AAAS, December 30, 1952, St. Louis, Missouri.

M. F. Fair, "Current Practices in Radiation Protection," Lecture presented at Baylor University, Prairie View College, and Mary Allen College.

K. Z. Morgan, "The Control of Radiation by the Health Physicist," U. S. Naval Medical School, Bethesda, Maryland, November 18, 1952.

K. Z. Morgan, "Maximum Permissible Dose from Ionizing Radiation," Annual Meeting of AAAS, December 30, 1952, St. Louis, Missouri.

K. Z. Morgan, "Maximum Permissible Concentration of Radioisotopes in Food, Water, and Air and Maximum Permissible Equilibrium Amounts in the Body," Radiological Conference, Stockholm, Sweden, September, 1952.

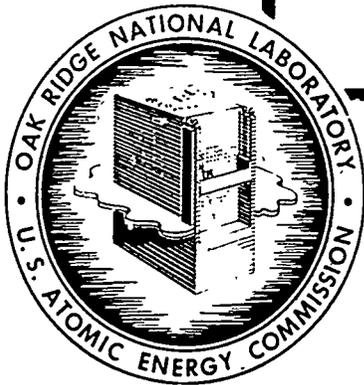
H. K. Richards, "Measurement of Ionizing Radiation by High Frequency Variation," American Physical Society Meeting, November 28, 1952, St. Louis, Missouri.

T. E. Bortner, "Ionization by Alpha Particles," Tennessee Academy of Science, November 28, 1952, Chattanooga, Tennessee.

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FOR PERIOD ENDING JULY 31, 1953



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for

Period Ending July 31, 1953

K. Z. Morgan, Director

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# CONTENTS

	Page
THEORETICAL PHYSICS .....	1
Disordering of Solids by Heavy Corpuscular Radiation .....	1
Energy Losses of Moving Charged Particles.....	1
Cooperative Program with Shielding Group.....	1
PHYSICS OF NUCLEAR RADIATION .....	2
Neutron Dosimetry .....	2
Ionization by Alpha Particles .....	2
Ionization by Recoil Atoms .....	2
Attachment Coefficient for Electrons .....	2
Applied Dosimetry .....	2
RADIATION MEASUREMENTS .....	3
Uranium Prospecting.....	3
RADIATION DOSE .....	4
Internal Dose .....	4
Maximum permissible concentrations .....	4
Maximum permissible concentration experiments on mice .....	4
Spectrographic analysis of human tissue.....	4
Radiochemical analysis .....	11
External Dose .....	11
Measurement of ionizing radiation by high-frequency variation .....	11
Backscattering of beta particles .....	12
Film monitoring for fast neutrons .....	12
X-ray shielding room .....	13
Film dosimetry .....	13
Energy losses of electron in foils .....	15
Special tests .....	15
Standardization of radiation monitoring film sensitometry .....	15
AIRBORNE RADIOPARTICULATE CONTAMINATION .....	16
Radioactive-Dust Studies and PEEP .....	16
Study of radioparticulate contamination at X-10 .....	16
Activity escaping from the graphite reactor filter house .....	17
Cloud chamber for measuring aerosol concentration.....	18
Atomic weapons test fall-out at ORNL .....	19
RADIOACTIVE WASTE DISPOSAL RESEARCH .....	19
Water and Liquid Waste Decontamination Process .....	19
Water decontamination studies .....	19
Process waste studies .....	25
Surveys and Evaluations – Field and Laboratory .....	25
Estimates of downstream effects in the event of emergency contamination in Clinch River.....	25
Instrumentation and Techniques .....	26
Counting response of crystal spectrometer .....	26
Radioactivity in river bottom sediments .....	28

ECOLOGICAL STUDY.....	30
EDUCATION, TRAINING, AND CONSULTATION .....	30
AEC Fellowship Program .....	30
Lectures .....	30
Consultation .....	30
PUBLICATIONS.....	32
PAPERS .....	33
LECTURES .....	33

# HEALTH PHYSICS DIVISION SEMIANNUAL PROGRESS REPORT

## THEORETICAL PHYSICS

J. Neufeld

R. H. Ritchie

W. S. Snyder

### DISORDERING OF SOLIDS BY HEAVY CORPUSCULAR RADIATION

A general method has been developed for determining the number of vacant lattice sites or interstitial atoms in a monoatomic substance exposed to heavy corpuscular radiation. The colliding atoms are assumed to be within the energy range for which the orbital picture can be applied. By following the treatment of Bohr, the energy range is divided into regions of excessive screening, moderate screening, Rutherford scattering, and electronic collisions. The first three regions cover the range in which the velocity of the atom is less than the velocity of the orbital electron of the hydrogen atom. In this range, which extends over  $0 \leq E \leq \gamma = 25 A \times 10^3$  ev (where  $A$  is the mass number of the atoms in the solid), only elastic collisions are considered. The theory predicts that the number of vacant lattice sites is approximately  $(E + a)/2a$ , where  $a$  is the energy required to displace an atom from its lattice site. Thus the energy used in producing vacancies is approximately half the total energy absorbed by the solid.

Work on the problem for energies  $E > \gamma$ , where electronic collisions are important, is in progress.

### ENERGY LOSSES OF MOVING CHARGED PARTICLES

The stopping power of a particle having charge  $Ze$  and moving with velocity  $v$  has been determined by Bohr for  $K = 2Ze^2/\hbar v \gg 1$  and  $\eta_s = 2v/u_s \gg 2$ , where  $u_s$  is the orbital electron velocity that is effective in stopping the particle. Bohr's results are formulated differently for  $K/\eta_s < 1$  and for  $K/\eta_s > 1$  and are based entirely on an orbital picture of the processes involved. In an alternative method that has been developed, the space surrounding the particle track is subdivided into three regions: (1) the region of validity of the Rutherford formula (adjacent to the track), (2) the intermediate region involving large perturbations for which no adequate theory exists at present, and (3) the

region of validity of the quantum perturbation theory (the region most remote from the track). By extrapolating the formulas valid in regions 1 and 3 into region 2, the contribution to the stopping power that is due to the region 2 has been evaluated; and by adding the contribution resulting from regions 1 and 3 to region 2, an expression has been derived for the total stopping power that is applicable for any  $K \gg 1$  and  $\eta_s \gg 2$ . The physical picture used for deriving this expression is somewhat similar to that used by Bohr for  $K/\eta_s < 1$ , but it is different from the one used by Bohr for  $K/\eta_s > 1$ . As an alternative of Bohr's formula for the stopping number for  $K/\eta_s > 1$ , namely

$$\sigma_s = \frac{2\pi Z^2 e^4}{mv^2} \ln \frac{\eta_s^3}{K},$$

the following expression is proposed:

$$\sigma_s = \frac{2\pi Z^2 e^4}{mv^2} \left[ \ln (\lambda^2 \eta_s^2 + 1) + 2 \left( \lambda \frac{K}{\eta_s} \right) K_0 \left( \lambda \frac{K}{\eta_s} \right) K_1 \left( \lambda \frac{K}{\eta_s} \right) \right],$$

where  $\lambda$  is a known function of  $K$  and  $\eta_s$ .

### COOPERATIVE PROGRAM WITH SHIELDING GROUP

During the 1953 Summer Shielding Session at ORNL, it was necessary to solve a neutron transport problem for design purposes. An approximate analytical solution which avoids the numerical work involved in solving the problem by the multigroup approach has been worked out. The details have been published elsewhere.<sup>(1)</sup>

<sup>(1)</sup>E. P. Blizzard and H. G. Goldstein (ed.), ORNL-1575 (classified).

## PHYSICS OF NUCLEAR RADIATION

G. S. Hurst  
T. E. Bortner  
W. G. Stone

W. A. Mills  
T. A. Barr, Jr.  
L. W. Cochran

## NEUTRON DOSIMETRY

In the neutron dosimetry studies, tissue-depth dose curves have been obtained with a phantom (dimensions: 6 by 6 in. and 12 in. high) and Po-B and Po-Be neutron sources. The ratio of the dose at surface to the dose in air without the phantom is 1.1, and the depth-dose curve drops by  $1/e$  in approximately 10 cm. Complete results will be reported by W. A. Mills, who will offer the work as a thesis for the Master of Science degree from Vanderbilt University.

A project involving the measurement of a fast neutron spectrum has been completed. Details will appear in a classified report.

## IONIZATION BY ALPHA PARTICLES

The average number of electron volts used in producing an ion pair in various gases has been measured for alpha particles from plutonium. Values for pure gases and mixtures are given in Table 1.

TABLE 1. VALUES OF  $w$  FOR PURE GASES AND MIXTURES

GAS	$w$ (ev per ion pair)
Nitrogen	36.3
Argon	26.4
Ethylene	28.0
Hydrogen	37.0
Freon	29.2
Sulfur hexafluoride	34.8
Boron trifluoride	36.2
Tissue-equivalent gas*	30.8
Air (both dry and 50% RH at 24°C)	35.0 ± 1%
Freon 50% } SF <sub>6</sub> 50% }	32.2**

\*Mixture used by Rossi-Failla to obtain soft-tissue-equivalent gas: CH<sub>4</sub>, 64.4%; CO<sub>2</sub>, 32.4%; N<sub>2</sub>, 3.2%.

\*\*Calculations based on energy division according to stopping powers, partial pressure, and  $w$  values for pure gases gave 32.8 ev per ion pair.

The value for He, 46.0 ev per ion pair, is approximately 4 ev higher than the value measured by other investigators. If helium is contaminated with less than 1% of argon, nitrogen, hydrogen, or methane, the value of  $w$  drops in each case to about 30 ev per ion pair, which is the value usually found in the literature. A complete report on the value of  $w$  for many gas mixtures is now in preparation.

## IONIZATION BY RECOIL ATOMS

The ionization produced by the recoil uranium atoms from the decay of Pu<sup>239</sup> (Pu<sup>239</sup> → He<sup>4</sup> + U<sup>235</sup>) is being studied with the use of a proportional counter whose length is large compared with its diameter and which has a collimated well in the wall for the plutonium source. The counter is filled with various gases at such a low pressure that the uranium atoms lose all their energy in the counter, whereas the alpha particles travel across the counter and dissipate their energy largely in the wall and thus produce a very small pulse in the counter. Another alpha emitter which produces alpha particles that travel the long length of the counter serves as a calibration source.

## ATTACHMENT COEFFICIENT FOR ELECTRONS

The equipment for measuring the electron attachment coefficient (that is, the probability that in moving 1 cm in a gas, an electron will be attached to an atom or a molecule) is now being assembled and tested.

## APPLIED DOSIMETRY

The irradiation of primates at the Bulk Shielding Facility, the first phase of the joint project of the USAF and the Health Physics Division, has been completed and a classified report is being prepared.

The participation of the Health Physics Division in the phase of the program at the University of Texas has been mainly that of assisting in the design and construction of the irradiation facility and of the fast neutron dosimeters of the proportional-counter type.

## RADIATION MEASUREMENTS

F. J. Davis  
P. W. Reinhardt

C. F. Harris  
J. A. Harter

URANIUM PROSPECTING<sup>(1)</sup>

The instrumentation for airborne prospecting has been redesigned, and duplicate instruments to equip the second aircraft have been constructed. In the redesign, particular attention has been given to eliminating temperature effects. A speaker system has been added so that an audio signal is given when the radiation reaches a prescribed level; the pitch of the signal increases as the radiation increases. This makes it possible to locate the position on the ground from which the peak radiation is received without having to refer to the recorder chart. An additional chart-marking system is included in the revised instrument: one set of edge markers gives edge marks at 12-sec intervals, and another set on the opposite side of the record automatically marks every tenth edge mark; every hundredth edge mark is indicated by a wide mark.

When the equipment is installed in the second aircraft, a series of flight tests over sources of various energies will be made for determining the optimum shielding of the scintillation detectors. When the aircraft is operated at 500 ft above the ground and large areas of low activity are scanned, small areas of high grade ore are difficult to locate.

In order to improve the detection of small areas, various methods of collimating the detectors with lead shielding have been tried. Experiments performed on the ground indicate that little advantage can be gained unless the detectors are limited to the harder radiation, which will thus reduce the scattered radiation component. This means reducing the counting rate from the source by about one-half; however, since the error that results from statistics is still small compared with variations in background, the use of lead shielding appears to be advantageous. Further test flights over a simulated ore outcrop of 60 tons of carnotite ore at Grand Junction, Colorado, are scheduled.

Flights were made over regions of fall-out from the spring tests in Nevada. Altitude curves showed an exponential variation of radiation intensity with height which compare favorably with curves reported previously.<sup>(2)</sup> The half thickness of air in the earlier report was 260 ft for fall-out that was 13 days old; the recent curve gives the half thickness as 310 ft for fall-out that was two days old. These data are as would be expected, since the fission products with shorter half lives emit harder radiations.

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(1) In cooperation with the U. S. Geological Survey.

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(2) F. T. Davis and P. W. Reinhardt, *H-P Quar. Prog. Rep.* Jan. 20, 1952 to July 20, 1952, ORNL-1353, p. 14.

## RADIATION DOSE

H. H. Hubbell

A. G. Barkow	E. D. Gupton
R. D. Birkhoff	P. N. Hensley
A. W. Blackstock	K. Z. Morgan
J. S. Cheka	F. H. W. Noll
M. J. Cook	H. K. Richards
M. R. Ford	M. Slater
A. F. Gabrysh	A. W. Smith

I. Tipton

## INTERNAL DOSE

## Maximum Permissible Concentrations

The previously published values<sup>(1)</sup> of maximum permissible concentrations of radioisotopes were submitted to the Subcommittee on Permissible Internal Dose of the National Committee on Radiation Protection. The conclusions of this subcommittee were published on March 20, 1953, by the National Bureau of Standards.<sup>(2)</sup> In the light of the recent data, some of the values are being reconsidered and may be revised. Further developments will be published soon.<sup>(3)</sup>

The Committee on Permissible Dose for Internal Radiation of the International Commission on Radiological Protection held a meeting in Copenhagen, Denmark, July 13 to 17, 1953. A report entitled *Maximum Permissible Internal Dose* is being prepared and will be submitted for publication by January 1954.

Maximum Permissible Concentration  
Experiments on Mice

An experiment is in progress to determine which is the critical organ for  $\text{Co}^{60}$ , to determine the ratio of  $\text{Co}^{60}$  in the critical organ to that in the whole body, and to check the conclusion that a continuous dose of  $2 \times 10^{-2} \mu\text{c}$  of  $\text{Co}^{60}$  per cubic

centimeter in drinking water consumed for a lifetime will not build up to give a weekly dose to the critical organ that is greater than the maximum permissible dose. It is also hoped that it will be possible to determine the percentage of cobalt that passes from the gastrointestinal tract to the blood. With the cooperation of the Biology Division, a number of C-57 strain mice are being given individual doses of  $32 \mu\text{c}$  of  $\text{Co}^{60}$  directly into the gastrointestinal tract, while another group is being given drinking water containing  $2 \times 10^{-2} \mu\text{c}$  of  $\text{Co}^{60}$  per cubic centimeter. The subsequent concentrations of the element in the various organs are to be determined and the dose rate to the organ will be calculated.

Spectrographic Analysis of Human Tissue<sup>(4)</sup>

The Spectrographic Laboratory at the University of Tennessee has completed a preliminary survey of trace elements in human tissue. The results of a semiquantitative estimation of trace elements in the normal tissues of 41 autopsies of human beings are shown in Figs. 1 through 11. The numbers in parentheses, which appear under the chemical symbols of the elements, are the limits of detection in parts per million in ash. The other numbers indicate the number of samples in which the element appeared. When an element appeared in over half the samples, a geometric mean value for the concentration was calculated, and it appears as the shaded portion of the bar. In every case, the dotted line at the top of the bar indicates the highest value that appeared; the dotted line in the shaded portion indicates the lowest value, this being determined only in those instances where the element appeared in every sample analyzed.

(1) K. Z. Morgan, M. J. Cook, and M. R. Ford, *H-P Prog. Rep. Jan. 20, 1952 to July 20, 1952*, ORNL-1353, p. 15.

(2) *Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water*, Handbook 52, National Bureau of Standards (March 20, 1953).

(3) K. Z. Morgan and M. R. Ford, "Developments in Internal Dose Determinations," *Nucleonics* (to be published).

(4) University of Tennessee research and development contract.

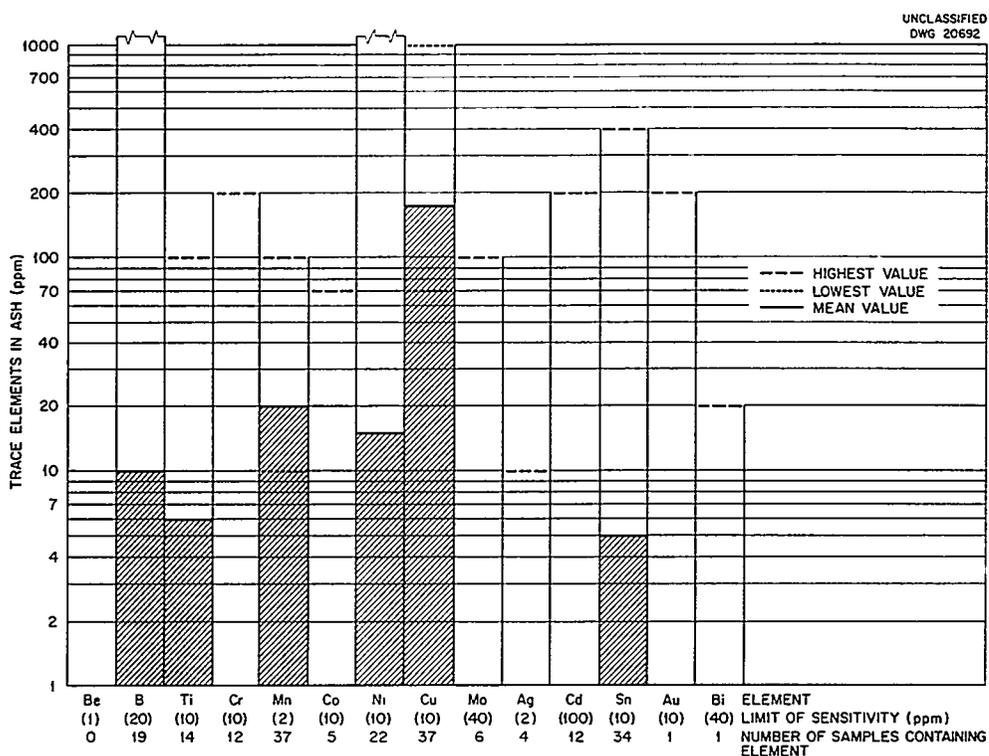


Fig. 1. Spectrographic Analyses of 37 Samples of Human Muscle for Trace Elements. Average Ash, 1.1%.

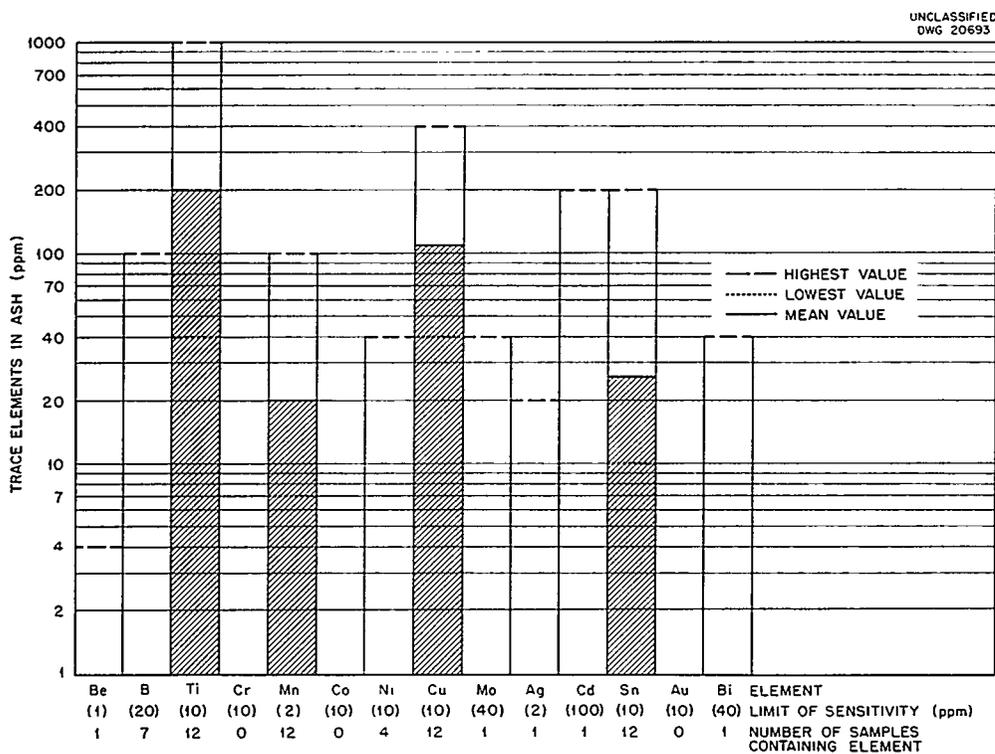


Fig. 2. Spectrographic Analyses of 12 Samples of Human Lung for Trace Elements. Average Ash, 1.1%.

HEALTH PHYSICS PROGRESS REPORT

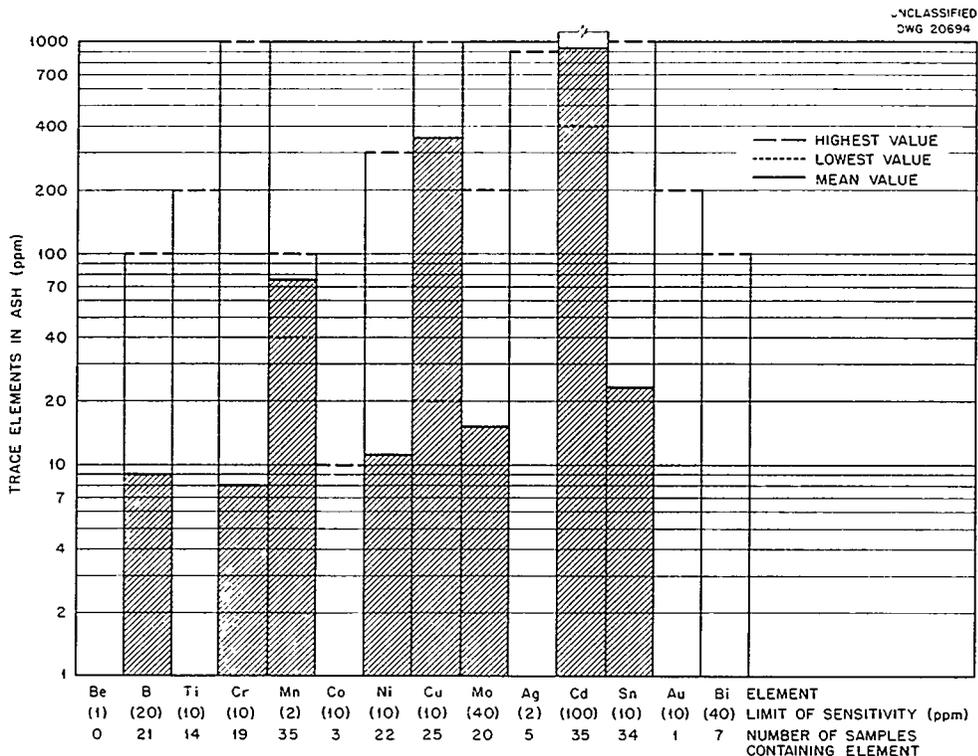


Fig. 3. Spectrographic Analyses of 35 Samples of Human Kidney for Trace Elements. Average Ash, 1.1%.

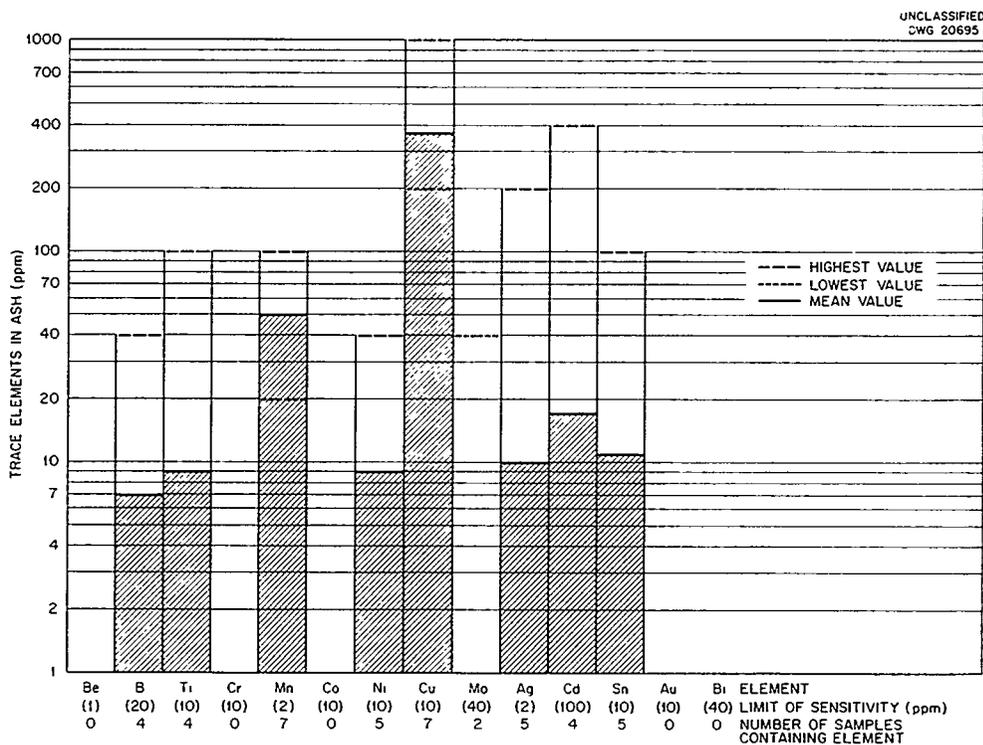


Fig. 4. Spectrographic Analyses of 7 Samples of Human Intestine for Trace Elements. Average Ash, 0.7%.

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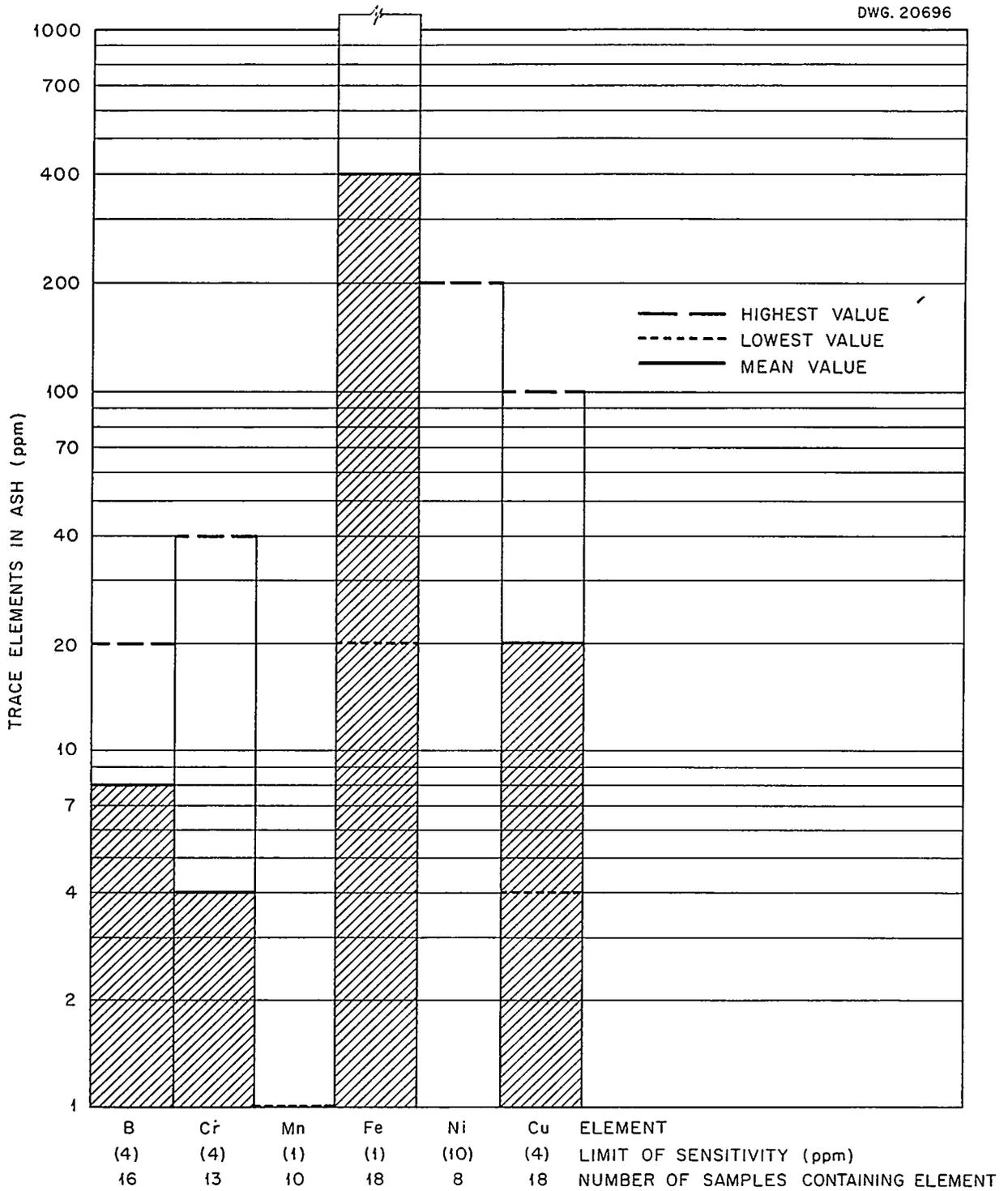


Fig. 5. Spectrographic Analyses of 18 Samples of Human Cartilage for Trace Elements. Average Ash, 2.4%.

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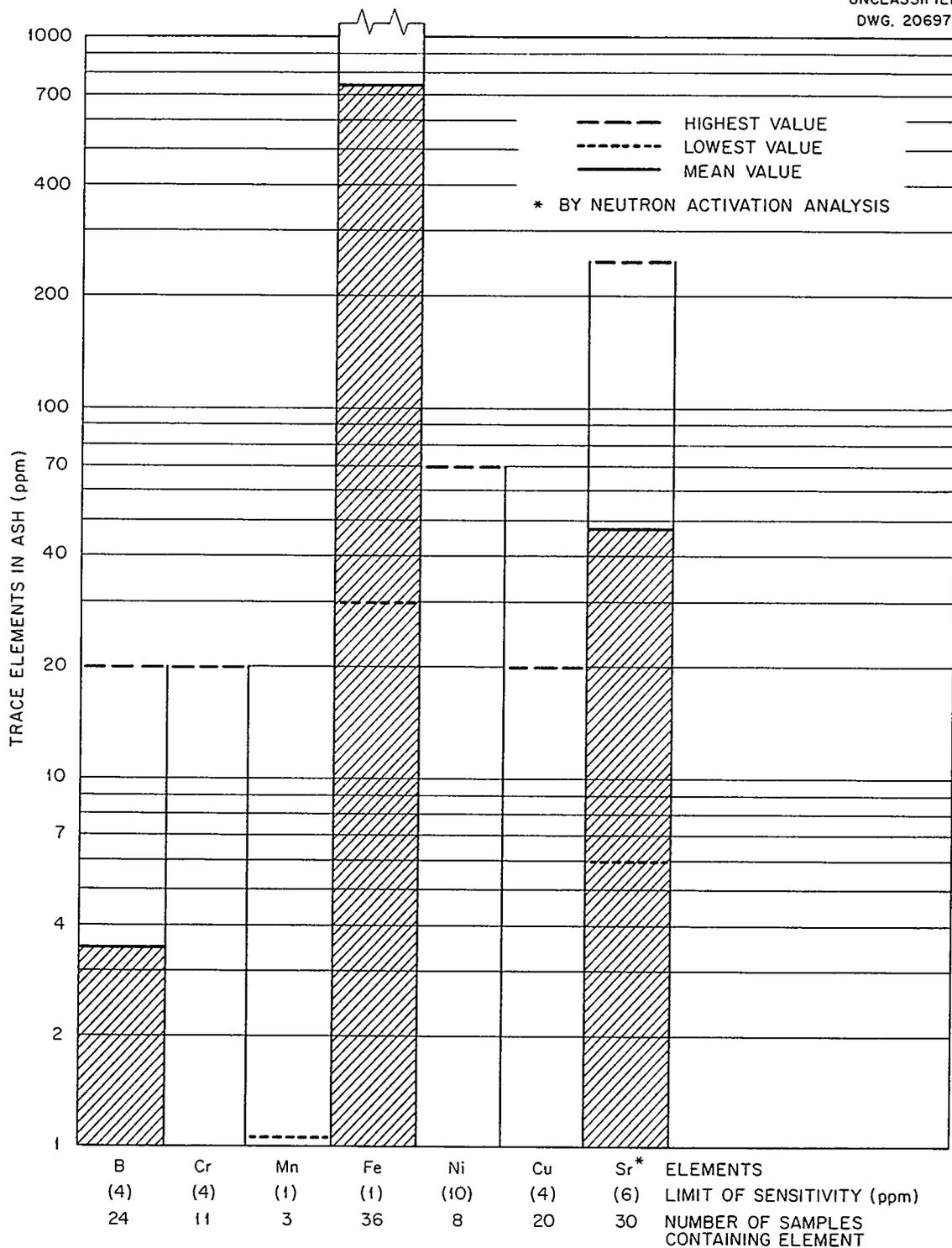


Fig.6. Spectrographic Analyses of 36 Samples of Human Bone for Trace Elements. Average Ash, 15.7%.

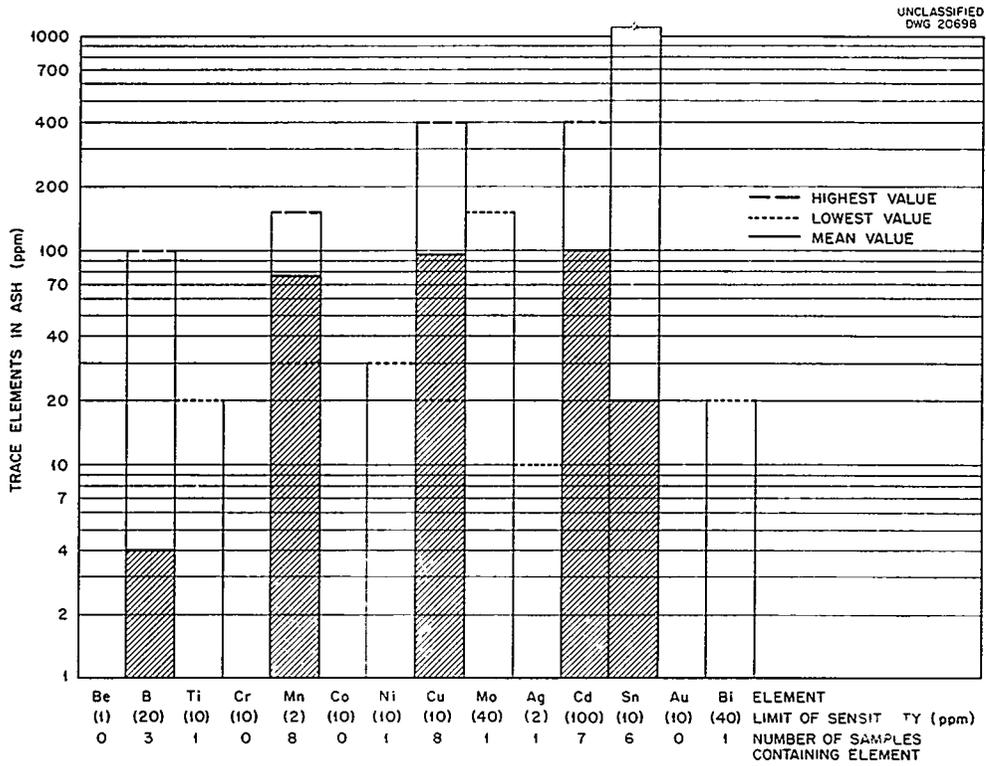


Fig. 7. Spectrographic Analyses of 8 Samples of Human Pancreas for Trace Elements. Average Ash, 1.1%.

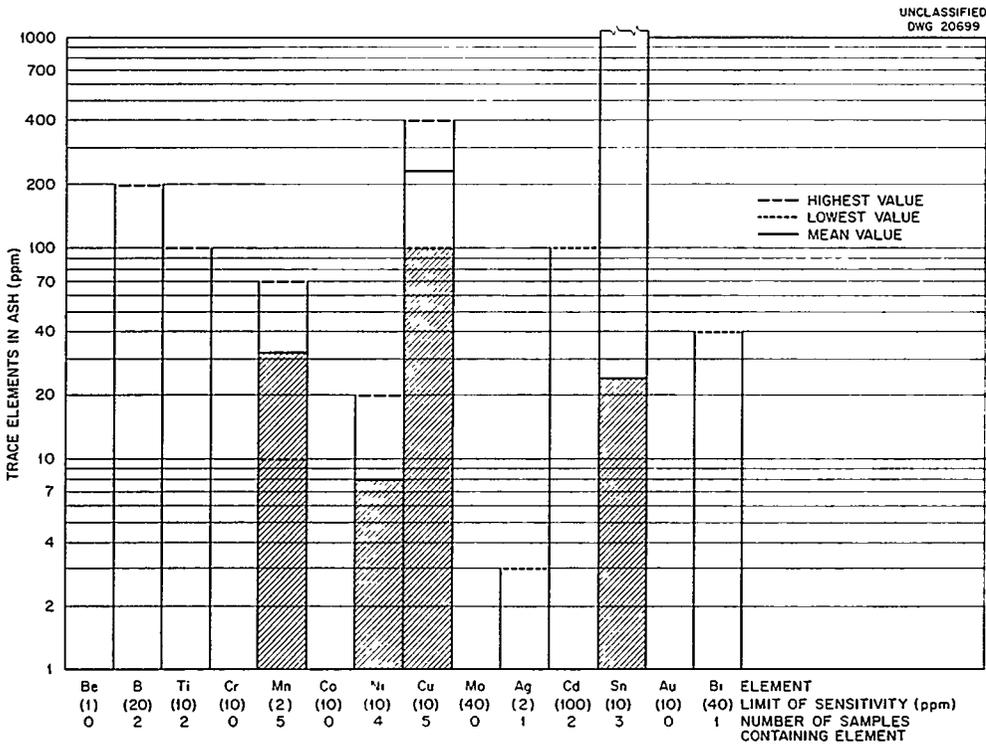


Fig. 8. Spectrographic Analyses of 5 Samples of Human Stomach for Trace Elements. Average Ash, 0.8%.

# HEALTH PHYSICS PROGRESS REPORT

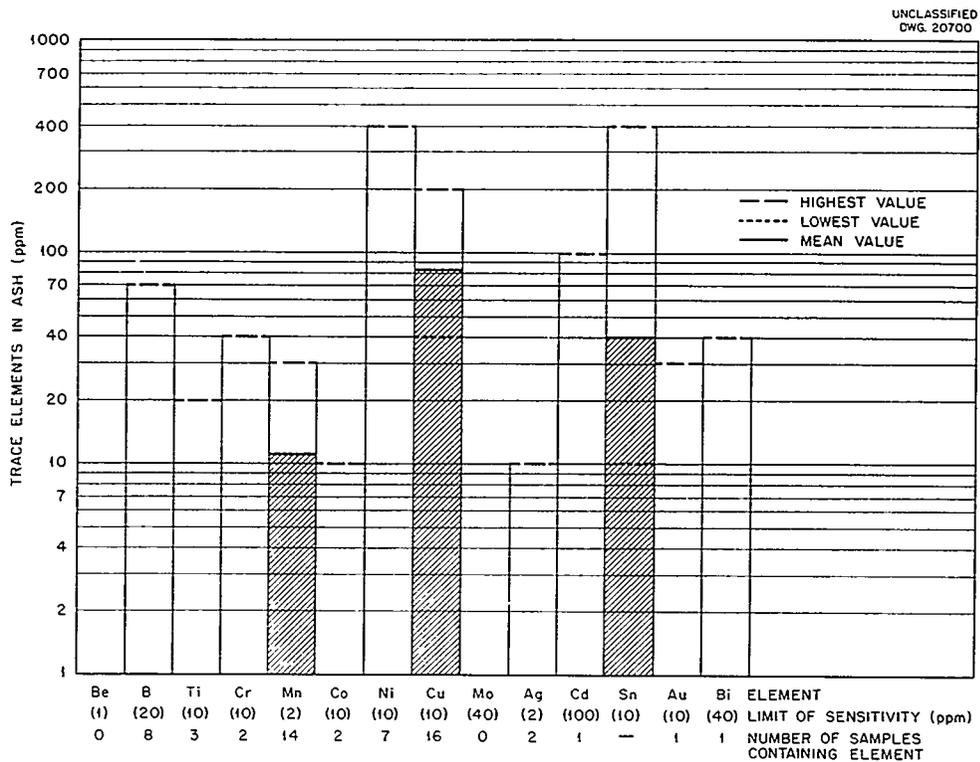


Fig. 9. Spectrographic Analyses of 16 Samples of Human Spleen for Trace Elements. Average Ash, 1.4%.

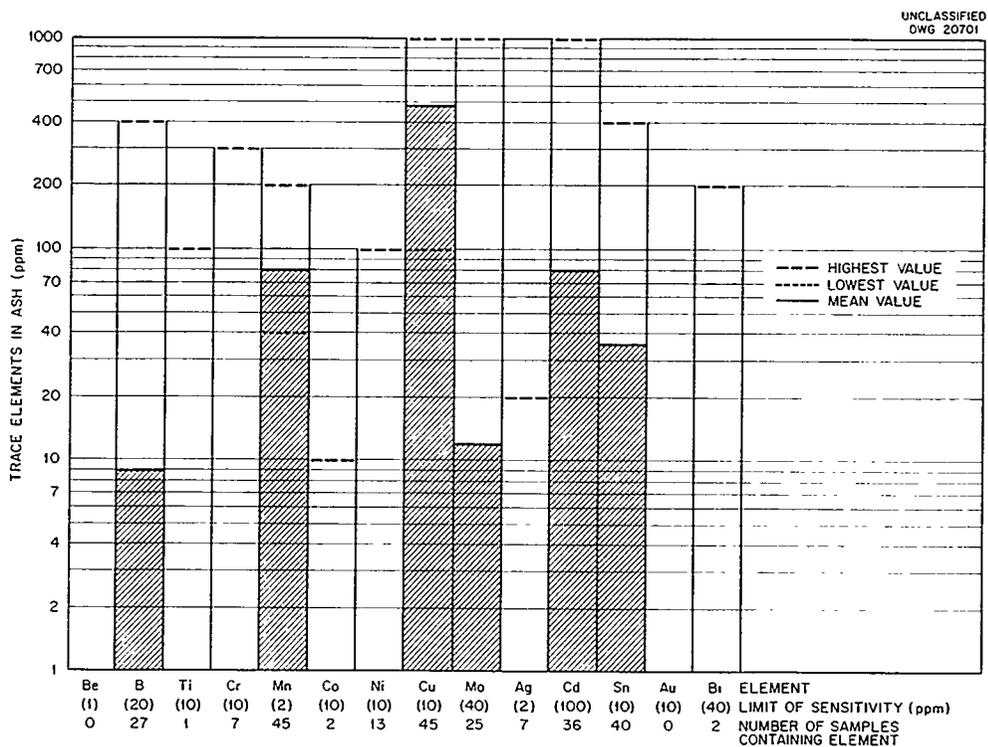


Fig. 10. Spectrographic Analyses of 45 Samples of Human Liver for Trace Elements. Average Ash, 1.4%.

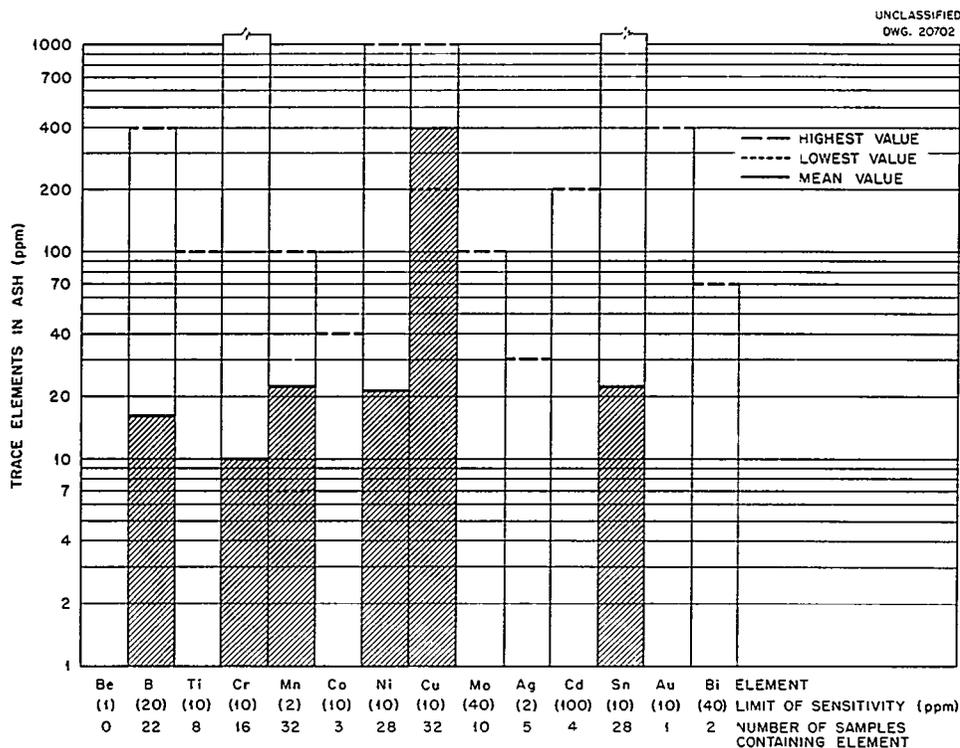


Fig. 11. Spectrographic Analyses of 32 Samples of Human Heart for Trace Elements. Average Ash, 1.0%.

Because of the high concentration of potassium and sodium in the ash, the sensitivity for many elements was greatly reduced. Zinc, for instance, could not be measured but was present in nearly every sample.

No vanadium was detected, but it could have been lost in the ashing process. A method for trapping the volatile products of the ashing is being investigated, and, if successful, a complete analysis that includes volatile elements can be made. A detailed report on procedures and the results of the preliminary survey has been written.<sup>(5)</sup>

#### Radiochemical Analysis

Work has continued on the development of an analytical procedure that requires a shorter time for the determination of radioactive strontium in urine than does the present method. Preliminary investigations have been made on the use of Versene (ethylenediamine tetra-acetic acid) for

(5) I. H. Tipton, W. D. Foland, F. C. Bobb, and W. C. McCorkle, *Spectrographic Determination of Trace Elements in Human Tissue*, CF-53-8-4 (Aug. 3, 1953).

(6) H. K. Richards, *Phys. Rev.* 89, 897A (1953).

selectively chelating calcium. This would provide a means of separating radioactive strontium from the calcium in urine.

The order of chelation of the alkaline earths by Versene is  $Ca > Mg > Sr$ . By controlling the pH of a urine specimen at 6.0 to 6.5 – with an excess of magnesium present – and by allowing the solution to flow over the column of a cation-exchange resin (Dowex-50 in sodium cycle), essentially all the radioactive strontium is taken up on the resin. Some magnesium is also retained on the column, but practically all the calcium will pass through as the chelate.

Subsequent separation of the radioactive strontium by using the procedure already established is made easier by the decreased amount of calcium present. The time required for an analysis may be reduced by a factor of 2 or more.

#### EXTERNAL DOSE

##### Measurement of Ionizing Radiation by High-Frequency Variation<sup>(6)</sup>

Experiments were continued on the use of an electrometer as the frequency-controlling element

## HEALTH PHYSICS PROGRESS REPORT

in a high-frequency circuit. As previously described, the electrometer leaf rotates on the quartz-fiber suspension as the electrostatic charge is changed by ionizing radiation. This turning varies the capacity that is seen by the radio-frequency circuit and thereby changes the frequency. A sensitivity of 0.5 mr/hr or better was observed when an ion-collecting volume of about 100 cm<sup>3</sup> was used. As little as 2000 beta particles from Sr<sup>90</sup> and Y<sup>90</sup> have been measured.

To utilize the ferroelectric effect to eliminate moving parts, the electrometer was replaced by a capacitance that had a dielectric of barium titanate. The barium titanate was in the form of a cylinder about 6 mm in length and 1 mm<sup>2</sup> in cross section that had silver-plated electrodes on the ends. The capacitance was about 25  $\mu$ mf. This capacitance was connected in series with an ordinary, highly insulated capacitance, and the combination formed a section of a frequency-determining network of a 5-megacycle per second, quartz-crystal-controlled oscillator. The center frequency could be varied by 5 to 10 kilocycles per second, since a coil in series with the crystal broadened the resonance. The connection between the barium titanate and the ordinary capacitance was joined to the inner electrode of an ionization chamber of about 100 cm<sup>3</sup> volume and charged to between 300 and 700 volts dc. This polarizing voltage reduces the dielectric constant of the barium titanate and therefore the capacitance; thus the oscillator frequency is increased by several thousand cycles per second. When the ionizing radiation in the chamber discharges the electrode, the polarizing voltage is lowered, the capacitance of the barium titanate is increased, and the frequency is thereby reduced. Reproducible measurements of dose rates from 35 to 500 mr/hr have been obtained. At present, the sensitivity is limited by the finite conductivity of the ferroelectric material and by temperature effects.

### Backscattering of Beta Particles

Calculations of backscattering for 0.6-Mev monoenergetic beta particles showed that for scatterers with low atomic numbers (Z) normally incident particles are largely reflected by single scattering up to depths of 100 to 200 mg/cm<sup>2</sup>. If the loss of particle energy that is due to absorption and the number of particles lost are taken into account, most of the reflected particles, even from elements

of medium Z, have suffered single scattering. Elements with high Z produce principally multiple scattering.

A plot of the calculated total number of electrons scattered between 90 and 180 deg vs. Z has the general shape which is observed experimentally. As yet, numerical agreement has not been obtained, and multiple scattering will have to be considered.

### Film Monitoring for Fast Neutrons<sup>(7)</sup>

Work has continued toward making the NTA film badge into a true neutron dosimeter by means of a compensated proton radiator. This radiator consists of laminations of aluminum foil and paper which adjust the film response to neutrons to agree with the dose vs. energy curve. The radiator was constructed to match the film response to W. S. Snyder's multiple-collision dose calculation.<sup>(8)</sup>

A question remained as to whether the multiple-collision dose calculation was the correct dose curve to use. If the dose was measured in air, this curve would give the dose to a body that is in the same position as the film. A series of exposures was made with and without a 20-cm-dia paraffin phantom that backed the film badges. A film placed 1 cm from the phantom (the separation produced by the badge clip) showed a track population 30% higher than that of a film without the phantom. Since the neutrons reflected from a phantom (or a body) also record on the film, film response matched to a first collision dose curve<sup>(9)</sup> gives a better approximation to the true body dose than one based on Snyder's curve - the latter gives too high a reading. Consequently, the first collision dose curve was calculated by use of the latest available cross-section data. The lamination thicknesses of the radiator were recalculated to match this curve.

One of the dimensions requiring change is the thickness of the film base. This problem was discussed with representatives of Eastman Kodak Company and, the technical staff at Eastman Kodak

(7) J. S. Cheka, *H-P Quar. Prog. Rep. Oct. 20, 1952*, ORNL-1420, p. 7; *H-P Quar. Prog. Rep. Jan. 20, 1953*, ORNL-1488, p. 3; *Phys. Rev.* 90, 353A (1953).

(8) W. S. Snyder and J. Neufeld, *Maximum Permissible Neutron Flux for Fast and Thermal Neutrons*, AECU-2328 (1953).

(9) This curve was recalculated by using the latest available data. Earlier data were given by K. Z. Morgan in *Health Control and Nuclear Research* (to be published). Morgan's curve was published by G. S. Hurst, R. H. Ritchie, and H. N. Wilson, *Rev. Sci. Inst.* 22, 981 (1951).

is checking on the feasibility of using a thinner plastic base. If a thinner base cannot be produced without curl, a different plastic will be tried.

The microscopy techniques recently reported<sup>(6)</sup> for counting proton tracks in film have been modified. It was found that with partly degenerate tracks, in the presence of fog, track counts at 440X magnification did not agree with those at approximately 900X. However, if 10X wide-field eyepieces and a 90X oil-immersion objective are used, and if the traverse method of reading is retained, there is still a great advantage because the total area scanned is greater than that obtained in reading discrete fields. The field diameter of 0.019 cm with a traverse length of 1.32 cm gives an area of 0.025 cm<sup>2</sup>, as compared with the 0.0024 cm<sup>2</sup> that is covered by 12 discrete fields in the present method. Statistical error for the permissible exposure of one week is based on about 60 tracks rather than on the 6 tracks used at present.

Since the traverse method of reading film takes about twice as long as the scanning of 12 fields, splitting the group of neutron films and reading half the films on alternate weeks would reduce the monitoring period to two weeks per film. However, under the present circumstances, such a program is not feasible because the proton latent images fade with time. A survey of the literature showed that exposure to 100% relative humidity at 35°C for 6 hr eradicates all latent images, even those of alpha tracks. A test was run to determine whether desiccation would prevent the rapid fading. A group of films was uniformly exposed to neutrons from a polonium-boron source and then divided into two sets. Both sets were stored at 24°C, one at a relative humidity of about 50% and the other in a desiccator over Drierite. Specimens of each set were developed at intervals from day zero to about two months. The set stored at 50% relative humidity showed 88% track retention after 11 days and 50% retention after 33 days. The desiccated set showed 95% retention after 21 days, 88% retention after 30 days, and 50% retention after 64 days. Previous tests have shown that under normal conditions at Oak Ridge, track retention is about 88% in seven days. Allowance is made for this in the present method of calibration.

In order to take advantage of low relative humidity to inhibit fading, a new sealed badge that contains a desiccant should be designed for NTA film or the films should be desiccated and sealed individually

in aluminum foil during manufacture. The latter may be more feasible, since the proposed dosimeter packet requires layers of aluminum.

#### X-Ray Shielding Room

Measurements were made on the attenuation of the beam from the 250-kv x-ray machine in samples of ordinary concrete block and of barytes-loaded concrete block. On the basis of these measurements, it was calculated that the dose rate in the direct beam could be reduced to about 7 mr/hr at a distance of 7 ft from the target by about 16 in. of ordinary concrete, 4.5 in. of barytes concrete, or  $\frac{3}{8}$  in. of lead. Barytes concrete was used in the construction of a shielding room for the x-ray machine because it provided, at the least cost, walls that are not unreasonably thick. The x-ray tube and stand were moved inside, and the controls remain outside. In order to allow a safety factor, the walls were made 6 in. thick and the ceiling was covered with  $\frac{3}{16}$  in. of lead to absorb scattered radiation. The door and window were lead-sheathed, and baffles were placed in the vents. Preliminary measurements indicate that the beam is attenuated to 10 mr/hr, even when it is aimed directly at the wall at a distance of 5 feet. The room considerably increases the safety and usefulness of the x-ray machine.

#### Film Dosimetry

The new, personnel monitoring and security badge adopted by ORNL was extensively tested for the Applied Health Physics Section. As has been reported,<sup>(10)</sup> the badge contains filters of 0.040-in. copper, 0.030-in. cadmium, and 0.020-in. lead, and an open window region. The variation in transmission of x rays and gamma rays through filters of different atomic numbers permits the blackening on the film to be interpreted in terms of both the dose and the energy of the radiation. Heavily filtered beams from the x-ray machine and a radium source permitted study of this effect with energy variations from about 20 to 700 kev, and over a dose range from 10 mr to 3000 r. Results for Du Pont type 502 film are shown in Fig. 12.

<sup>(10)</sup>D. M. Davis and J. C. Hart, *A Review of Film Dosimetry*, paper presented at the Meeting on Industrial Health sponsored by US-AEC, Los Angeles, California, April 24, 1953.

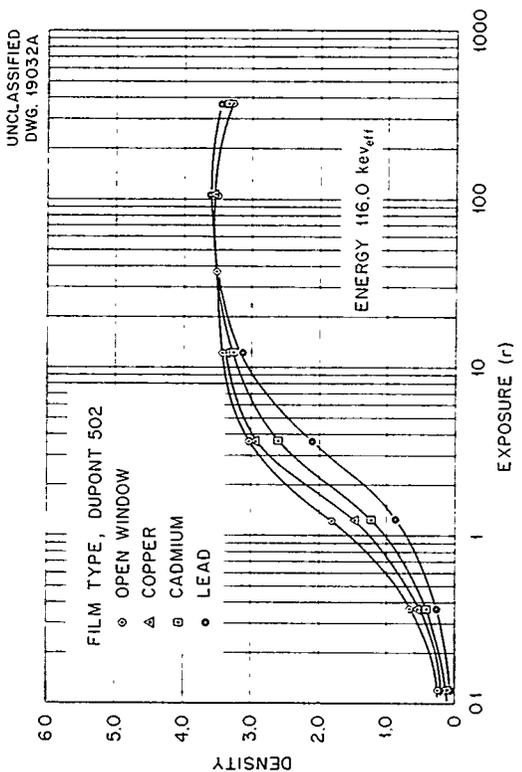
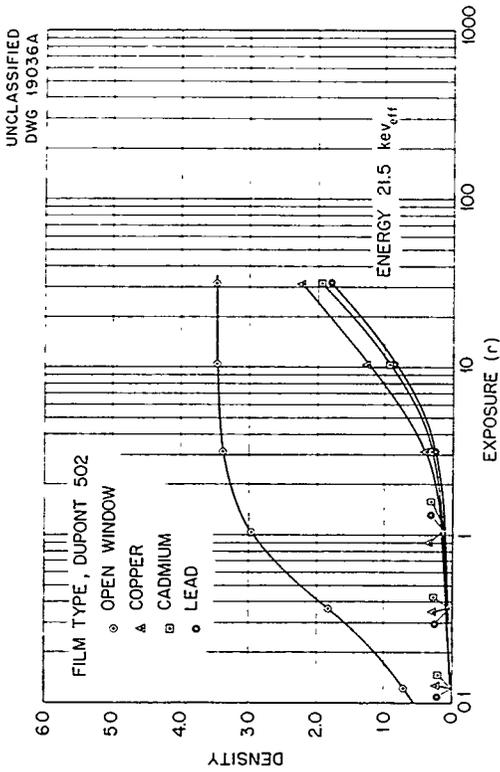
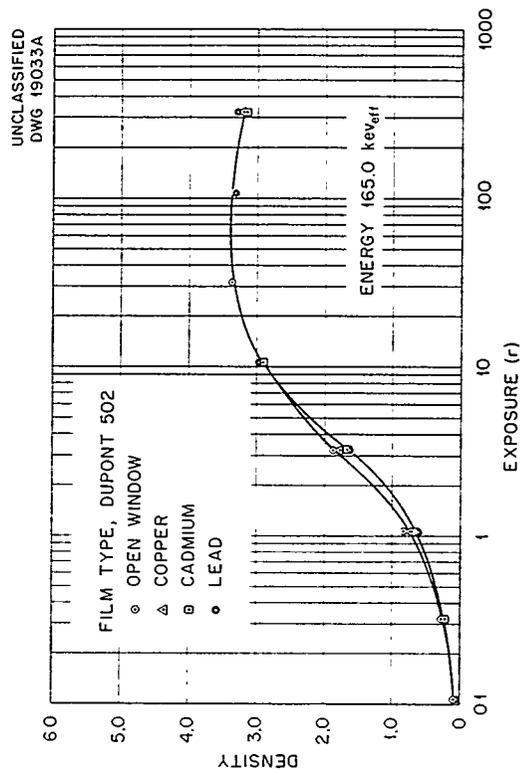
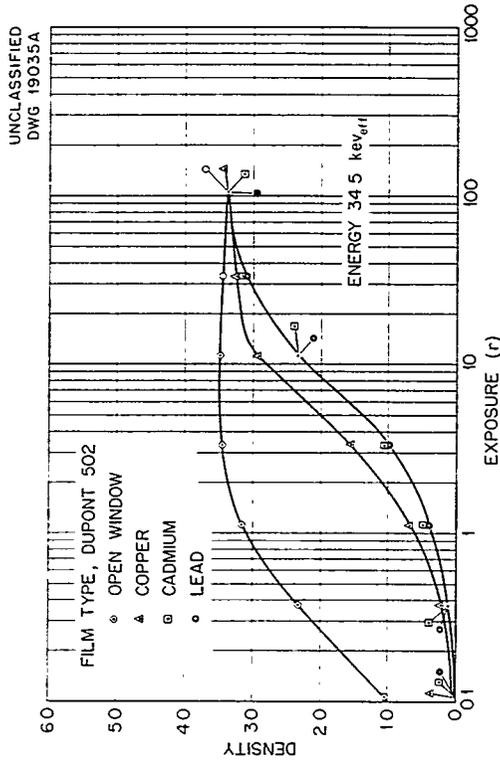


Fig. 12. Response of Du Pont Type 502 (Sensitive) Film as a Function of Exposure for Different Effective Radiation Energies behind the Four Filtered Areas in the Film Badge.

### Energy Losses of Electrons in Foils

**Beta Particle Spectrometer.** A paper to be published soon<sup>(11)</sup> describes experiments on the determination of energy losses of electrons in passing through thin foils of materials of various atomic numbers. The 624-keV K conversion electrons from Cs<sup>137</sup> were allowed to pass through thin absorbers of beryllium, aluminum, copper, tin, tantalum, and lead. The energy spectra of the transmitted electrons were analyzed with the small, high-resolution, solenoidal, beta spectrometer. Agreement with the theory of Landau was found for the displacement of the peaks of the energy-loss distribution, but the widths of the distributions were about 1.8 times the Landau values. An extension of the simple theory by Blunck and Leisegang treated the resonance transfers of energy to the atomic electrons more completely and predicted wider distributions for the heavy elements. This prediction agreed with the data obtained, but disagreement was still found for the light elements.

The larger beta spectrometer mentioned in earlier progress reports<sup>(12)</sup> is nearing completion. The fabrication of the vacuum chamber, 10 ft in length and 3 ft in diameter, was completed at K-25, and the instrument has now been installed in Building 2001. Plumbing and electrical work have been substantially completed, and the unit has been vacuum tested. Work is progressing on the magnet-current control and the ripple-correcting circuit. Tests are in progress to determine the geometry of the compensating coils needed to correct the magnetic field to homogeneity within 0.1% throughout the useful volume of the instrument. The slit and vacuum lock systems have been completed, and plans have been drawn up for the detector assembly. A console has been constructed and several control and monitoring units have been installed in it. The unit is designed to analyze electron beams having energies from about 100 keV to 2 MeV.

**Accelerator.** The high-voltage accelerator mentioned in previous progress reports<sup>(13)</sup> was designed for several purposes. One of the purposes was the study of energy losses of electrons in

foils at incident-electron energies from a few keV up to 125 keV; thus the range of the beta spectrometer was extended and overlapped. By first accelerating the electrons, then passing them through the foil, then slowing them down to nearly zero energy before collection, it appeared possible to obtain an energy resolution of a few parts per million.<sup>(14)</sup> However, when very slow electrons approached the collector, the beam defocused so badly that the high resolution was lost. Numerous attempts to prevent the loss of resolution by the addition of grids and magnetic focussing coils were unsuccessful. Therefore an electrostatic analyzer has been built to resolve the beam after it has been decelerated to 100 volts, but is still well focussed.

Recent work on the accelerator has included completion of a high-voltage transfer switch, a precision high-voltage voltmeter, and controls to permit the use of the high-voltage supply for the x-ray machine to operate either the x-ray tube or the accelerator.

### Special Tests

At the request of the Radiation Instruments Branch of the AEC in Washington, a classified project involving the calculation of an expected induced gamma-ray dose and its experimental verification was attempted during the recent Nevada tests with the cooperation of the ORNL Physics of Nuclear Radiations Section of the Health Physics Division.

### Standardization of Radiation Monitoring Film Sensitometry

At the request of the Photographic Sensitometry Committee of the American Standards Association, ORNL has been represented for the past two years on the Subcommittee on X-ray Sensitometry. This subcommittee has prepared standards for determining the speed and contrast of medical x-ray film and of film for industrial radiography. A standard for determining the useful range of film for radiation monitoring has been the subject of repeated discussions and some experimental work, particularly at ORNL and at the National Bureau of Standards. The draft of the standard has undergone several revisions, and it is hoped that a final form acceptable to the representatives of the photographic industry and other interested parties may be completed soon.

<sup>(14)</sup>J. Bergstein and R. D. Birkhoff, *Phys. Rev.* 91, 223 (1953).

<sup>(11)</sup>R. D. Birkhoff and F. Kalil, *Phys. Rev.* 91 (to be published).

<sup>(12)</sup>R. D. Birkhoff and A. W. Smith, *H-P Prog. Rep.* Jan 20, 1952 to July 20, 1952, ORNL-1353, p. 9.

<sup>(13)</sup>R. D. Birkhoff, A. W. Smith, and J. Bergstein, *H-P Quar. Prog. Rep.* Oct. 20, 1952, ORNL-1420, p. 7; R. D. Birkhoff, J. Bergstein, M. Slater, and H. H. Hubbell, *H-P Quar. Prog. Rep.* Jan. 20, 1953, p. 4.

AIRBORNE RADIOPARTICULATE CONTAMINATION

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 R. L. Bradshaw  
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 E. E. Grassel  
 J. W. Thomas

RADIOACTIVE-DUST STUDIES AND PEEP

Study of Radioparticulate Contamination at X-10

During this period, the Health Physics Division, in cooperation with the Oak Ridge Office, AEC-U.S. Weather Bureau, resumed a study of radioparticulate air contamination at X-10. The immediate objective was to evaluate the degree of airborne contamination produced by all the research and production operations in the Laboratory area.

The data collected over a period of four years by ten continuous air monitors stationed throughout the Laboratory area were reduced to histograms. Each histogram shows the number of particles per 1000 ft<sup>3</sup> of air collected weekly by a continuous air monitor (CAM) during the period of March 1949 to December 1952. The histogram (Fig. 13) for the average of the same ten monitors shows a

general upward trend in the number of particles per 1000 ft<sup>3</sup> during the four-year period as follows:

	1949	1950	1951	1952
Particles per 1000 ft <sup>3</sup>	0.16	0.55	0.56	3.35

The increase in the number of particles per 1000 ft<sup>3</sup> collected each year is ascribed to the greater amounts of radioactive materials handled and to the new processes placed in operation.

A log was compiled of all ORNL process and reactor operations. A preliminary survey indicates that a significant correlation exists between the operation of certain of these processes and the peaks of the histograms.

As a start in isolating a single source of radioparticulate contamination, one particular operation was selected for study during a complete cycle of operation. Four CAM stations were chosen on the

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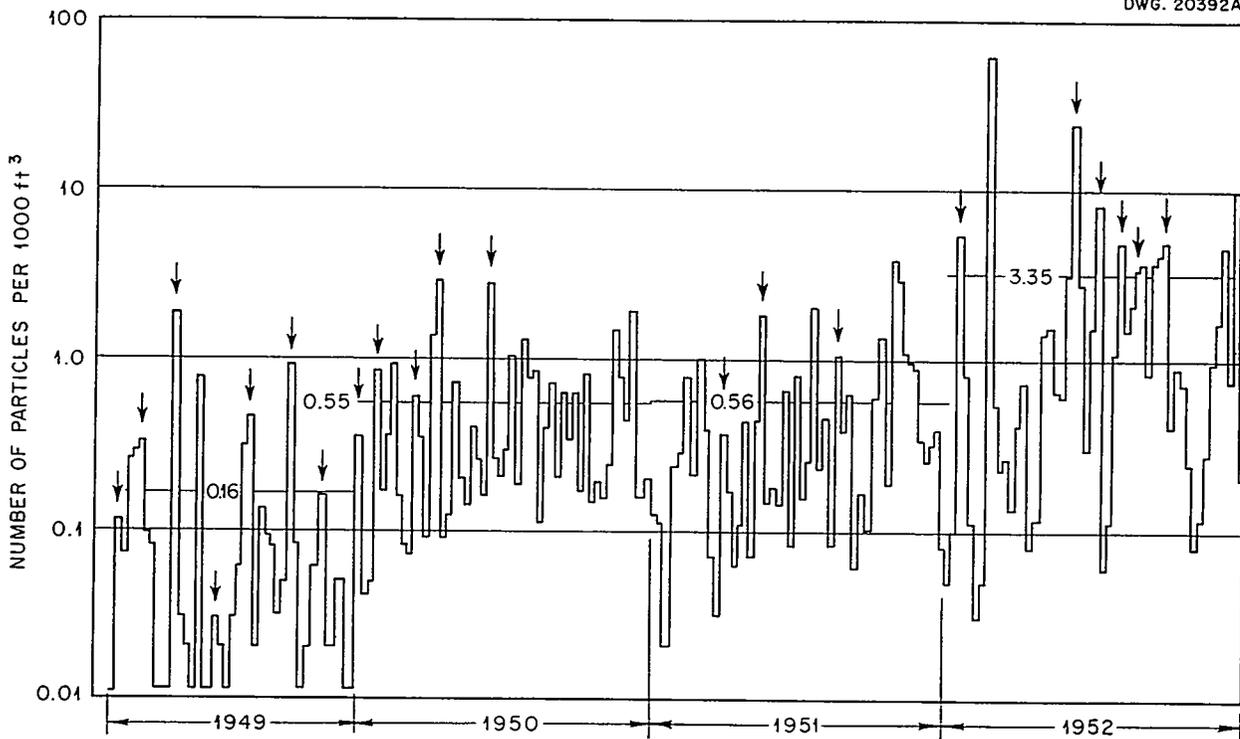


Fig. 13. Trend of Particle Concentration at ORNL from 1949 to 1952.

basis of wind direction, and collections were made on Hollingsworth and Vost Co. No. 70 filter papers. Millipore (molecular) filters were also set up at the four stations, as well as in the process area, and collections were made continuously throughout the process run. Off-gas and ventilation air from the process were sampled by cascade impactors and by millipore filters before they were discharged into the atmosphere. Fall-out trays were located about the X-10 area, and the roof of Building 2001 was scrubbed with water and the water was collected in a tank. Radiochemical analyses have been made of representative samples. CAM and millipore filters have been autoradiographed, and the number of particles on each filter has been counted. Work is continuing on the identification of the collected particles and all data, including weather conditions, are being correlated with the operational stages of the process.

**Activity Escaping From the Graphite Reactor Filter House**

The primary objective of the work was to determine whether the filter house is effectively cleaning the effluent from the ORNL graphite reactor. A secondary objective was to investigate the value of activated carbon in removing radioactive xenon and krypton from the effluent gases.

A flow-type ionization chamber that was equipped with a vibrating-reed electrometer and a recorder<sup>(1)</sup> was used to sample the effluent gases. Chemical Corps No. 6 filter paper was used to sample the particulate matter. It was found that if alpha contamination is present on the filter papers, it corresponds to an activity of less than  $5 \times 10^{-12} \mu\text{c}/\text{cm}^3$ <sup>(2)</sup> of the effluent gases.

When the filter house effluent is passed directly into the flow ion chamber, the ion current produced in the 1-liter ionization chamber is about  $1.0 \times 10^{-12}$  ampere. For a 0.17-Mev  $\beta^-$  emitter, this is equivalent<sup>(1)</sup> to  $1.5 \times 10^{-4} \mu\text{c}/\text{cm}^3$  of effluent. However, most of this activity is due to  $\text{A}^{41}$  (1.2-Mev  $\beta^-$ ), and a smaller amount is due to krypton and xenon

(1) J. W. Thomas and R. L. Quinn, *Calibration of a Flow-Type Ionization Chamber with Radioactive Sulfur Dioxide*, Y-793 (Aug. 20, 1951).

(2) *Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water*, Handbook 52, National Bureau of Standards (March 20, 1953), gives  $5 \times 10^{-12} \mu\text{c}/\text{cm}^3$  as the permissible concentration of assay alpha-emitting radioisotope in the air beyond the area of control for short periods of exposure. The value given for the beta emitter  $\text{A}^{41}$  is  $5 \times 10^{-7} \mu\text{c}/\text{cm}^3$ .

and the decay product of these gases. The ion chamber has not been calibrated for this higher  $\beta^-$  energy. An order-of-magnitude estimate is that  $10^{-3}$  to  $10^{-4} \mu\text{c}/\text{cm}^3$  of  $\beta^-$  and  $\gamma$  activity is present in the effluent less than 1 min after it has left the filter house.

Several experiments were made to estimate the effectiveness of activated carbon in removing argon, krypton, and xenon from the effluent. The flow rate was 10 liters/min through a 300-ml carbon bed. In the first of two techniques used, the filter-house effluent was passed directly into the ionization chamber, a sample was isolated in the chamber, and the decay-rate was observed. In the second technique, the experiment was repeated except that the effluent was passed through an activated-carbon layer at room temperature and then passed into the ionization chamber for observation of the decay rate. The second procedure was varied in that the carbon layer was cooled to  $-170^\circ\text{C}$ . The results are shown in Fig. 14.

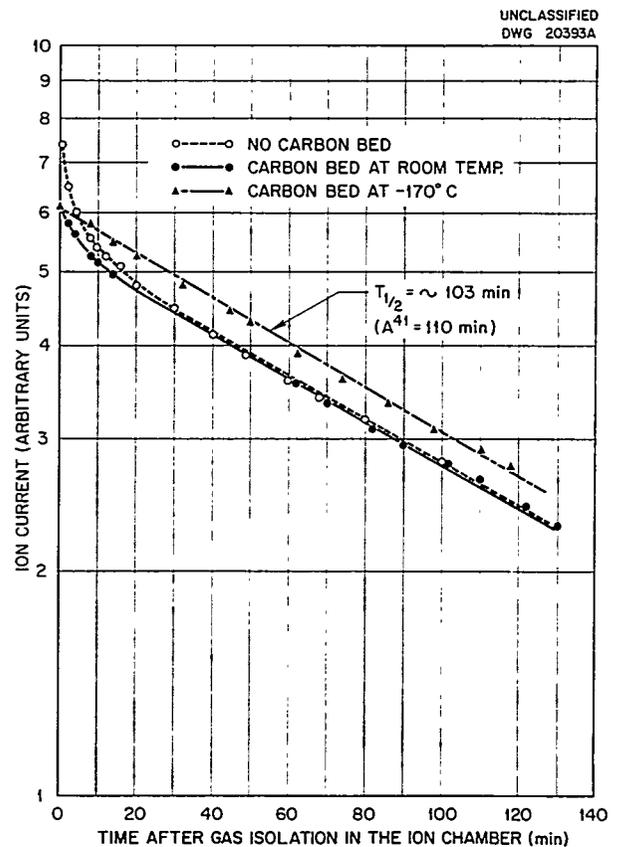


Fig. 14. Activity Decay of Effluent from Filter House.

## HEALTH PHYSICS PROGRESS REPORT

The second technique was similar to that used by Coughlen<sup>(3)</sup> and Spiewak.<sup>(4)</sup> The filter-house effluent, after passing through the charcoal bed, was passed through four No. 6 filter papers in series. The first two papers were placed adjacent to each other, as were the last two papers. There was a distance of 66 cm between the two sets of papers, which corresponded to a flight time of 2 sec. This arrangement detects the radioactive daughters of krypton and xenon. Krypton and xenon penetrate the first two papers as gases, decay to particulate daughters enroute to the second set of papers, and are collected by the second set of papers. Three experiments were made in which there was (1) no carbon bed in the line ahead of the filter papers, (2) a carbon bed at room temperature ahead of the papers, (3) a carbon bed at  $-78^{\circ}\text{C}$  ahead of the papers. The results indicated that even at room temperature the carbon bed was removing a large fraction ( $\sim 50\%$ ) of the krypton and/or the xenon, and that at  $-78^{\circ}\text{C}$  essentially all the krypton and the xenon were removed from the filter house effluent. (Argon is known to condense at  $-186^{\circ}\text{C}$ .)

The results are confirmed in a general way by the decay curves of Fig. 14. Although no experiment was made at  $-78^{\circ}\text{C}$  in which the decay-rate technique was used, it is apparent from the curves that the carbon bed removes a large fraction of the very short-lived krypton and/or xenon isotopes at room temperature, and that with the carbon bed at  $-170^{\circ}\text{C}$ , there appears to be very little activity present, except  $\text{A}^{41}$ .

Because of the limited scope of this investigation, the results are not conclusive, but the following two points seem to be fairly well established:

1. The filter house is at present operating efficiently, and little or no alpha contamination passes through. The activity that does escape from the filter house ( $\sim 10^{-3}$  to  $10^{-4}$   $\mu\text{C}/\text{cm}^3$ ) has a short half life and is largely due to  $\text{A}^{41}$ , xenon, and krypton.

2. A carbon bed at  $-78^{\circ}\text{C}$  will efficiently remove krypton and xenon from the filter house effluent.

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<sup>(3)</sup>C. P. Coughlen, *Determination of Potential Sources of Area Atmospheric Radio-Active Contamination*, ORNL-677 (June 8, 1950).

<sup>(4)</sup>J. Spiewak, *Notes on Pile Filter House Efficiency*, M-4393 (Aug. 17, 1949).

### Cloud Chamber for Measuring Aerosol Concentration

One method of measuring the concentration of otherwise invisible particles in a gas is to use a cloud chamber of special design. The chamber creates a supersaturated state of the vapor. The particles act as nucleation centers for liquid droplets and thus the apparent diameters are enlarged a thousandfold or more so that they can be seen and counted.

In the operation of the cloud chamber of H. L. Green, which was loaned to this section by the Ministry of Supply of Great Britain, a beam of light from a zirconium arc passes through the chamber. The cross section of the beam is defined by a slit that is imaged at the center of the chamber by a microscope objective. Thus only droplets occupying a known volume are illuminated. The droplets are photographed at  $90^{\circ}$  to the beam path. A count of the droplet images on the film gives the particle concentration of the aerosol in the expanded chamber.

For a concentration of  $10^5$  particles per  $\text{cm}^3$ , about 40 droplets are photographed at a time. In order to obtain a statistically valid count, many photographs of the aerosol sample must be taken; therefore a repeating or so-called "continuous-action" cloud chamber is useful. The Green cloud chamber is of this type. A fresh sample of aerosol is drawn into the chamber every 2 sec, and a cam-operated piston creates an expansion during the cycle. With this apparatus, the shutter must be cocked and released and the film changed by hand for each cycle.

Inasmuch as the Green apparatus is being returned, it was decided to build a similar apparatus for use in future studies. The apparatus has been designed and is partly built. A 16-mm motion picture camera will be used to obtain photographs of the droplets. One of the most objectionable features of the Green apparatus is that the droplets are in motion and can be stopped only by introduction of a current of air into the system; however, tests show that a G-E flash tube (type FT-230) is sufficiently intense (200 watt-sec) and fast enough ( $10^{-4}$  sec) to "stop" the droplet motion and yet give adequate exposure. The new machine will use this type of illumination, synchronized with the camera shutter.

Provision has been made so that either of two types of cloud chambers can be used in the apparatus. In the first, a volume-defined cloud chamber,

a rotating valve (1) admits aerosol into the chamber, (2) closes the chamber, (3) expands the chamber by allowing vacuum to operate a siphon bellows, and (4) removes the aerosol. In the second, a pressure-defined cloud chamber, a cam actuates three solenoid valves through the same cycle, except that in step 3 the aerosol expands into an evacuated chamber.

#### Atomic Weapons Test Fall-Out at ORNL

Five radioactive particles collected at ORNL on March 19, 1953 during the Nevada atomic weapons test fall-out were examined as to appearance, size, and activity.

All the particles examined were spherical and had the appearance of having been formed from molten material. All appeared to be black and opaque, with the exception of one which was glassy and transparent. Their diameters ranged from 18 to 24 microns. There was no correlation between the activities of the particles and their sizes. The beta activities ranged from approximately  $1.1 \times 10^3$  to  $1.7 \times 10^5$  dpm. Half-life and absorption measurements showed that the particles did not contain the same relative amounts of radioactive components.

A detailed account will be found in a memorandum to be issued by this section under the title *Atomic Weapons Test Fall-Out at ORNL on March 19, 1953*.

## RADIOACTIVE WASTE DISPOSAL RESEARCH

R. J. Morton

### WATER AND LIQUID WASTE DECONTAMINATION PROCESS

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#### Water Decontamination Studies

A re-examination of the data obtained in an earlier  $3^4$  factorial study in which the effects of four parameters (three levels of each) were investigated simultaneously indicated that it would be possible, by setting up a  $\frac{1}{3}$  replication of the  $3^4$  factorial experiment, to reduce the number of samples evaluated from 243 to 54 and still observe the effects of the variables. By utilizing this new procedure, coagulation studies were made in which the effects of the day-to-day variations, activity levels (approximately 200, 2000, and 20,000 counts/min/ml), coagulants used ( $\text{FeSO}_4$ ,  $\text{FeCl}_3$ , and alum), and coagulant dose (1, 2, and 6 gr/gal) on the removal of specific radioisotopes was noted. The radioisotopes investigated included  $\text{P}^{32}$ ,  $\text{Sc}^{46}$ ,  $\text{Cr}^{51}$ ,  $\text{Sr}^{89}$ ,  $\text{Y}^{91}$ ,  $\text{Zr}^{95}$ - $\text{Nb}^{95}$ ,  $\text{Mo}^{99}$ ,  $\text{Ru}^{103}$ ,  $\text{I}^{131}$ ,  $\text{Cs}^{137}$ - $\text{Ba}^{137}$ ,  $\text{Ba}^{140}$ - $\text{La}^{140}$ ,  $\text{Pr}^{142}$ ,  $\text{Ce}^{144}$ - $\text{Pr}^{144}$ ,  $\text{Pm}^{147}$ ,  $\text{Sm}^{153}$ ,  $\text{W}^{185}$ ,  $\text{Re}^{186}$ , and a fission product mixture; all were obtained from the Operations

Division of ORNL. The results are summarized in Table 2.

In a series of experiments with the use of an electrolytic ion-exchange cell in which permselective ion-exchange membranes were employed to separate the central chamber of the cell from the anode and cathode compartments, it was found that more than 99% of mixed-fission-product activity could be removed from distilled water at flow rates of 5 ml/min. In other studies with  $\text{Cs}^{137}$  and  $\text{I}^{131}$  (singly and in combination), removals of 99.5% were obtained with  $\text{Cs}^{137}$ , and removals of about 95 to 96% were obtained with equal mixtures of  $\text{Cs}^{137}$  and  $\text{I}^{131}$  activities.

A mixed-fission-product waste solution was passed through a Greensand (Zeo-Dur) ion-exchange column to the point of breakthrough of hardness and radioactivity; then the column was regenerated with 20% NaCl. Six such cycles have been studied. Prior to the seventh pass, the bed was exhausted with  $\text{CaCl}_2$ ; then the mixed radioactive waste solution was passed through the bed. The four results obtained thus far show: (1) that an average of about 90% of the activity is removed to the hardness breakthrough, (2) that 20% NaCl may be used for regeneration, (3) that about 50% of the adsorbed activity is removed by regeneration, and (4) that with a calcium-exhausted bed, removals of about 70 to 80% of the activity may still be obtained.

HEALTH PHYSICS PROGRESS REPORT

TABLE 2. COAGULATION RESULTS - 3<sup>4</sup> FACTORIAL EXPERIMENTS

RADIOISOTOPE	COAGULANT DOSE <sup>(a)</sup> (gr/gal)	REMOVAL (%) <sup>(b,c)</sup>		
		Low	Intermediate	High
Coagulant: FeSO <sub>4</sub>				
P <sup>32</sup>	1	90-95	95-99	95-99
	2	95-99	95-99	95-99
	6	95-99	95-99	99 <sup>+</sup>
Sc <sup>46</sup>	1	75-90	95-99	95-99
	2	75-90	95-99	95-99
	6	75-90	95-99	95-99
Cr <sup>51</sup> <sup>(d)</sup>	1	0-25	0-25	25-75
	2	25-75	0-25	0-25
	6	0-25	0-25	25-75
Sr <sup>89</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Y <sup>91</sup>	1	90-95	90-95	90-95
	2	95-99	95-99	90-95
	6	95-99	95-99	90-95
Zr <sup>95</sup> -Nb <sup>95</sup>	1	25-75	95-99	95-99
	2	95-99	75-90	95-99
	6	90-95	95-99	95-99
Mo <sup>99</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Ru <sup>103</sup>	1	75-90	75-90	90-95
	2	75-90	75-90	90-95
	6	75-90	95-99	90-95
I <sup>131</sup> <sup>(e)</sup>	1	0-25	0-25	25-75
	2	25-75	0-25	0-25
	6	0-25	25-75	0-25
Cs <sup>137</sup> -Ba <sup>137</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Ba <sup>140</sup> -La <sup>140</sup>	1	25-75	25-75	25-75
	2	25-75	25-75	25-75
	6	25-75	25-75	25-75
Pr <sup>142</sup>	1	90-95	90-95	75-90
	2	95-99	99 <sup>+</sup>	95-99
	6	90-95	99 <sup>+</sup>	99 <sup>+</sup>
Ce <sup>144</sup> -Pr <sup>144</sup>	1	75-90		95-99
	2	75-90	95-99	99 <sup>+</sup>
	6	90-95	95-99	

TABLE 2 (continued)

RADIOISOTOPE	COAGULANT DOSE <sup>(a)</sup> (gr/gal)	REMOVAL (%) <sup>(b, c)</sup>		
		Low	Intermediate	High
Coagulant: FeSO <sub>4</sub>				
Pm <sup>147</sup>	1	90-95	95-99	
	2	75-90		75-90
	6		99 <sup>+</sup>	99 <sup>+</sup>
Sm <sup>153</sup>	1	75-90	75-90	90-95
	2	90-95	95-99	95-99
	6	95-99	90-95	99 <sup>+</sup>
W <sup>185</sup>	1	25-75	25-75	25-75
	2	75-90	0-25	25-75
	6	75-90	95-99	25-75
Re <sup>186</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	25-75	0-25	0-25
Fission-product mixture	1	75-90	25-75	75-90
	2	75-90	75-90	
	6	75-90		75-90
Coagulant: FeCl <sub>3</sub>				
P <sup>32</sup>	1	25-75	95-99	95-99
	2	75-90	95-99	95-99
	6	95-99	95-99	95-99
Sc <sup>46</sup>	1	25-75	95-99	90-95
	2	25-75	95-99	95-99
	6	75-90	90-95	95-99
Cr <sup>51(d)</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	25-75
	6	0-25	0-25	0-25
Sr <sup>89</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Y <sup>91</sup>	1	25-75	25-75	90-95
	2	25-75	75-90	95-99
	6	95-99	90-95	95-99
Zr <sup>95</sup> -Nb <sup>95</sup>	1	0-25	25-75	25-75
	2	25-75	25-75	25-75
	6	0-25	75-90	95-99
Mo <sup>99</sup>	1	0-25	0-25	0-25
	2	25-75	0-25	0-25
	6	25-75	25-75	0-25

HEALTH PHYSICS PROGRESS REPORT

TABLE 2 (continued)

RADIOISOTOPE	COAGULANT DOSE <sup>(a)</sup> (gr/gal)	REMOVAL (%) <sup>(b,c)</sup>		
		Low	Intermediate	High

Coagulant: FeCl<sub>3</sub>

Ru <sup>103</sup>	1	25-75	25-75	25-75
	2	25-75	75-90	75-90
	6	75-90	75-90	95-99
I <sup>131</sup> <sup>(e)</sup>	1	25-75	25-75	0-25
	2	0-25	25-75	25-75
	6	25-75	0-25	25-75
Cs <sup>137</sup> -Ba <sup>137</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Ba <sup>140</sup> -La <sup>140</sup>	1	0-25	25-75	25-75
	2	25-75	25-75	25-75
	6	25-75	25-75	25-75
Pr <sup>142</sup>	1	90-95	90-95	95-99
	2	90-95	95-99	95-99
	6	95-99	95-99	99 <sup>+</sup>
Ce <sup>144</sup> -Pr <sup>144</sup>	1	25-75	90-95	
	2	90-95		75-90
	6	90-95	75-90	95-99
Pm <sup>147</sup>	1		25-75	75-90
	2	0-25	90-95	
	6	75-90		90-95
Sm <sup>153</sup>	1	25-75	90-95	90-95
	2	90-95	90-95	90-95
	6	95-99	95-99	99 <sup>+</sup>
W <sup>185</sup>	1	25-75	25-75	0-25
	2	25-75	25-75	25-75
	6	25-75	25-75	75-90
Re <sup>186</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Fission-product mixture	1	25-75		25-75
	2	75-90	75-90	25-75
	6	25-75	25-75	

Coagulant: Alum

P <sup>32</sup>	1	95-99	95-99	95-99
	2	95-99	95-99	95-99
	6	99 <sup>+</sup>	95-99	99 <sup>+</sup>

TABLE 2 (continued)

RADIOISOTOPE	COAGULANT DOSE <sup>(a)</sup> (gr/gal)	REMOVAL (%) <sup>(b,c)</sup>		
		Low	Intermediate	High
Coagulant: Alum				
Sc <sup>46</sup>	1	75-90	95-99	95-99
	2	75-90	95-99	95-99
	6	75-90	95-99	99 <sup>+</sup>
Cr <sup>51</sup> <sup>(d)</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	25-75	0-25	25-75
Sr <sup>89</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Y <sup>91</sup>	1	90-95	90-95	90-95
	2	95-99	95-99	90-95
	6	95-99	95-99	95-99
Zr <sup>95</sup> -Nb <sup>95</sup>	1	95-99	95-99	95-99
	2	75-90	95-99	96-99
	6	95-99	95-99	95-99
Mo <sup>99</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	25-75	0-25	0-25
Ru <sup>103</sup>	1	25-75	25-75	25-75
	2	25-75	25-75	90-95
	6	25-75	75-90	90-95
I <sup>131</sup> <sup>(e)</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	25-75
	6	25-75	0-25	0-25
Cs <sup>137</sup> -Ba <sup>137</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Ba <sup>140</sup> -La <sup>140</sup>	1	25-75	25-75	25-75
	2	25-75	25-75	25-75
	6	25-75	25-75	25-75
Pr <sup>142</sup>	1	90-95	90-95	95-99
	2	75-90	90-95	95-99
	6	95-99	95-99	95-99
Ce <sup>144</sup> -Pr <sup>144</sup>	1	95-99	95-99	99 <sup>+</sup>
	2	95-99	95-99	
	6	90-95		99+
Pm <sup>147</sup>	1	75-90		95-99
	2		95-99	95-99
	6	90-95	95-99	

HEALTH PHYSICS PROGRESS REPORT

TABLE 2 (continued)

RADIOISOTOPE	COAGULANT DOSE <sup>(a)</sup> (gr/gal)	REMOVAL (%) <sup>(b,c)</sup>		
		Low	Intermediate	High
Coagulant: Alum				
Sm <sup>153</sup>	1	90-95	95-99	95-99
	2	25-75	95-99	95-99
	6	95-99	95-99	95-99
W <sup>185</sup>	1	0-25	0-25	0-25
	2	25-75	0-25	0-25
	6	25-75	25-75	25-75
Re <sup>186</sup>	1	0-25	0-25	0-25
	2	0-25	0-25	0-25
	6	0-25	0-25	0-25
Fission-product mixture	1	25-75	75-90	
	2	75-90		25-75
	6	75-90	75-90	25-75

(a) Value of 1 gr/gal represents 1 gr/gal of primary coagulant (FeSO<sub>4</sub>, FeCl<sub>3</sub>, or alum), 0.4 gr/gal of sodium silicate, and 1 gr/gal of lime. Similar ratios hold for doses of 2 and 6 gr/gal.

(b) Removals are indicated in the following class intervals: 0-25, 25-75, 75-90, 90-95, 95-99, and 99<sup>+</sup>. These values supplement those reported in ORNL-1488.

(c) The low, intermediate, and high activity levels are ~200, 2000, and 20,000 counts/min/ml.

(d) The low, intermediate, and high activity levels in this instance were 10, 100, and 200 counts/min/ml.

(e) Values somewhat higher than those previously reported.

Several commercial units which are available for producing deionized water have been evaluated for their efficacy in removing mixed fission products. One unit, designed primarily for producing deionized water for steam irons, storage batteries, etc., contained a small quantity of mixed-bed resin and a chemical compound to indicate exhaustion of the bed by a change of color. With a total flow of 1 to 2 liters, the maximum removals did not exceed 90%. Another unit that was studied contained 0.07 ft<sup>3</sup> of mixed bed resin and produced good results. Break-through of both activity and hardness occurred at about 60 gal of flow (2 gpm/ft<sup>2</sup> flow rate), and the average removal of activity amounted to 99.8%, with a range of removal of 99.2 to 99.97%.

The effect of such factors as pH, buffer solution, substrates, carrier concentration, clay concentration, kind of clay, exchange capacity, etc. on the

removal of Co<sup>60</sup>Cl<sub>2</sub>, Zn<sup>65</sup>Cl<sub>2</sub>, Se<sup>75</sup>Cl<sub>4</sub>, K<sub>8</sub>Ta<sup>182</sup>O<sub>19</sub>, Na<sub>2</sub>Ir<sup>192</sup>Cl<sub>6</sub>, and TI<sup>204</sup>(NO<sub>3</sub>)<sub>3</sub> from water by clays has been investigated. A jar-test laboratory procedure was employed. With an initial concentration of 10,000 counts/min/ml, clay concentrations of 2500 to 5000 ppm will remove about 90% of the radioelements listed. With the clays and the radioisotopes employed, there appeared to be no relation between the base-exchange capacity and the removal of activity. It was found that pH, added carrier, added salts, and substrate had a decided effect on removals by the clays investigated.<sup>(1)</sup>

A study was made to compare the removal of radioactive contaminants from water by four ion-exchange resins and three types of clay. Finest

<sup>(1)</sup>C. P. Straub and H. L. Krieger, *Removal of Radioisotopes from Waste Solutions - Soil Suspension Studies*, 8th Industrial Waste Conference, Purdue University, May 5 to 6, Lafayette, Indiana.

(less than 60 mesh) of Permutit Q, Zeo-Dur, Amberlite XE-69, and Amberlite MB-3, were compared with a local clay from the X-10 Area, montmorillonite, and a montmorillonite-bentonite clay. The three contaminants used were (1) W-6, a concentrate from the ORNL waste evaporator, (2) MFP-3, a three-year old dissolver solution containing approximately 20% trivalent rare earths, 20% strontium, 20% cerium, 16% cesium, 3% ruthenium, and 21% undetermined, and (3) the three radioisotopes shown in Table 3. A jar-test procedure using Oak Ridge tap water with five different dosages of each of the adsorbent materials was employed. The results obtained, with the lowest and the highest dosage in each test as shown in Table 3, indicated that, with the test methods used,  $Zr^{95}$ - $Nb^{95}$  was easy to remove, up to 99% of the  $Ce^{141-144}$ - $Pu^{144}$  could be removed by MB-3 (2700 ppm) or local clay (4000 ppm), and that 2700 ppm of either Permutit Q, Amberlite XE-69 or montmorillonite clay would remove at least 92% of the  $Sr^{90}$ - $Y^{90}$ .

**Process Waste Studies**

The statistical evaluation of all data pertaining to the volume of flow to and from the settling basin, the activity of both influent and effluent, and the total curies discharged is being continued to pro-

vide specific information for the design of full-scale facilities for the treatment of the radioactive process waste waters. The design of the full-scale plant will be predicated upon the results obtained in the operation of the pilot-scale experimental units now being installed.

**SURVEYS AND EVALUATIONS - FIELD AND LABORATORY**

T. W. Brockett, Jr.                      R. J. Morton  
 M. J. Cook                                  R. L. Nichols  
 J. M. Garner                                O. R. Placak  
 B. Kahn                                      C. P. Straub  
 H. J. Wyrick

**Estimates of Downstream Effects in the Event of Emergency Contamination in the Clinch River**

Studies of surface water conditions in the Clinch and Tennessee River systems in relation to hazards that might result from an emergency release or escape of radioactive materials into the Clinch River have been in progress for about two years. This is a cooperative effort of ORNL and the Health and Safety Division of the Tennessee Valley Authority. The purpose is to make available basic data and methods of analysis in a form which can be used promptly for estimating the extent and

**TABLE 3. COMPARISON OF REMOVAL OF RADIOACTIVE MATERIALS FROM WATER BY ION-EXCHANGE RESINS AND CLAYS**

CONTAMINANT	ACTIVITY* (counts/min/ml)	DOSAGE OF ADSORBENT MATERIAL (ppm)	REMOVAL (%)						
			Ion-Exchange Resin Fines				Clays		
			Permutit		Amberlite		Montmorillonite- bentonite	Montmorillonite	Local X-10 Area**
			Q	Zeo-Dur	XE-69	MB-3			
W-6 solution	5,000	450	61.3	46.3	54.0	38.4	74.8	59.5	58.8
		2700	76.3	62.7	64.9	86.9	81.2	67.7	63.4
MFP-3 as nitrates	48,000	450	50.7	52.5	57.4		42.6	49.8	
		2700	83.9	66.2	89.5		59.8	69.5	
$Sr^{90}$ - $Y^{90}$ as chlorides	4,100	450	77.7	68.0	92.5		73.9	75.5	
		2700	92.7	77.0	93.0		88.9	92.7	
$Zr^{95}$ - $Nb^{95}$ as oxalate	2,000	450	92.3	96.3	93.7	83.1	97.9	99.3	93.5
		2700	93.7	97.7	95.1	97.9	98.6	0.9	98.5
$Ce^{141,144}$ - $Pu^{144}$ as chloride	8,000	450	53.1			95.4			98.7
		2700	53.8			99.0			99.3

\*Count rates are at approximately 10% geometry.

\*\*Dosages are an exception and were 1000 and 4000 ppm.

## HEALTH PHYSICS PROGRESS REPORT

duration of potential hazards and for planning the necessary countermeasures.

The TVA has completed tabulations of hydraulic data, and two reports containing charts, tables, and explanatory text are now available for use as needed.<sup>(2,3)</sup> The reports are designed particularly to aid in the determination of river flows, time of water travel, dilution factors, and dispersion of masses of contaminated water in the rivers from Norris Dam to as far downstream as Chattanooga. A manual with illustrative examples and instructions for use of the basic charts and tables is being prepared by sanitary engineers of the TVA.

At the request of the Physics Division of the Laboratory, an analysis of one specific problem was made; the results were used in the preparation of a Reactor Safeguard Report on the Tower Shielding Facility. In the analysis of this problem, the data of the TVA report<sup>(2)</sup> were used, and TVA specialists were consulted. It was assumed that a large quantity of mixed fission products of various ages might be accidentally discharged into the Clinch River near ORNL during a 6-hr period. From the assumed conditions, the total quantity, the average half life, and the approximate composition of the radioactive mixture that would be dispersed were calculated with the use of the tables and charts prepared by Hunter and Ballou;<sup>(4)</sup> and the peak concentration in microcuries per cubic centimeter at the point of entry could be estimated for any given volume of stream flow in the Clinch River.

The data provided by TVA made it possible to estimate (1) the combination of conditions in the rivers that would cause the highest peaks of radioactivity in the water at various downstream locations, (2) the time of water travel from the point of

entry of the contaminants to each of four downstream locations of particular interest and the reduction of activity by radioactive decay during these time intervals, and (3) the percentage of reduction of the maximum peak concentration in the Clinch River by dispersion and by dilution before the activity reached each of the downstream locations. Some of the pertinent values obtained by analysis of the problem are shown in Table 4.

The last two lines in Table 4 show maximum permissible concentration (MPC) values of radioactive contamination in drinking water for emergency use for periods of one day and of 30 days. With the use of the methods developed by Morgan and Straub,<sup>(5)</sup> these values were estimated for the particular mixture of radioisotopes that would reach each of the four locations. In the Clinch River at K-25 and at the mouth of the river, the estimated peak concentrations would be nearly equal to the one-day emergency MPC values. In the Tennessee river, the peak concentrations would be far lower than the 30-day emergency MPC values.

### INSTRUMENTATION AND TECHNIQUES

H. G. Conner

B. Kahn

J. M. Garner

F. Kalil

R. L. Nichols

#### Counting Response of Crystal Spectrometer<sup>(6)</sup>

The determination of the counting response of a thallium-activated sodium iodide scintillation spectrometer on which progress was reported previously<sup>(7)</sup> has been completed. Over-all counting efficiencies were determined experimentally for sources placed 2.45 cm from a cylindrical crystal 1½ in. in diameter and 1 in. in length. The sources were radioisotopes emitting x and gamma rays with energies between 31 kev and 2.76 Mev. Their disintegration rates were found by coincidence counting, 4π counting, and by the use of a calibrated high-pressure ion chamber. The variation of counting efficiency with energy of gamma radiation is given in Fig. 15. The counting efficiency has been corrected for absorption of gamma rays in

(2) *Effect of Accidental Spillage of Radioactive Waste in Clinch River: Report No. 1, Time of Travel, Probable Flows, and Dispersion*, Nov. 10, 1952 (unpublished report prepared for the Division of Health and Safety by the Hydraulic Branch, Division of Water Control Planning, Tennessee Valley Authority).

(3) *Effect of Accidental Spillage of Radioactive Waste in Clinch River: Report No. 2, Water Control Possibilities and Their Results*, April 20, 1952 (unpublished report prepared for the Division of Health and Safety by the Hydraulic Branch, Division of Water Control Planning, Tennessee Valley Authority).

(4) H. F. Hunter and N. E. Ballou, *Simultaneous Slow Neutron Fission of U<sup>235</sup> Atoms. I. Individual and Total Rates of Decay of the Fission Products*, ADC-65 (Feb. 24, 1949); H. F. Hunter and N. E. Ballou, *Nucleonics* 9:5, C-2 (Nov. 1951).

(5) K. Z. Morgan and C. P. Straub, *Maximum Permissible Exposure Levels of Ionizing Radiation for Peacetime Operations and for Emergency Conditions* (unpublished).

(6) In cooperation with W. S. Lynn, Analytical Chemistry Division.

(7) T. W. Brackett et al., *H-P Quar. Prog. Rep. Jan. 20, 1953, ORNL-1488, p. 10.*

TABLE 4. ESTIMATED FACTORS AND EFFECTS FROM ASSUMED DISPERSION OF RADIOACTIVE CONTAMINANTS INTO THE CLINCH RIVER UNDER ADVERSE\* RIVER CONDITIONS

	LOCATION OF MAXIMUM PEAK CONCENTRATION AFTER DISPERSION	K-25 WATER INTAKE	MOUTH OF CLINCH RIVER	WATTS BAR DAM	CHATTANOOGA WATER INTAKE
Miles above mouth of Clinch River	20.8	13.2	0.0		
Miles above mouth of Tennessee River			567.7	529.9	465.3
Stream flow, cfs	1,000	1,000	1,000	18,900	25,500
Time of water travel, days (cumulative from point of entry)	0.25	3.50	9.75	17.25	25.75
Total radioactivity, curies (approximate, after reduction by decay)	100,000	60,000	50,000	42,000	37,000
Reduction of maximum peak concentration:					
By dispersion, %	0	38	76	97	99
By dilution, %	0	0	0	95	96
Peak concentration, $\mu\text{c}/\text{cm}^3$	$1.7 \times 10^{-1}$	$62 \times 10^{-3}$	$20 \times 10^{-3}$	$11 \times 10^{-5}$	$2.4 \times 10^{-5}$
Emergency maximum permissible concentration values; $\mu\text{c}/\text{cm}^3$ :					
For 1-day use		$58 \times 10^{-3}$	$55 \times 10^{-3}$		
For 30-day use		$1.7 \times 10^{-3}$	$1.5 \times 10^{-3}$	$1.4 \times 10^{-3}$	$1.2 \times 10^{-3}$

\*Adverse river conditions are those that would result in the highest concentrations of contaminants at downstream locations, that is:

Pool elevations,

    Watts Bar Reservoir - 740 ft

    Chickamauga Reservoir - 682 ft

Stream flows as in table

Thermally stratified conditions in Clinch River Embayment and Watts Bar Reservoir.

the MgO reflector and in the aluminum container which enclose the crystal, and for the escape of x rays from the crystal.

The calibrated detector has been used to determine the intensities of gamma rays in some radioisotopes with decay schemes that are not well known, such as  $\text{K}^{42}$  and  $\text{Rh}^{106}$ . It has also been used to identify gamma-emitting radioisotopes in dust and water samples when the activity was

sufficient ( $0.01 \mu\text{c}$  or greater) to warrant use of the spectrometer.

#### Analytical Methods of Radioisotope Determination

Methods of radiochemical analysis are being compiled to assist those interested in the determination of radioisotopes in water supplies. The chemical procedures selected are those on which information is readily accessible in the unclassified

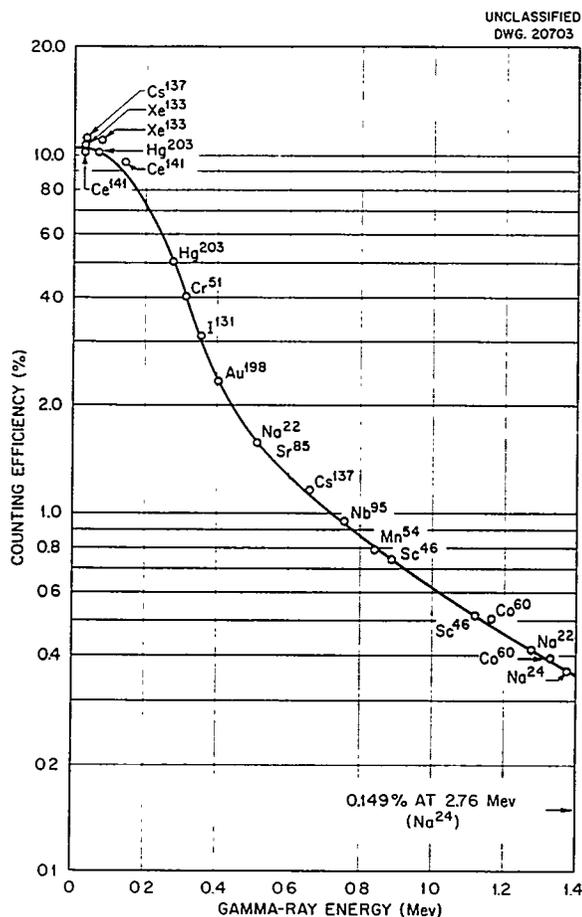


Fig. 15. Counting Efficiency of Thallium-Activated Sodium Iodide Scintillation Spectrometer.

literature; pertinent references will be listed. The procedures for the separation of radionuclides have been abstracted and indexed and in some cases have been modified so as to be of specific use for the above purpose. It is intended that this compilation will serve as a source book for use at ORNL and at other laboratories.

#### Radioactivity in River Bottom Sediments

The previously reported<sup>(8)</sup> survey of radioactivity in bottom sediments in the Clinch and Tennessee Rivers was repeated during the summer of 1952. The same detector "flounder" was used for both surveys. The weighted average of the readings for a particular cross section of the river was obtained by weighting the individual observations by the total area represented by each individual reading. The weighted average reading of each cross section is plotted as a point in Fig. 16 and in which the results of the two surveys (1951 and 1952) are compared. The more recent survey shows a considerable increase in the radioactivity in river bottom sediments in the Clinch River below the mouth of White Oak Creek. Increases in radioactivity are also noticeable in the Tennessee River for a distance of approximately 200 miles downstream. Although it is too soon to draw conclusions, these data indicate the possibility of a trend toward increasing accumulations of radioactive materials in the rivers with time.

(8) E. R. Eastwood et al., *H-P Quar. Prog. Rep. Jan. 20, 1952*, ORNL-1277, p. 1.

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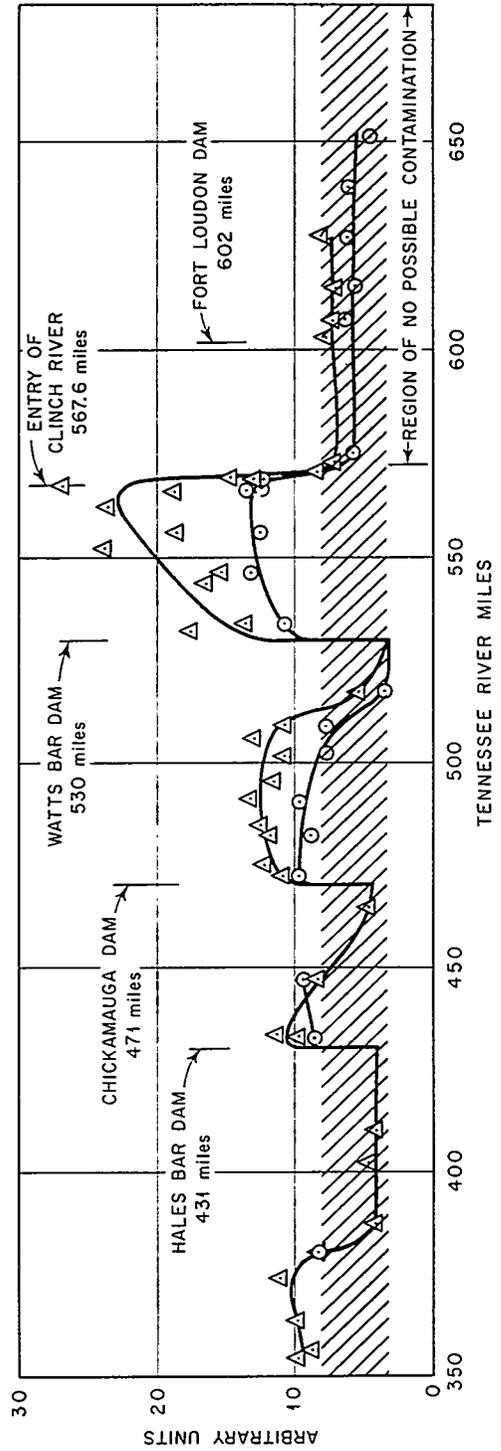
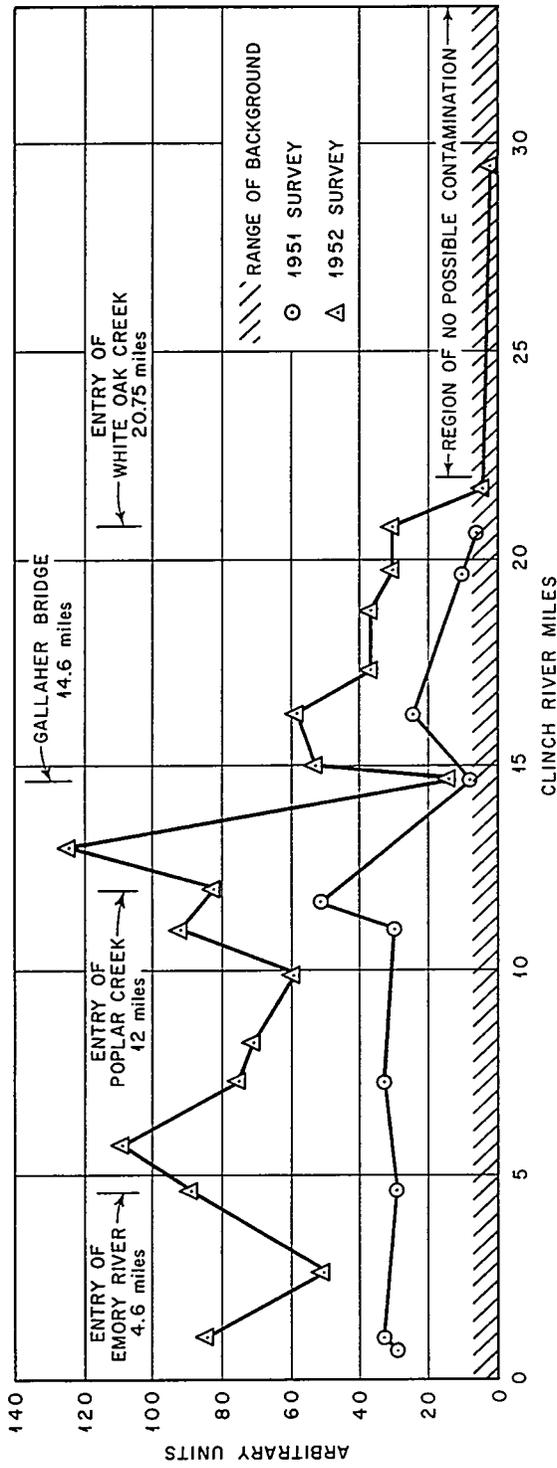


Fig. 16. Weighted Average Concentration of Radioactivity in River Sediments.

ECOLOGICAL STUDY<sup>(1)</sup>

L. A. Krumholz  
W. T. Helm

W. T. Miller  
E. R. Eastwood

The reports of the fifth and sixth semiannual estimates of the fish population in White Oak Lake have been completed. These reports will not be distributed as previously, but will be incorporated in the final over-all report which is being written. In April, the entire fish population of White Oak Lake was killed with rotenone and removed from the lake. Preliminary figures indicate that more than 250,000 fish with a total weight of over 25,000 lb were recovered during the study.

During the past winter season a total of 1203 migratory waterfowl was captured in traps on White Oak Lake. Of that total, 647 birds were banded and 556 banded birds were recaptured. The eight species of waterfowl banded were mallard, black duck, wood duck, pintail, gadwall, baldpate, green-winged teal, and coot. Reports of 20 ducks

banded at White Oak Lake have been returned by hunters who shot the birds in Tennessee, Alabama, Kentucky, Louisiana, and Texas. The carcass of one bird was found in Ontario, Canada.

In March, a muskrat bearing approximately  $1 \mu\text{c}$  of radiostrontium per gram of bone tissue was captured in the X-10 area. This concentration of radiostrontium is believed to have induced an osteogenic sarcoma in the right tibiofibula with consequent metastases into the lungs and kidneys. Estimates by photometric methods indicate that the bone of the animal had been receiving a dose of approximately 1.5 rep/hr.

All field work on the ecological survey program has been discontinued, and the entire efforts of the group are being expended toward the preparation of a final report. It is estimated that the report will be completed by the end of the present fiscal year.

<sup>(1)</sup>In cooperation with the Tennessee Valley Authority.

EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson  
M. F. Fair

M. R. Ford  
T. H. J. Burnett

K. Z. Morgan

AEC FELLOWSHIP PROGRAM

The 1952-53 group of AEC Fellows in Radiological Physics completed the year of graduate study at Vanderbilt University with very creditable records, and reported to the Laboratory June 9 for 12 weeks of field training in the Health Physics Division. Three members of the Division taught a six-credit graduate course in Radiological Physics at Vanderbilt University during the last two quarters of the academic year. While designed primarily for the AEC Fellows, this course is open to other students in the University.

LECTURES

Lectures on current practices in radiation protection were given at two universities in conjunction with the ORINS-ORNL Traveling Lecture Program. Seminars given during the reported period

consisted of two on nuclear and health physics for R. T. Overman's groups at ORINS; one for officers in training at the Navy Medical School at Bethesda, Maryland, one at Harwell, England, and one at Stockholm, Sweden. A paper on the developments in internal dose determinations was given at the American Industrial Hygiene Conference in Los Angeles.

CONSULTATION

A detailed justification of the fencing based on direct radiation estimates for the Tower Shielding Reactor was prepared.<sup>(1)</sup> Calculations were made of the airborne hazards associated with the following types of catastrophe postulated for this reactor: a power excursion sufficient only to melt down the

<sup>(1)</sup>T. H. J. Burnett, ORNL-1550, Appendix A (classified).

fuel plates that would result in a total release of halogens and rare-gas fission products as a thermally cold cloud; and an Al-H<sub>2</sub>O reaction that would result in the total release of all fission products in a hot cloud of considerable thermal content. The data from the calculations, in terms of permissible concentrations, were supplied to the Oak Ridge Office, AEC-U.S. Weather Bureau for inclusion in the feasibility report to be submitted to the Reactor Safeguards Committee. Table 5 gives the maximum concentrations which are permissible for a single dose of 10 rep to the specified body organ during the exposure times given by the meteorologists. For the values given

in Table 5, the isotope mixture is taken to be that present at time 0 + 10<sup>3</sup> sec.

Values for maximum permissible contamination of Laboratory personnel and surfaces in relation to the maximum permissible concentrations in air and water have been developed. The factors determining the dispersal of contamination were studied and the limits were developed on the basis of experimental data. Considerable progress was made toward agreement and acceptance of these values by X-10, Y-12, and K-25; final acceptance will give a uniform basis for contamination control at the three Oak Ridge plants.

TABLE 5. SPECIFIC CONCENTRATIONS OF FISSION PRODUCTS FOR A SINGLE DOSE OF 10 rep TO THE SPECIFIED BODY ORGAN\*

TYPE OF CATASTROPHE	EXPOSURE TIME (sec)	PRODUCT CONCENTRATIONS REQUIRED TO DELIVER A DOSE OF 10 rep ( $\mu\text{c}/\text{ml}$ )		
		Halogen	Total Maximum Fission Products	Submersion-volatile Fission Products**
Thermally cold cloud				
Night	30	$2.8 \times 10^{-3***}$	Not present	1.14
Day	64	$1.3 \times 10^{-3***}$	Not present	0.54
Thermally hot cloud				
Night	228	$3.7 \times 10^{-4}$	$3.2 \times 10^{-3***}$	$1.5 \times 10^{-1}$
Day	624	$1.4 \times 10^{-4}$	$1.2 \times 10^{-3***}$	$5.5 \times 10^{-2}$

\*Critical organ

for halogens: thyroid gland

for fission products: lungs or gastrointestinal tract

for submersion-volatile fission products: total body

\*\*The value would be  $1.9 \times 10^{-2}$  if the dosage rate were limited to 20 rep/hr.

\*\*\*These values are closest to those actually reached under the assumed conditions of the accident.

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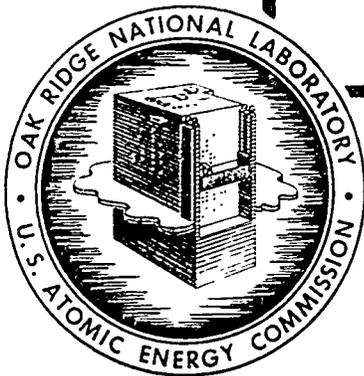
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ORNL-1488	Period Ending January 20, 1953
ORNL-1596	Period Ending July 31, 1953

## CONTENTS

THEORETICAL PHYSICS .....	1
Disordering of Solids by Heavy Corpuscular Radiation .....	1
Spectral Degradation of Neutrons .....	1
Effect of Recombination Upon Radiation Damage by X and Gamma Radiation .....	1
PHYSICS OF NUCLEAR RADIATION .....	2
Neutron-Scattering Experiment .....	2
Electron-Drift Velocity .....	2
Ionization of Mixtures of Gases by Plutonium Alpha Particles .....	7
Applied Dosimetry .....	7
Ionization Produced by Recoil Atoms in Methane .....	8
RADIATION MEASUREMENTS .....	11
Uranium Prospecting .....	11
RADIATION DOSE .....	13
Spectrographic Analysis of Human Tissue .....	13
Radiochemical Analysis .....	13
External Dose .....	14
Measurement of ionizing radiation by high-frequency variation .....	14
Measurement of thermal neutrons by high-frequency variation .....	14
Film dosimetry for fast neutrons .....	15
Energy losses of electrons in foils .....	16
Film dosimetry .....	17
AIRBORNE RADIOPARTICULATE CONTAMINATION .....	17
Radioactive-Dust Studies and Protective Equipment Evaluation Program (PEEP) .....	17
Joint Chemical Corps-ORNL program .....	17
Study of radioparticulate contamination at X-10 .....	17
RADIOACTIVE WASTE DISPOSAL RESEARCH .....	19
Water and Liquid-Waste Decontamination Processes .....	19
Water decontamination studies .....	19
Process-waste-treatment experimental plant .....	19
Surface adsorption - a mechanism in the removal of radioactive materials from aqueous solutions by clay slurry .....	21
Surveys and Evaluations - Field and Laboratory .....	21
Continued study of waste-storage pit No. 2 .....	21
Radioactivity in river-bottom sediments .....	22
Instrumentation and Techniques .....	22
Determination of radioactive nuclides in river-bottom sediments .....	22
Compilation of radiochemical methods .....	25
Portable well-logging instrument for beta measurements .....	25
ECOLOGICAL STUDY .....	26
EDUCATION, TRAINING, AND CONSULTATION .....	27
AEC Fellowship Program .....	27
Other Training Programs .....	27
Lectures .....	27
Consultation .....	27
PUBLICATIONS .....	28
PAPERS .....	28
LECTURES .....	29

# HEALTH PHYSICS DIVISION

## SEMIANNUAL PROGRESS REPORT

### THEORETICAL PHYSICS

J. Neufeld  
R. H. Ritchie                      W. S. Snyder

#### DISORDERING OF SOLIDS BY HEAVY CORPUSCULAR RADIATION

The number of vacant lattice sites in a monatomic substance exposed to heavy corpuscular radiation has been calculated for the range  $E > \gamma$ , where  $E$  is the energy of a recoil atom produced by the radiation and  $\gamma = 25A \times 10^3$  ev ( $A$  is the mass number of the atoms of the solid).

#### SPECTRAL DEGRADATION OF NEUTRONS

The change in the energy spectrum of neutrons that have penetrated a slowing-down medium has been calculated. The calculated spectrum has been compared with experimental data and there is fair agreement. This work has been reported.<sup>1</sup>

#### EFFECT OF RECOMBINATION UPON RADIATION DAMAGE BY X AND GAMMA IRRADIATION

The greater part of damage to living tissue subjected to x or gamma irradiation is thought to be due to indirect chemical effects of ionization products, as opposed to direct hits of the primary ionizing particles upon a vulnerable portion of the cell.

Volume recombination of H and OH radicals which are formed in the decomposition of water by the ionizing particles and which are believed to be responsible for chemical effects<sup>2</sup> may reduce, to

<sup>1</sup>G. S. Hurst, J. A. Harter, P. N. Hensley, W. A. Mills, and R. H. Ritchie, ORNL-1671 (classified), to be published.

<sup>2</sup>D. E. Lea, *Actions of Radiations on Living Cells*, McMillan, 1947.

some extent, the biological damage done at high dose rates.

To estimate the magnitude of this effect, the equation describing  $n$  (the density of radicals of either sign) is written as follows:

$$an^2 + \beta n - q = 0 .$$

Here  $a$  is the number of radicals disappearing through volume recombination per unit time for unit radical density,  $\beta$  is the number disappearing through chemical action per unit time for unit density, and  $q$  is the number of radicals generated per unit volume per second by the ionizing radiation. The variation of  $n$  with time is neglected, since chemical combination times are of the order of  $10^{-9}$  sec, which is short compared with any realistic irradiation time. By solving this equation for  $n$  and determining the source density  $q$  at which the recombination effect accounts for the disappearance of half the radicals, a generated radical density of  $q = 2\beta^2/a$  is found. Lea<sup>3</sup> estimates that  $\beta$  may be as high as  $10^9$  sec<sup>-1</sup> in the cell fluid and assumes a value for  $a$  of  $4 \times 10^{-10}$  cm<sup>3</sup>/sec. If it is assumed that about one radical of each kind is produced per ion pair and that about  $2 \times 10^{12}$  ion pairs/cm<sup>3</sup> are equivalent to 1 r, then the dose rate would be  $2.5 \times 10^{15}$  r/sec. The extremely high value of the dose rate at which the chemical effects are reduced by one-half through volume recombination shows that this effect will be negligible in any realistic irradiation of living cells.

<sup>3</sup>*Ibid.*, pp. 52, 60.

## PHYSICS OF NUCLEAR RADIATION

G. S. Hurst	W. A. Mills	C. E. Melton <sup>1</sup>
T. E. Bortner	M. Slater	L. W. Cochran <sup>2</sup>
W. G. Stone	J. W. Cure, III <sup>1</sup>	R. H. Ritchie <sup>3</sup>

## NEUTRON-SCATTERING EXPERIMENT

The purpose of the neutron-scattering experiment in the determination of the neutron dose at a point in air was threefold: (1) to determine the variation in dose at different distances (D) between the source and point, and to check the reliability of the inverse-square law for estimating the correct dose, (2) to determine the variations in dose with changes in height (H) of the source and detector (point) above a large block of concrete, 3 to 4 in. thick, and the effect of neutrons scattered from the concrete on the dose, and (3) to determine whether or not the detector can be shielded by a paraffin cone so that the dose at the point is due only to scattered neutrons.

The experimental arrangement is shown in Fig. 1. The neutron source is  $\text{Po}^{210}\text{-B}$ , and the counter is a proportional counter, ethylene-polyethylene type,<sup>4</sup> with a pulse integrator<sup>5</sup> for measuring the dose.

The differences in the neutron dose as a function of height above concrete at various distances between the source and the detector are shown graphically in Figs. 2a through 2f. These differences are important since they enable an experimenter to determine how much neutron scattering can be expected from concrete walls, floors, etc. For distances up to 1 meter between the counter and source, the dose due to scattered neutrons is less than 2% of the dose due to the primary beam of neutrons if the counter and source are at least 1.5 meters away from the concrete wall or floor. Also, it should be noted that if the distance between the source and counter is greater than 1.5 meters, there is a height above the concrete at which the

dose rate is at a maximum. This is attributable to the scattering of the neutrons in the concrete at some distance below the surface. The neutrons are effectively soaked up by the concrete, because, when they are scattered at some distance below the surface, they must go through a considerable thickness of concrete to reach the detector. Figure 3 is a graph of the dose rates as read from the flat portions of the curves of Figs. 2a through 2f (i.e., for heights above the concrete where neutron scattering from the concrete is negligible and for the corresponding distances between source and detector). It is noted that the inverse-square law gives the correct dose rate up to a distance of about 1.5 meters between the counter and source. At distances greater than 1.5 meters the dose rate is appreciably greater than that predicted by the inverse-square law. It is believed that this increase is due to air scattering. It was determined that a 44-cm-long paraffin frustum, having diameters of approximately 3 and 10 cm, placed between the source and counter cut off the primary beam of neutrons from the detector, thereby reducing the dose due to the primary beam of neutrons by a factor greater than 1000. Comparison of the shapes of the curves with and without the paraffin (Figs. 2c and 2d compared with Figs. 4a and 4b) indicates that the dose at the detector with the paraffin in front of the source is due only to scattered neutrons.

Complete details of this experiment will be reported by J. W. Cure, III in a thesis for the degree of Master of Science in physics at Vanderbilt University.

## ELECTRON-DRIFT VELOCITY

In the experiment for measuring the attachment coefficient of electrons, the drift velocity of the electrons under specific conditions has been determined. The apparatus described by Stevenson<sup>6</sup>

<sup>1</sup>AEC Fellow in Radiological Physics (Vanderbilt University, cooperating university).

<sup>2</sup>Consultant from Department of Physics, University of Kentucky.

<sup>3</sup>Theoretical Physics Group, Health Physics Division.

<sup>4</sup>G. S. Hurst and R. H. Ritchie, *Radiology* 60, 864 (1953).

<sup>5</sup>F. M. Glass and G. S. Hurst, *Rev. Sci. Instr.* 23, 67 (1952).

<sup>6</sup>A. Stevenson, *Rev. Sci. Instr.* 23, 93 (1952).

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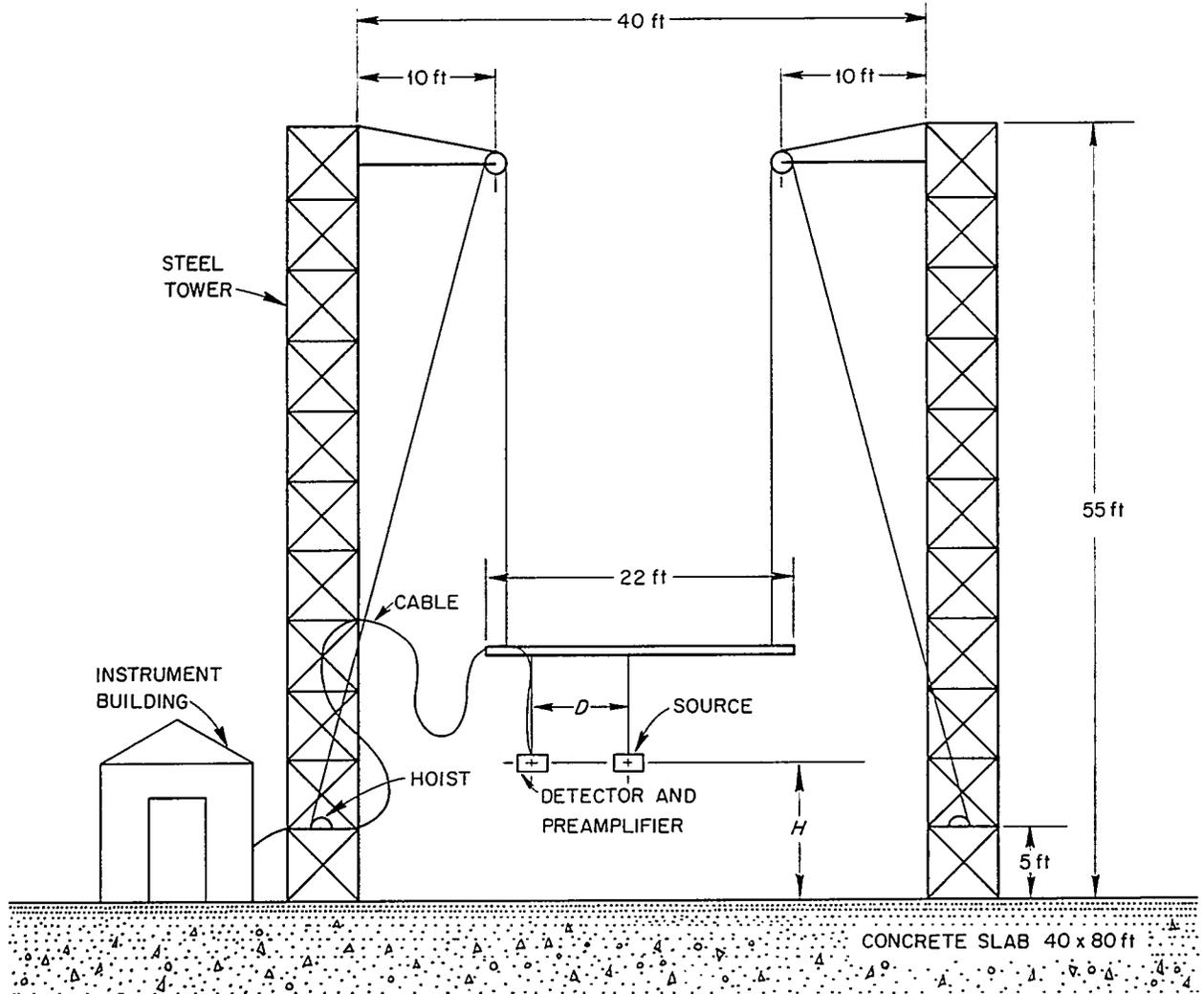


Fig. 1. Experimental Arrangement for Scattering of Fast Neutrons.

was used, and the data obtained (Fig. 5) for pure  $N_2$  are in good agreement with those reported by Klema and Allen.<sup>7</sup> A mixture of 90% argon and 10% methane showed a rapid rise to a maximum drift velocity of  $6.6 \text{ cm}/\mu\text{sec}$  at a field strength of  $0.1 \text{ volt/cm-mm}$  of Hg, followed by a gradual decrease to  $3.1 \text{ cm}/\mu\text{sec}$  at a field strength of  $0.8 \text{ volt/cm-mm}$  of Hg, after which the value remained constant to the maximum measured field strength of  $2.0 \text{ volts/cm-mm}$  of Hg. These results for the argon-methane mixture have an important practical

implication, since such mixtures are commonly used in proportional counters and ionization chambers. The data indicate that an optimum voltage can be chosen so as to give a minimum electron-collection time. Further, the results are of interest since the maximum drift velocity in the mixture is approximately four times that in pure argon.

<sup>7</sup>E. D. Klema and J. S. Allen, *Phys. Rev.* 77, 661 (1950).

# HEALTH PHYSICS PROGRESS REPORT

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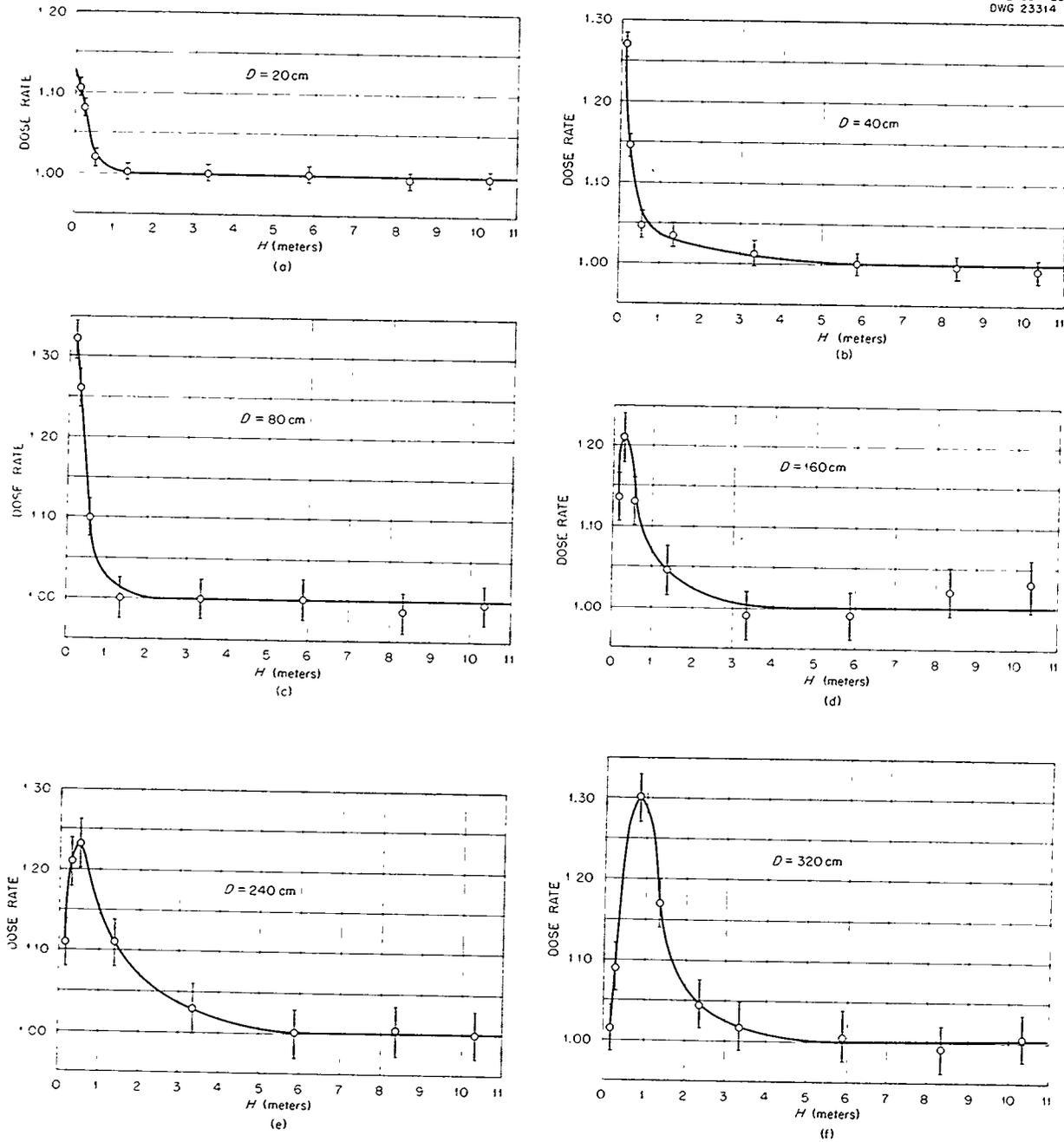


Fig. 2. Neutron Dose as a Function of Height Above Concrete for Various Distances Between Source and Detector.

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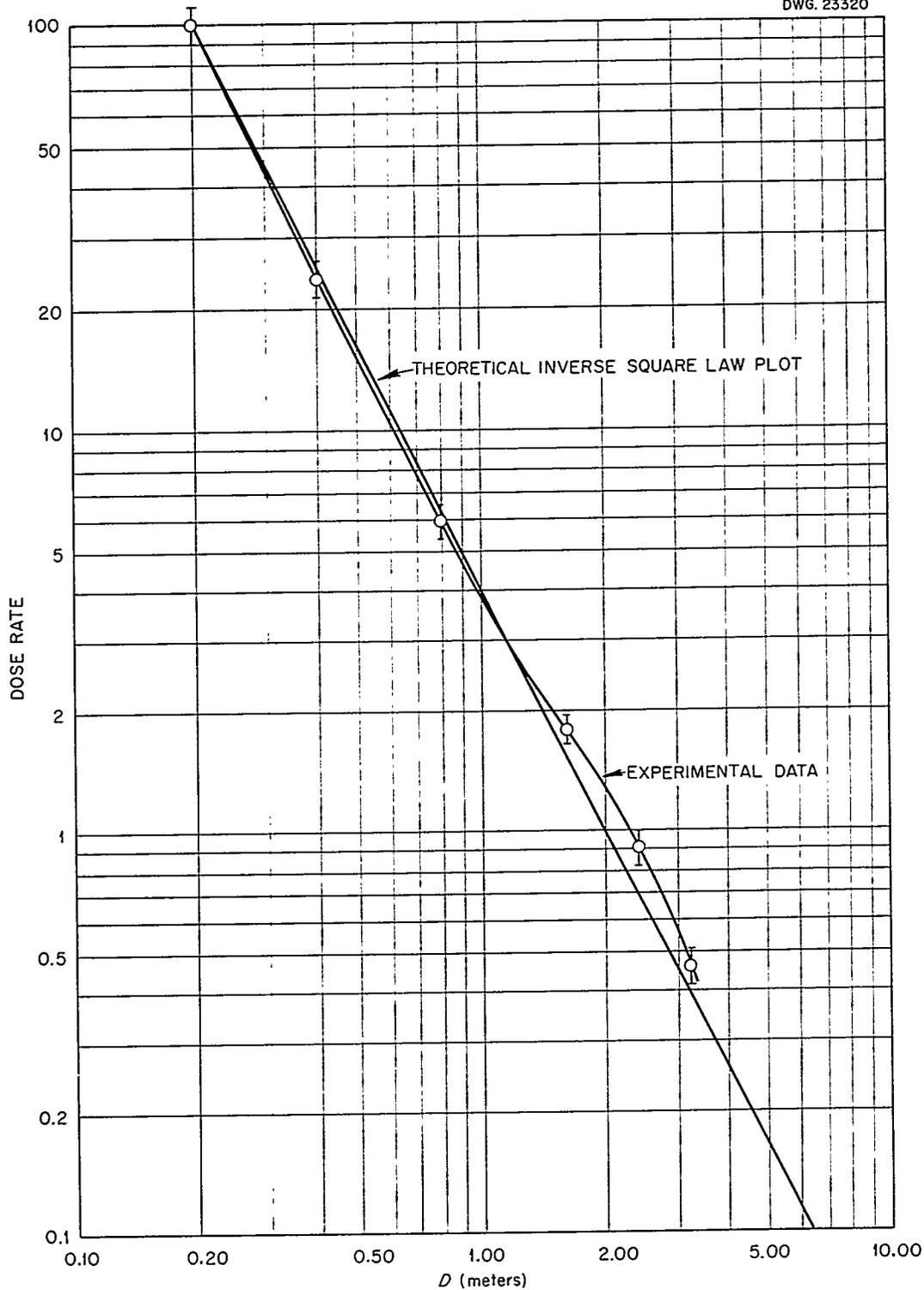


Fig. 3. Comparison of the Measured Dose and the Dose as Calculated from the Inverse-Square Law.

# HEALTH PHYSICS PROGRESS REPORT

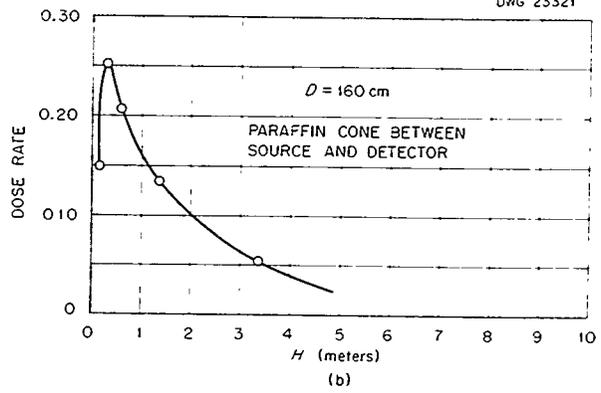
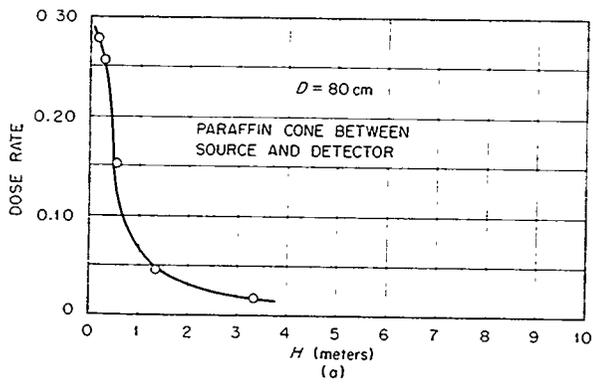


Fig. 4. Dose of Scattered Neutrons as a Function of Height Above Concrete for Two Distances Between Source and Detector.

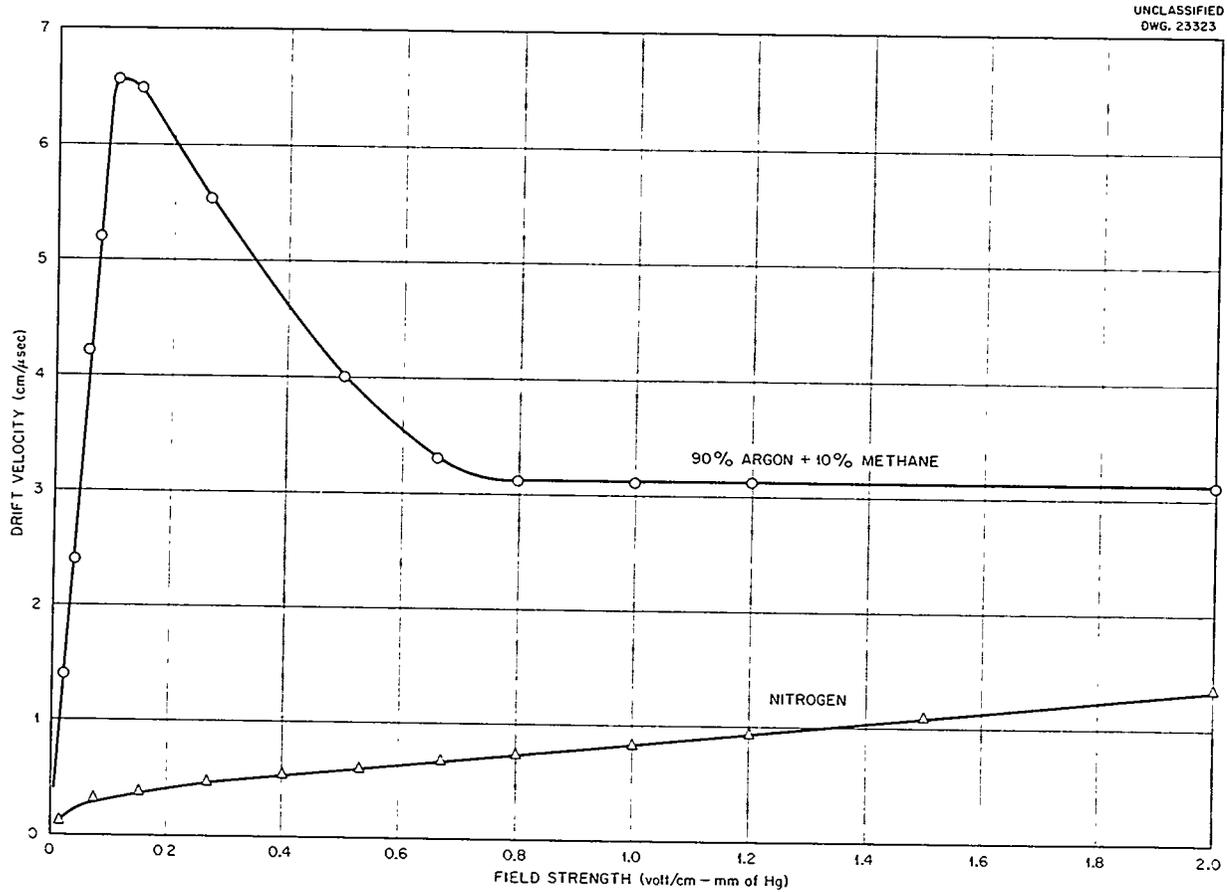


Fig. 5. Electron Drift vs. Field Strength.

IONIZATION OF MIXTURES OF GASES BY  
PLUTONIUM ALPHA PARTICLES

Measurements of the ionization of gas mixtures by alpha particles from Pu<sup>239</sup> has continued, and two types of mixtures are of interest. The first class of gas mixtures is one for which the  $W$  (average electron volts dissipated by the alpha particle per ion pair produced) changes gradually as the proportions of the two gas components are changed. It was found that for this case the  $W$  for a gas mixture ( $W_m$ ) may be written in terms of the values of  $W$  of the components  $W_1$  and  $W_2$  having pressures  $P_1$  and  $P_2$ , as follows:

$$\frac{1}{W_m} = \left( \frac{1}{W_1} - \frac{1}{W_2} \right) P + \frac{1}{W_2}$$

where  $P = P_1/(P_1 + aP_2)$  and  $a$  is constant for a given two components. For the following mixtures,  $a$  has the values shown in Table 1.

A complete paper on this work has been accepted for publication in the *Physical Review* and is scheduled to appear in the April 15, 1954 issue.

For the second class of gas mixtures, the  $W$  value shows a minimum when a small percentage of the second gas is added to argon. This is true of gases having an ionization potential less than 14.5 volts. The minimum value of  $W$  for mixtures of argon and these gases is given in Fig. 6, where  $W$  is plotted as a function of the ionization potential of the gases. The percentage of the gas which gives the minimum  $W$  value is indicated in paren-

theses below the point. No amount of H<sub>2</sub> or N<sub>2</sub> (the ionization potentials are above 14.5 volts) added to argon would depress the  $W$  value below that of pure argon, while gases having ionization potentials below 14.5 show a minimum in the value of  $W$  below that of pure argon for the mixtures. An attempt is being made to explain the results by considering the effect of a radiation transition state in argon (between 14.5 and 15.5 volts) which has a long lifetime; hence, when the impurity is added, there is a good chance of many collisions between the excited argon atoms and the impurity. Some of these collisions would result in a transfer of the energy of the excited state to ionization of the impurity atoms; hence the increased ionization would be explained.

APPLIED DOSIMETRY

Measurements of the fast-neutron dose were made at two biological exposure facilities. One facility is at the CP3' reactor, Argonne National Laboratory, and is used by H. H. Vogel, Jr. and associates for the irradiation of mice and other small animals. The other facility is the 86-in. cyclotron located at Y-12 and used by the Biology Division, Oak Ridge National Laboratory.

At the ANL facility, the neutron dose was measured with a proportional counter which measures the dose directly. Details of the counter have been reported by Hurst and Ritchie.<sup>8</sup> The source of fast neutrons at the facility is a 1-in.-thick natural-uranium plate irradiated by thermal neutrons from the reactor, giving a fission spectrum which is modified by 3 in. of lead. The dose was measured at different locations in the animal exposure cage for various operating levels of the reactor. The results agreed within 14% with the data previously obtained by Vogel using a Victoreen condenser chamber calibrated with the Rossi tissue-equivalent chamber. The close agreement may be explained by the facts that (1) the gamma contamination in the facility is low and (2) the Victoreen was used in the location where it was calibrated with the tissue chamber.

To measure the dose at the Y-12 facility, two methods were used - a proportional counter and fission threshold detectors. Not only was the dose measurement at the cyclotron of interest to the

TABLE 1. VALUES OF CONSTANT  $a$  FOR  
VARIOUS MIXTURES

MIXTURE	$a$
N <sub>2</sub> -H <sub>2</sub>	0.28
N <sub>2</sub> -A	0.53
N <sub>2</sub> -O <sub>2</sub>	1.06
He-A	0.75
He-H <sub>2</sub>	3.55
He-N <sub>2</sub>	8.47
He-CH <sub>4</sub>	0.68
A-H <sub>2</sub>	0.56
H <sub>2</sub> -CH <sub>4</sub>	4.03

<sup>8</sup>G. S. Hurst and R. H. Ritchie, *Radiology* 60, 864-868 (1953).

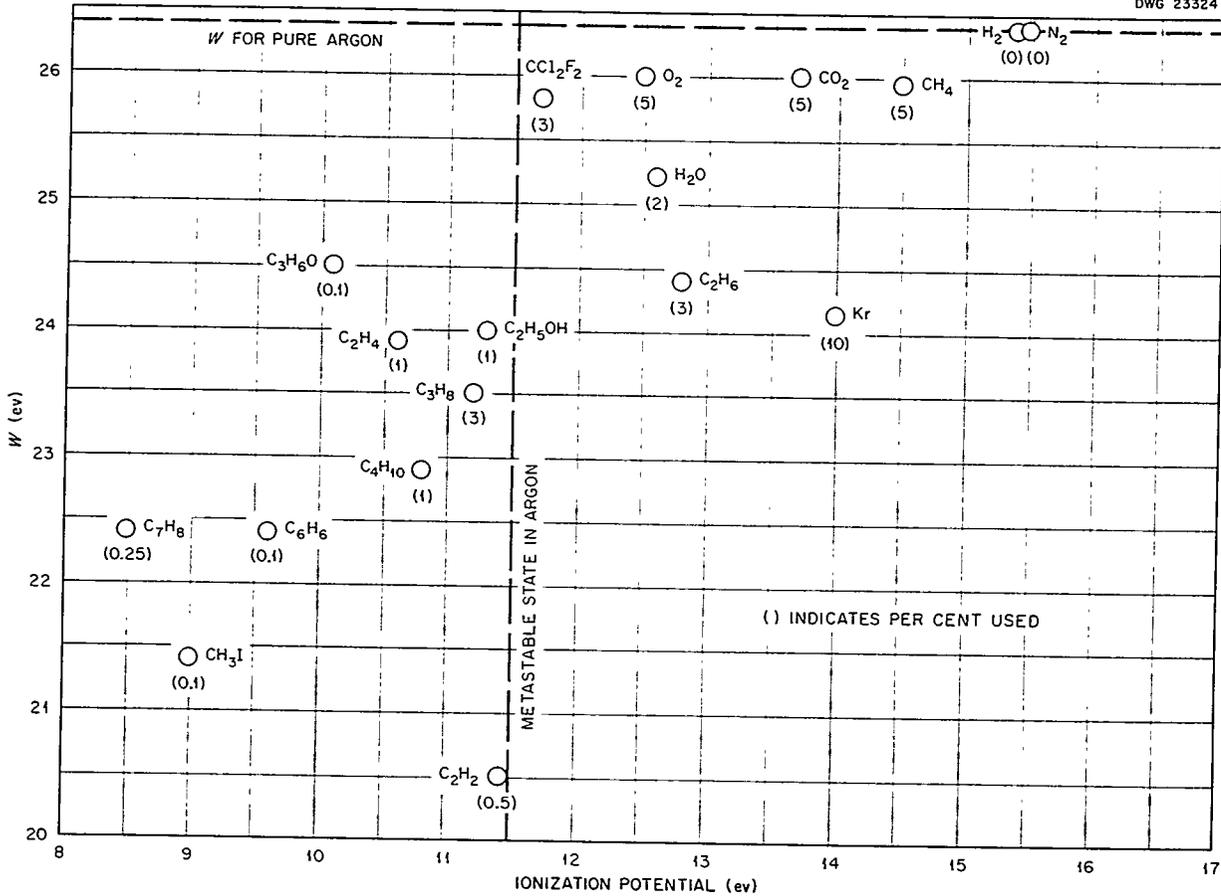


Fig. 6. W Values vs. Ionization Potentials of Gases Used as Impurities in Argon.

Biology Division but also the cyclotron afforded an opportunity to compare the two methods of dosimetry. Since the proportional counter is essentially a detector for low neutron intensities and the threshold detectors are usable only for high intensities, a comparison could be made by varying the beam current of the cyclotron; however, even at the very lowest beam current, the neutron intensity was so great that a new and very insensitive proportional counter had to be designed. Dose rate measurements with the two methods agreed within 20%. The difference may be due to the fact that in using the threshold detectors the dose is calculated by means of first-collision tissue-dose curves, whereas the proportional counter measures dose directly when calibrated with a neutron source, Po-B, the strength of which is

known. Therefore the proportional counter determination is believed to be the more accurate of the two methods. Use of the fission threshold detectors does give valuable information on the fast-neutron spectrum, and this method of dosimetry is very satisfactory for field use at atomic tests.

#### IONIZATION PRODUCED BY RECOIL ATOMS IN METHANE

The value of W, the average energy required to produce an ion pair, has been measured in methane for the recoil atoms resulting from the alpha decay of thorium C and thorium C'.

The number of ion pairs produced by a recoil particle is of the order of  $10^3$ . To measure such a small number with reasonable accuracy, a proportional counter which gives considerable gas

amplification within the counter itself is used. To calibrate the gain of such a counter, a source which will produce a determinable number of ions is placed within the counter.

The experimental arrangement similar to that used by Madsen<sup>9</sup> is shown in Fig. 7. A long proportional counter, with an active length sharply defined by field tubes, has at one end a plutonium source used for calibration; and it is so well collimated that the alphas traverse the entire length. Each alpha produces a pulse of measurable size. By reference to the tables of Hirshfelder and Magee,<sup>10</sup> the number of ion pairs corresponding to the size of the pulse can be calculated if the energy of the alphas from plutonium, the measured pressure of the methane in the counter, and the value of  $W$  for alphas in methane are known. The dimensions of the counter and the pressures used are such that the calibrating pulses are from 10 to 70 times as large as those produced by the recoil atoms to be studied.

The source of recoil atoms is  $\text{Pb}^{212}$  (ThB) from

<sup>9</sup>B. S. Madsen, *Kgl. Danske Videnskab. Selskab, Mat. fys. Medd.* 23, No. 8 (1945).

<sup>10</sup>J. O. Hirshfelder and J. L. Magee, *Phys. Rev.* 73, 207 (1948).

natural thorium nitrate. The ThB is deposited on a mica window (thickness  $1 \text{ mg/cm}^2$ ) which is sealed into the wall of the long counter at the midpoint. The surface of the window facing the long counter is coated with a very thin electrically conducting layer of silver, over which is deposited the ThB. The other face is covered with an opaque coating of graphite, over which is placed a brass plate  $\frac{3}{8}$  in. thick with a collimating hole  $\frac{1}{4}$  in. in diameter. This side of the window forms one end of an alpha counter. All recoil atoms from the ThB are stopped in the window, but the alphas penetrate easily. The alphas which enter the alpha counter come from disintegrations so oriented that the associated recoil atoms expend all their energy within the volume of the long proportional counter.

The long proportional counter is connected to a preamplifier and A-1 amplifier whose low output terminal is connected to a single-channel analyzer (Fig. 8). The output of this single-channel analyzer is fed to one input of a coincidence circuit. The alpha counter is connected to a preamplifier and an A-1 amplifier. The discriminator output of the A-1 is lengthened to a pulse about  $4 \mu\text{sec}$  long so as to overlap the signal from the long counter

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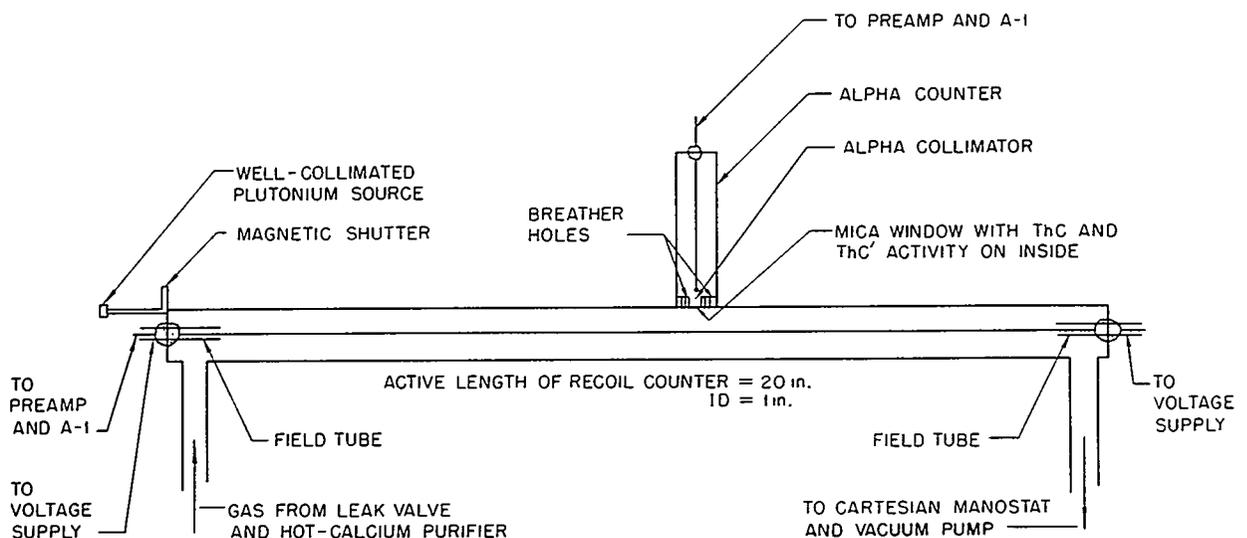


Fig. 7. Recoil-Measurement Proportional Counter.

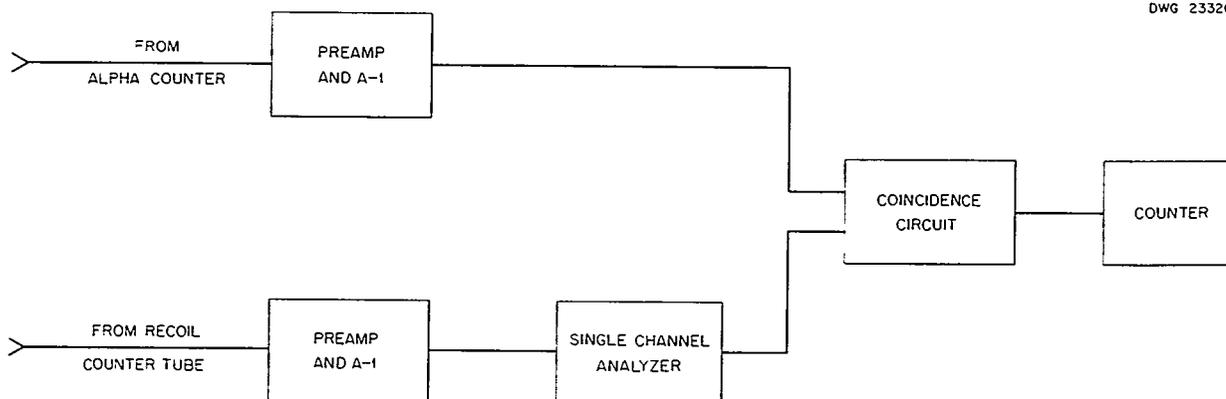


Fig. 8. Schematic Diagram of Recoil Ionization Measurement Circuits.

which is delayed by the single-channel analyzer. The output from the A-1 amplifier of the alpha counter is connected to the other input of the coincidence circuit.

A plot is made of the number of coincidences per unit time for various base lines of the single-channel analyzer, which gives two well-defined peaks corresponding to the pulse heights of ThC and ThC'. The same type of plot is made without the alpha counter and coincidence circuit to get the pulse height of the calibrating alphas.

The slow counting rate and the short half-life of the Pb<sup>212</sup> (10.6 h) limited the counting statistics to the order of 10% probable error. The location

of the peaks on the plots seems to be somewhat better than this. Table 2 gives the final data.

To compare the value of *W* of the recoil atoms in methane obtained in this experiment with the value obtained by Madsen for the *W* in 95% argon and 5% air, it is necessary to calculate the differential *W*, that is, the value of *W* calculated from the difference in energy of the ThC' recoil atom (166,000 ev) and that of the ThC atom (115,000 ev) divided by the difference in ion pairs produced by the two recoil atoms. This calculation yielded a value of 107.8 ev per ion pair for methane. Madsen's value for the argon-air mixture was 67 ev per ion pair.

TABLE 2. MEASUREMENTS OF *W* USING SINGLE-CHANNEL ANALYZER\*

EXPERIMENT NO.	PRESSURE OF METHANE (cm Hg)	<i>W</i> = ELECTRON VOLTS PER ION PAIR	
		ThC' Recoil Atom	ThC Recoil Atom
1	1.078	125.0	141.0
2	1.056	130.7	131.5
3	1.056	126.9	137.4
4	1.824	126.4	149.6
5	1.464	117.9	121.3
6	1.822	128.2	132.7
7	1.056	130.1	145.7
Average		126.5	137.0

\**W* (differential) = 107.8 ev per ion pair for the ThC' recoil atom in the energy region from 166 to 115 kev.

RADIATION MEASUREMENTS

F. J. Davis                      P. W. Reinhardt  
 J. A. Harter

URANIUM PROSPECTING<sup>1</sup>

The radiation-survey instrumentation of the second DC-3 aircraft has been completed. A series of flights over four sources (Ra, Co<sup>60</sup>, Cs<sup>137</sup>, and Au<sup>198</sup>) placed on islands in Cherokee Reservoir were made at 10 altitudes from 200 to 2000 ft above the water surface. Plotting the measured intensity of radiation (counts per second) times height vs. height on semilog paper (Fig. 9) shows that the data can be represented as a straight line for altitudes above 400 feet.

Using 0.00118 g/cc as the density for air, the values of half-thickness correspond to absorption coefficients given in col. 3, Table 3. The corresponding theoretical values calculated from the Klein-Nishina formula are given in the last column. The value 1.07 Mev shown for radium is the energy corresponding to the 0.062 cm<sup>2</sup>/g experimental value.

A straight line indicates that the buildup factor *B* (the increase in intensity due to the scattered radiation) is proportional to the height; so the intensity at a height *b* can be expressed as

$$I = k_1 \frac{e^{-\mu b} B}{b^2} = k_2 \frac{e^{-\mu b}}{b} ,$$

where  $\mu$  is the linear absorption coefficient in air.

For altitudes below 400 ft, the buildup factor may be represented by  $B = 1 + a(\mu b)$ , since as *b* approaches zero the buildup factor should approach

unity. For aerial surveying of radiation the first relation is sufficiently accurate. If this relation is used and if a plane source such as fall-out from atomic tests is integrated, the variation in intensity with altitude is a simple exponential of  $\mu b$ . Also in measuring a radioactive ore outcrop, if it is assumed that the buildup factors in the ground and in the air are proportional to the respective absorption coefficients of ground and air, a simple exponential is obtained. Thus in both cases the relation  $I = ke^{-\mu b}$  holds.

The experimental data shown in Fig. 10 were taken at various locations but are normalized to an altitude of 5000 ft above sea level to correct for change of  $\mu$  with altitude. If the half-thickness of air for radium gammas shown in Fig. 9 as 310 ft is corrected to 5000 ft above sea level, it becomes 360 ft, which compares very well with the half-thickness of air above ground shown as 370 ft in Fig. 10 for natural activity.

Tests were made with various forms of lead shielding for detector collimation of different discriminator settings of the amplifier, thus restricting the energies of radiation detected. The results showed that the lead shielding did not sufficiently improve the differentiation between a wide area of low-intensity radiation and a small area of high intensity, and hence it was omitted to save weight. The best signal-to-noise ratio was obtained with the discriminator set to accept all energies above approximately 50 kev.

A 6- or 12-volt battery-operated scintillation detector, weighing approximately 31 lb without the

<sup>1</sup>In cooperation with the U.S. Geological Survey.

TABLE 3. EXPERIMENTAL AND CALCULATED ABSORPTION COEFFICIENTS

SOURCE	E (Mev)	$\mu_{exp}$ cm <sup>2</sup> /g	$\mu_{th}$ cm <sup>2</sup> /g
Co <sup>60</sup>	1.25	0.055	0.056
Ra	(1.07)	0.062	
Cs <sup>137</sup>	0.66	0.081	0.077
Au <sup>198</sup>	0.41	0.101	0.095

# HEALTH PHYSICS PROGRESS REPORT

recorder, has been designed and built for use in a car or light aircraft. The unit contains a built-in calibration system consisting of a simple Q pulser (ORNL-Q-1066). The d-c voltage for the Q pulser is supplied from an RM12 mercury cell, and the output pulse is used to standardize the amplifier gain and to calibrate the rate meter. By switching input to the Q pulser from the RM12 battery to a

voltage divider across the negative high-voltage supply, the stability of the high voltage can be checked directly with the amplifier discriminator.

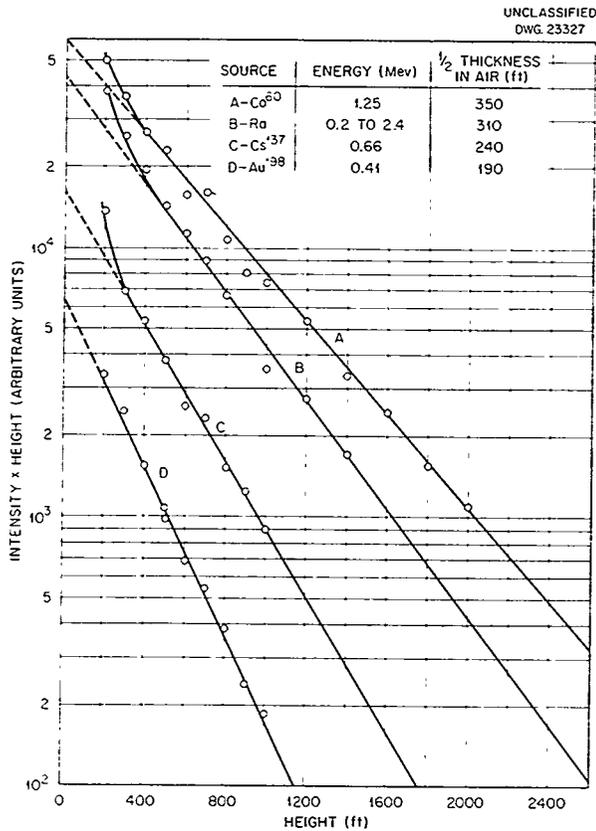


Fig. 9. Point-Source Measurements.

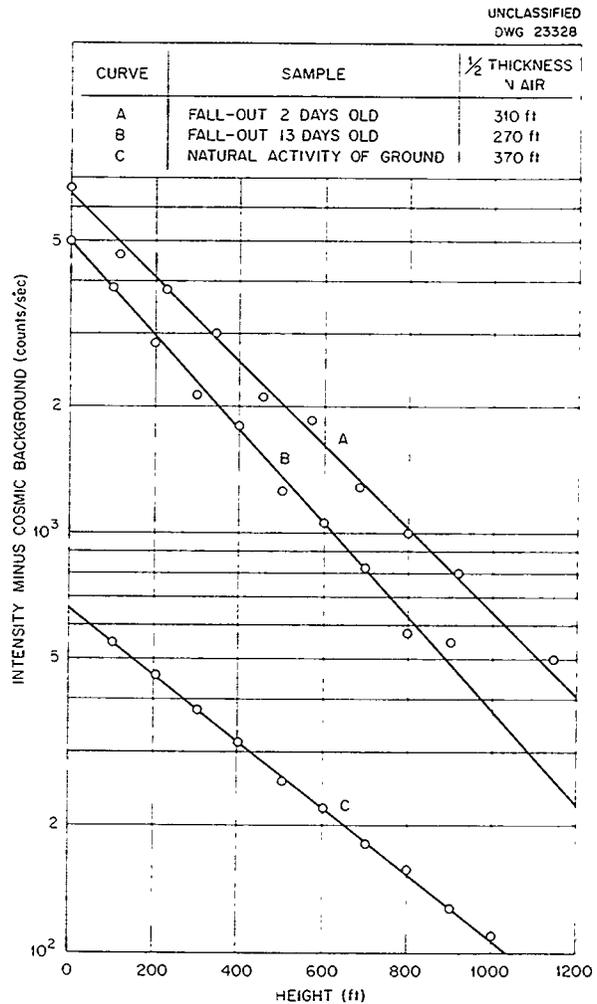


Fig. 10. Broad-Source Measurements.

## RADIATION DOSE

H. H. Hubbell

R. D. Birkhoff	E. D. Gupton
A. W. Blackstock	F. H. W. Noll
J. S. Cheka	H. K. Richards
E. Denman	A. W. Smith
L. B. Farabee	I. Tipton

SPECTROGRAPHIC ANALYSIS OF  
HUMAN TISSUE<sup>1</sup>

The entire procedure of the spectrographic laboratory for the analysis of trace elements in human tissue is being changed. Instead of dry ashing samples of tissue and analyzing the ash by visual comparison of the spectrum of the tissue ash with standard spectra, a method of wet ashing, precipitating the elements to be analyzed with organic precipitants, and analyzing by means of an internal standard is now being employed.

The tissue is homogenized, dried under vacuum, and wet ashed with a mixture of nitric, perchloric, and sulfuric acids. The elements for which the sample is to be analyzed are precipitated with 8-hydroxyquinoline and thionalide ( $\beta$ -aminonaphthalidethioglycolic acid), using indium as a carrier and later as an internal standard. At the proper pH, sodium and potassium are not precipitated and thus are not present in the sample to decrease the spectrographic sensitivity for certain elements as in the old method. The precipitate is ashed at 450°C, and the ash is ground with graphite to make an arcing mixture. The entire treatment is carried out in fused-silica vessels.

The spectrographic procedures are much the same as have been reported previously. The d-c arc-cathode layer technique is used, the image of the cathode layer being focused on the collimator of the spectrograph. Quantitative analyses involving indium as an internal standard have replaced the visual comparison method previously reported. Blanks are carried through the entire procedure, and corrections are made for impurities in the reagents used in the new method.

The sensitivity for most elements has been increased from two- to tenfold by the new method, and the accuracy is many times greater than before.

<sup>1</sup>University of Tennessee research and development contract.

This method can be used in the analysis for approximately 30 elements.

## RADIOCHEMICAL ANALYSIS

A new technique for the separation of tracer amounts of radioactive strontium from bulky quantities of calcium has been achieved. The separation is possible because Versene forms stable complexes with calcium, whereas complexes with strontium do not exhibit such stability, provided the pH is controlled within a limited range. The separation is carried out on a cation-exchange resin such as Dowex-50. By this system it is possible to recover more than 99% of Sr<sup>89</sup> tracer from as much as 600 mg of calcium with a separation factor of strontium from calcium of 10<sup>3</sup>.

The solution containing alkaline earths is chelated with disodium dihydrogen versenate at a pH of 7.5. A 20% additional amount of chelating agent is added. The pH of the solution is then adjusted to 5.5, and the solution is passed over a column containing Dowex-50 (sodium cycle). Extraneous sodium and calcium can be eluted from the resin with 0.8 N HCl. The Sr<sup>89</sup> can be eluted with stronger acid.

A procedure for separating radioactive strontium from urine, using the general technique outlined previously, is being worked out. Since urine contains appreciable quantities of magnesium, and since the stability constants of versenate chelates of magnesium and strontium are almost alike, an additional separation of magnesium from strontium can be made by eluting the magnesium with ammonium citrate. A recovery of more than 97% of tracer Sr<sup>89</sup> from a 1500-ml urine sample can be achieved. Approximately 2 to 3 mg of alkaline earths are present in the eluent, and this small amount can be easily counted without further separation.

The foregoing procedure could be used for recovery of minute amounts of strontium from bulky water samples, from bone, and from urine.

## HEALTH PHYSICS PROGRESS REPORT

### EXTERNAL DOSE

#### Measurement of Ionizing Radiation by High-Frequency Variation

Experiments on the use of a ferroelectric material in the frequency-controlling circuit of a radio-frequency oscillator were continued. As previously described,<sup>2</sup> ionizing radiation varied the electrostatic charge on a capacitance made with a ferroelectric material, thus changing its dielectric constant and hence the frequency. Improvements on this technique extended the sensitivity range down to about 15 mr/hr. This work is described by E. Denman in a master's thesis to be submitted to Vanderbilt University.

Further improvements were made in the method by using capacitances of the order of 10 to 20  $\mu\mu\text{f}$ . These were constructed with the cooperation of the ORNL Research Shop under the direction of R. J. Fox. These capacitances consisted of barium titanite 0.05 to 0.15 cm in thickness and less than 1 mm<sup>2</sup> in surface area. The capacitances were placed between phosphor-bronze springs that served as electrodes. The leakage resistance of these capacitances was less than that of larger pieces used previously, and their application for detection of ionizing radiation by frequency variation increased the sensitivity.

A detailed report by R. J. Fox on the construction of the capacitances will be included in the final report of the study.

In order to determine whether gamma radiation would produce measurable changes in the natural frequency of a cut quartz crystal, two crystals were exposed to  $3 \times 10^7$  r of Co<sup>60</sup> gamma radiation. One crystal retained its original frequency (990 kc), while the other, having initially the same frequency, had its resonant frequency lowered by 79 cps.

#### Measurement of Thermal Neutrons by High-Frequency Variation

The aforementioned method was applied to the detection of thermal neutrons by using a crystal of the piezoelectric material potassium pentaborate ( $\text{KB}_5\text{O}_8 \cdot \text{H}_2\text{O}$ ) as the frequency-controlling element in a radio-frequency circuit. The material was

supplied by H. Jaffe of the Brush Development Company. As may be seen in Fig. 11, the crystal was operated at series resonance. Its thickness was about 1.5 mm and the frequency about 1.03 Mc. The thickness was in the approximate direction of the X axis, and the vibration is a thickness shear mode.

The curve of frequency as a function of temperature for this cut of crystal has an extreme value at 25°C, and its frequency is therefore relatively stable against slight temperature variations at room temperature. When the crystal is exposed to thermal neutrons, the boron ( $n, \alpha$ ) reaction will occur, where  $\text{B}^{10} + n \rightarrow \text{Li}^7 + \alpha + 2.79 \text{ Mev}$ . The amount of normal boron was about 48 mg/cm<sup>2</sup>. Using the absorption cross section of 718 barns for this reaction, the macroscopic cross section is about 2, and therefore practically all thermal neutrons are absorbed. The following effects per captured neutron can be expected:

1. One boron atom will be removed, thus producing a vacancy in the lattice.

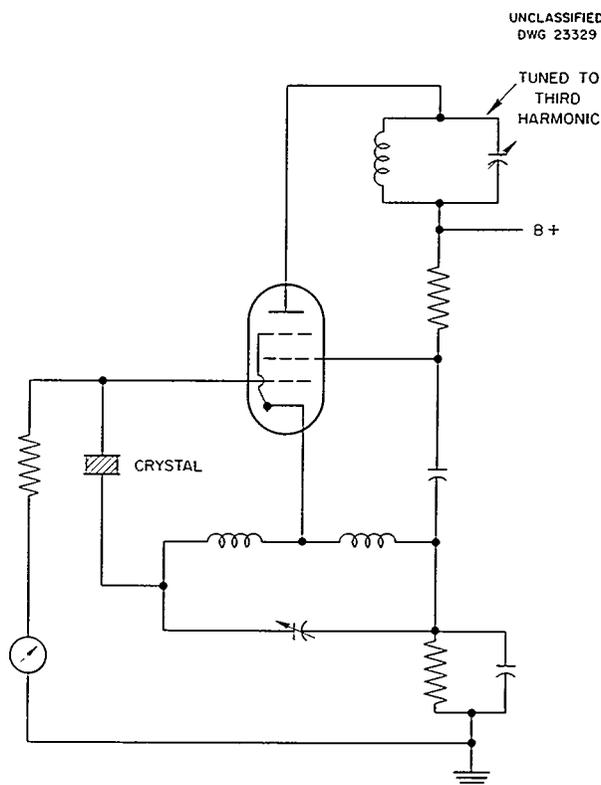


Fig. 11. Circuit for Studying Irradiated Piezoelectric Crystals.

<sup>2</sup>H. H. Hubbell et al., *H-P Semiann. Prog. Rep.* July 31, 1953, ORNL-1596, p. 11.

2. The kinetic energy of the He<sup>4</sup> and the Li<sup>7</sup> will displace other atoms inside the lattice.

3. Recoils produced by the helium and lithium will produce further interstitials and vacancies in the lattice.

4. After loss of their kinetic energy, the helium and lithium will become impurity atoms.

The frequency of the crystal is given by

$$(1) \quad F = \frac{1}{4\pi x} \sqrt{\frac{E}{\rho}} = \frac{1}{2} \sqrt{\frac{EYZ}{mx}}$$

where

- Y, Z = length and width,
- m = mass of the crystal,
- x = thickness,
- ρ = density,
- E = elastic modulus,
- F = frequency of vibration.

Any change in E or ρ will vary the frequency. The frequency variation can be represented by

$$(2) \quad \frac{\partial F}{F} = \frac{1}{2} \frac{\partial E}{E} + \frac{1}{2} \frac{\partial Y}{Y} + \frac{1}{2} \frac{\partial Z}{Z} - \frac{1}{2} \frac{\partial x}{x}$$

To determine whether temporary exposure to different temperatures would affect the frequency permanently, the crystal was exposed to temperature variations from about 0 to 50°C. After 20 to

30 min in a room with an ambient temperature between 24 to 25°C, the frequency returned to its original value within ±25 cps. Since the thermal-neutron channel in the ORNL Graphite Reactor contained some gamma radiation, the crystal was exposed to an equivalent x-ray dose. No measurable effect was observed. Some uncertainty in all measurements was introduced by the variation of about 25 cps, due to the variation of the room temperature between 24 and 25°C. Standard equipment with quartz-crystal control and interpolation oscillator permitted observation of every cycle per second of frequency variation on the oscilloscope. The crystal was placed in the slow-neutron channel, where the temperature was kept below 50°C. No frequency variation was measured at exposures of the order of 10<sup>12</sup> thermal neutrons/cm<sup>2</sup>. At magnitudes exceeding 10<sup>14</sup> neutrons/cm<sup>2</sup> effects were observed.

Setting n, the total number of neutrons per square centimeter, and ΔF, the frequency change after irradiation (plus sign is increase, minus sign is decrease of frequency), the results given in Table 4 were obtained.

#### Film Dosimetry for Fast Neutrons

Work had previously been done on the problem of converting the NTA film badge to a true dosimeter

TABLE 4. VARIATION IN FREQUENCY

n (neutrons/cm <sup>2</sup> )	ΔF (cps)	APPROXIMATE TIME FROM END OF EXPOSURE TO FREQUENCY MEASUREMENT
2.25 × 10 <sup>14</sup>	-391	½ hr
	-444	2 hr
1.73 × 10 <sup>14</sup>	-218	½ hr
	-156	2 hr
2.23 × 10 <sup>14</sup>	-272	½ hr
	-150	1 day
	-126	2 days
3.2 × 10 <sup>14</sup>	-601	½ hr
	-175	3 days
	-58	6 days

## HEALTH PHYSICS PROGRESS REPORT

by means of a compensating proton radiator and absorber consisting of laminations of paper and aluminum to adjust the over-all response, in tracks per neutron, to the calculated dose per neutron as a function of energy. It had been decided that the response should be fitted to the first-collision dose curve, as has already been reported.<sup>3</sup> The structure of the packet and the agreement of dose-energy response with calculated values still remained to be developed and evaluated.

Although the best fit to the first-collision dose curve required a thinner film base as the first proton radiator, J. Spence and W. F. Swann of Eastman Kodak recommended that the original base be retained to avoid both manufacturing and processing difficulties due to a tendency of thin film to curl. The component laminations were recalculated for the original 0.008-in. film base. The maximum deviation of the response of the packet from the dose curve was +10% at 5 Mev. This is considered acceptable since (1) under the most favorable conditions, the reading errors are of this magnitude and (2) the monitoring is usually of a broad neutron spectrum and thus would tend to produce a smaller average deviation than 10%.

The final packet devised is symmetrical to the plane of the emulsion in that it contains a blank film base facing the emulsion and one sheet of aluminum foil on each side. The blank film base makes the dosimeter independent of effect of reversal of the badge, though not completely non-directional. The aluminum foil allows the manufacturer to use present packaging machinery with only minor adjustments, merely substituting the aluminum foil for the usual black paper. The resulting packet is energy independent within 10% up to 10 Mev. A measurement with a Po-Be source showed agreement between observed and calculated track counts within the probable error of the count. If higher-energy neutrons are to be monitored, additional shields and radiators may be incorporated in the badge.

A report on this project has been written and submitted to *Nucleonics* for publication.

### Energy Losses of Electrons in Foils

**Beta Spectrometer.** The large beta-ray spectrometer of the solenoidal type mentioned in earlier progress reports is practically complete and has

undergone preliminary tests. Correcting coils have been added, and the magnetic field has been measured and found to be uniform within 0.2%. The controls on the console have been completed and are operating dependably. These include a current regulator which maintains the current constant within 0.01% at any specified value and a ripple corrector which eliminates generator brush noise by feeding an equal but out-of-phase signal to a geometrically similar coil which is interwound with the main coil. An automatic sequencer has been installed which directs the spectrometer to scan any desired energy range and which prints the time required to accumulate a predetermined number of counts both on the spectrum under investigation and on the background. In addition, interlocks have been installed which shut down the instrument in case of vacuum, power, or water failure. The motor-generator has been enclosed in a sound-proof housing, and a fan has been installed to circulate outside air through this housing.

The slits have been constructed, installed, and aligned with the magnetic field by noting the performance of the instrument on *K* conversion lines appearing in the spectra of Sc<sup>46</sup> and Ag<sup>110</sup> (629 and 886 kev, respectively).

**Accelerator.** During this period the electrostatic analyzer was installed and is now operating. It was found necessary to add collimating slits in front of the analyzer to achieve the required resolution. The source of electrons originally was a tungsten filament, but this has now been discarded in favor of a commercial unit taken from a 5-in. cathode-ray tube.

A method of breaking the tube envelope and introducing the gun into the accelerator without destroying the activation of the cathode has been found. The new electron gun delivers high currents in a well-focused beam with narrow energy spread.

A technique of making thin Zapon films has been worked out. Films of about 10  $\mu\text{g}/\text{cm}^2$  are placed on an electromesh backing and have proved sufficiently sturdy to permit vacuum deposition of metallic layers of about the same thickness. A film holder and vacuum-lock arrangement allow easy introduction of the foils into the beam. The various meters in use in the instrument have been calibrated, and an energy calibration of the decelerating and deflecting system has been made.

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<sup>3</sup>*Ibid.*, p. 12.

Aluminum foils of about  $10 \mu\text{g}/\text{cm}^2$  have been placed in the beam of 45-kev electrons, and a peak in the energy-loss curve at  $15.65 \pm 0.05 \text{ ev}$  has been found. This agrees with the plasma oscillation theory of Pines and Bohm,<sup>4</sup> if the effective number of free electrons per atom in aluminum is taken as 2.93.

#### Film Dosimetry

Studies have been continued on the ORNL personnel monitoring and security badge in the hope of developing a technique for routine interpretation of the film blackening in terms of gamma-ray energy and exposure and beta-ray exposure. Sample badges were exposed to several more x- and gamma-ray energies in addition to those previously reported<sup>5</sup> and to combinations of various doses of uranium beta rays and different x- and gamma-ray doses and energies. Considerable analysis of the

data has produced a system which promises to permit satisfactory interpretation of a film badge exposed to a single moderately narrow range of x- or gamma-ray energies, with or without additional uranium beta-ray exposure. Exposures of the film to radiations of more than one energy are much more difficult to interpret correctly, and the problem is still under study.

A new type of film, Du Pont 555, was investigated. It has a much wider dose range than any one now in use, and, if it proves to be sufficiently stable, it might replace the three films currently used. Somewhat lower exposures can be read on this film, and the variation of its sensitivity with energy is about the same as that of other films studied.

<sup>4</sup>D. Pines and D. Bohm, *Phys. Rev.* 82, 625 (1951); 85, 338 (1952); 92, 609 (1953); 92, 626 (1953).

<sup>5</sup>H. H. Hubbell *et al.*, *op. cit.*, p. 13.

## AIRBORNE RADIOPARTICULATE CONTAMINATION

E. G. Struxness  
R. L. Bradshaw  
W. D. Cottrell

E. E. Grassel  
B. G. Saunders  
J. W. Thomas

### RADIOACTIVE-DUST STUDIES AND PROTECTIVE EQUIPMENT EVALUATION PROGRAM (PEEP)

#### Joint Chemical Corps-ORNL Program

This period marks the end of the cooperative support of the Protective Equipment Evaluation Program by the U.S. Army Chemical Corps. The program was initiated as a joint effort of the Chemical Corps and ORNL and was authorized on a one-year basis July 1, 1949. The objective of the program was to study the performance of protective equipment such as filtering devices, masks, clothes, etc., when used in the presence of radioactive gases and radioactive submicron particulates. Sponsorship of the program was withdrawn October 1, 1953 by the Chemical Corps, because of a sharp cut in budget. A substantial amount of money was turned over to the group for completion of current activities.

Work prior to January 1, 1952 has been summarized in Quarterly Progress Reports, Protective

Equipment Evaluation Program, Y-531, Y-532, Y-605, Y-638, Y-687, Y-724, Y-768, ORNL-1258, and ORNL-1352. Subsequent work has been summarized in Health Physics Division progress reports.

Tests have been made on the performance of gas-mask canisters with radioactive  $\text{SO}_2$  and of filter papers with radioactive methylene blue. This research resulted in three reports: Y-700, Y-685, and ORNL-1378. The major effort of this program, however, has been directed toward the development of instruments, since the instrumentation in this field is not adequate. The following nine reports of this endeavor were issued: Y-791, Y-793, ORNL-1413, ORNL-1648, ORNL-1655, ORNL-1656, ORNL-1657, ORNL-1660, ORNL-1666.

#### Study of Radioparticulate Contamination at X-10

During this period, the Health Physics Division, in cooperation with the Oak Ridge Office, AEC-U.S. Weather Bureau, continued a study of radioparticulate air contamination at X-10.

## HEALTH PHYSICS PROGRESS REPORT

A histogram (Fig. 12) shows the average number of particles per 1000 ft<sup>3</sup> collected weekly during the period from March 1949 through December 1953 by 10 continuous air monitors stationed throughout the Laboratory area.<sup>1</sup>

As a start in isolating a single source of radio-particulate contamination, a special isotope-recovery process was selected for study. A complete cycle of operation was monitored during the last reporting period, and another cycle was monitored during this reporting period.

Evaluation of the data showed that the major portion of the activity discharged through the stack appeared to be gaseous radioiodine. This gaseous activity masked the particulate activity and made it difficult, by radiochemical analysis or autoradiographic techniques, to identify the nature of the collected particulates. Only those samples containing particulates showed elements other than iodine.

Gaseous and particulate samples were collected simultaneously in the recovery process building and in the stack for a period of 30 hours. The con-

centration of particulates per unit volume of air inside the building was 3.2 times higher than the concentration of particulates per unit volume of stack effluent.

An underground tank that serves to store wastes from the special isotope-recovery process was monitored during the second cycle studied. This tank proved to be a profuse source of airborne contamination. Peaks of airborne activity occurred whenever wastes were jetted from the process building to the tank. Air was sampled 18 in. away from the vent in the top of the tank. The level of activity two days prior to the first jetting amounted to  $10^{-9}$   $\mu\text{c}/\text{cc}$ . The average activity for the period that covered the entire cycle of operation averaged  $2 \times 10^{-6}$   $\mu\text{c}/\text{cc}$ . The highest activity observed in a 24-hr period was  $2 \times 10^{-5}$   $\mu\text{c}/\text{cc}$ .

Peaks of activity at the tank vent were always accompanied by peaks of activity and particle count at the continuous air monitors located about the Laboratory area. The composition of the activity coming from the tank vent varied with the different stages of the process cycle. Radiochemical analyses showed considerable quantities of various isotopes. Because of a diffuse background, individual particulates could not be resolved for measurement of size when autoradiograms were made from the samples.

<sup>1</sup>The arrows on the histogram mark the periods when large chemical separation processes were known to be in operation in the Laboratory, and in most cases these periods were accompanied by peaks of radioparticulate activity in the area.

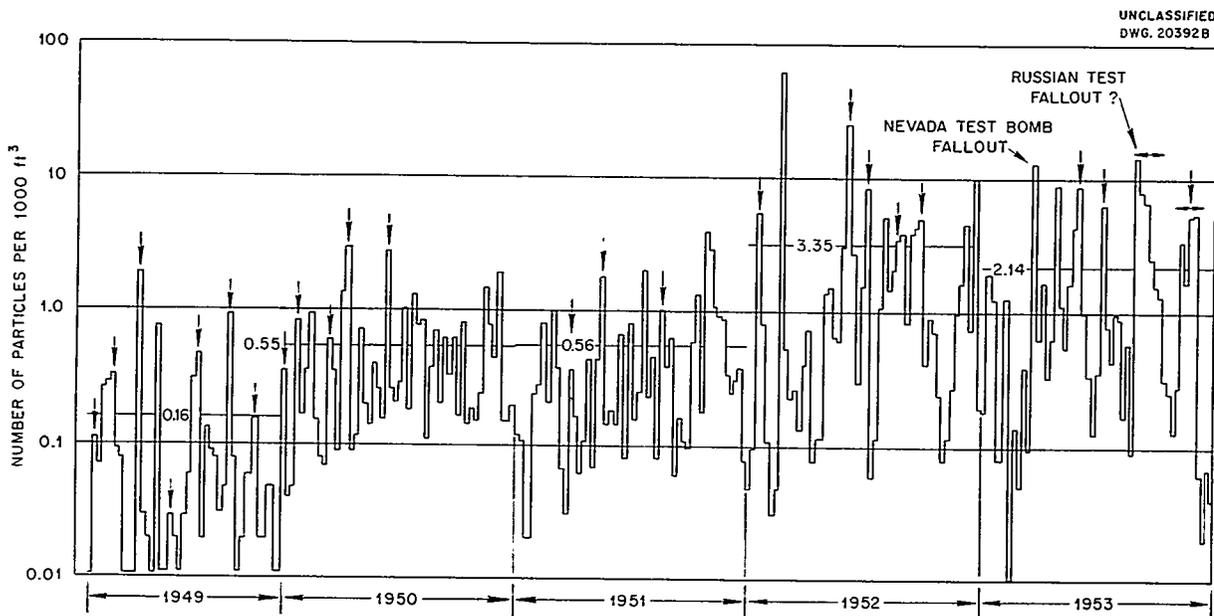


Fig. 12. Trend of Particle Concentration at ORNL from 1949 to 1953.

The concentration of particulates in the process building ranged from 0 to 2600 particles in each 1000 ft<sup>3</sup> of air, the average for one entire cycle amounting to 177 particles in 1000 ft<sup>3</sup>. Decay and

absorption studies of the samples collected in the process building indicated that a mixture of isotopes was present in the air.

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## RADIOACTIVE WASTE DISPOSAL RESEARCH

R. J. Morton

### WATER AND LIQUID-WASTE DECONTAMINATION PROCESSES

F. L. Cobler	D. A. Pecsok
J. M. Garner	O. R. Placak
H. L. Krieger	M. S. Seal
W. J. Lacy	C. P. Straub

#### Water Decontamination Studies

At the October meeting, the Technical Advisory Board for Research on the Decontamination of Radioactive Waters discussed topics pertinent to radioactive-waste problems and water decontamination and reviewed the "Interim Progress Report on the Decontamination of Radioactive H<sub>2</sub>O" compiled by the Radioactive Waste Disposal Research Section of ORNL. The following statements appear to represent the consensus of the Advisory Board as reported at the meeting:

1. The water-decontamination studies at ORNL have progressed in a satisfactory and integrated manner.
2. The military-equipment testing program has progressed to the point where future planning can be limited to the dissemination of operational information.
3. The decontamination research should continue on a selective basis to obtain data on those radioisotopes which are most hazardous and which will probably reach water courses in the most significant quantities.
4. The interim report, as revised and edited, should be prepared for broader distribution as an unclassified document through normal informational channels.

5. The proposed AEC waste-disposal policy, although applying specifically to AEC contractors, has wide implications. The utilization of the NCRP standards as a base is sound. However, coordination with public-health and stream-pollution agencies will be necessary to prevent inadvertent establishment of double standards for individual streams.

6. From a health-protection standpoint, the development of continuous water-monitoring devices can be given a low priority (in the ORNL joint program).

7. The work has progressed to a stage where consideration should be given to the dissolution of the Board as an active administrative group.

8. The creation of an appropriate program development and review group for research on disposal of waste from nuclear reactors warrants consideration.

#### Process-Waste-Treatment Experimental Plant

Three pilot-scale experimental waste-treatment units have been installed near the settling basin. Experimental studies will be made with these units in an effort to devise a method of treatment applicable to a full-scale installation for reducing the radioactivity in the discharge from the settling basin. A schematic flow diagram for the three units is shown in Fig. 13. Two of the units are approximately 7 ft in diameter and 5 ft in depth, and the third is 5 ft in diameter and approximately 3 ft in depth. They are comprised of a solids contact chamber, an up-flow type of sedimentation chamber, and a sludge-concentrator compartment, as typified by the conventional Accelerator unit shown in Fig.

## HEALTH PHYSICS PROGRESS REPORT

14. The SR (sludge recirculation) Accelerator is a new development that is better adapted to water-softening processes. The Erdlator, developed by the Corps of Engineers Research and Development Laboratories, will also be evaluated for treatment of the settling-basin waste. It is anticipated that operation of the experimental plant will be started during the week of February 1, 1954.

The general objectives of these experimental studies will be (1) to determine the efficiency of each of the three types of units in the removal of radioactive constituents from the wastes by water-treatment methods using various coagulating chemicals and various adsorbents, (2) to determine the volume of sludge produced and suitable methods for handling and disposing of this sludge, and

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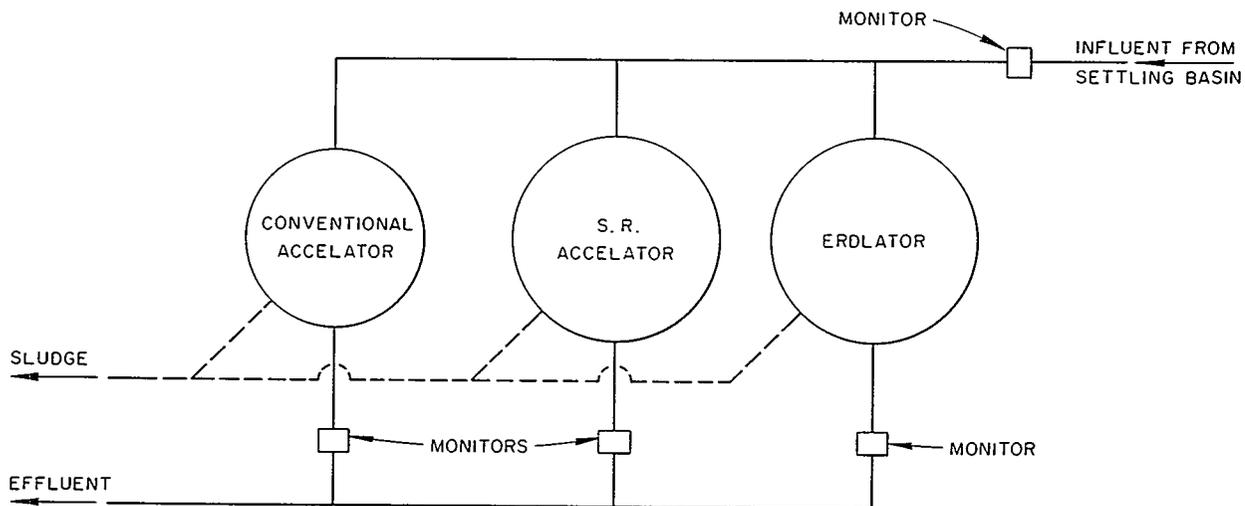


Fig. 13. Flow Diagram of Waste-Treatment Pilot Plant.

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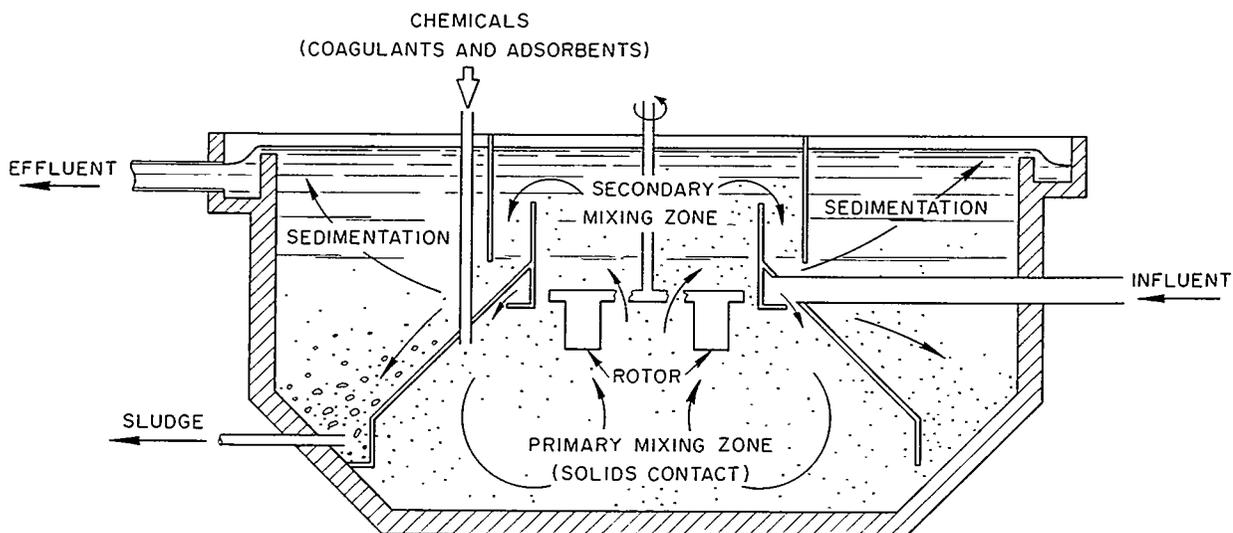


Fig. 14. Diagrammatic Cross Section of Accelerator.

(3) to determine whether radiological hazards are likely to develop due to external radiation in the vicinity of the sludge or the equipment.

A continuous monitoring system for the measurement of the levels of radioactivity in the influent and effluent of the treatment units has been designed and partially constructed. The system includes four detectors with their associated pre-amplifiers (one on the influent and one on each of the three effluent pipes), an automatic switching unit, and recording count-rate meters. Each of the detectors, which were developed especially for these experiments, consists of a Lucite cylinder approximately 3½ in. in diameter and 18 in. in length through which the influent and effluent liquids flow continuously. In each cylinder a thin-walled glass G-M counter tube is suspended concentrically and supported by a watertight compression seal at the top of the cylinder. The monitoring system will be calibrated by periodic sampling of the influent and effluent liquids.

**Surface Adsorption – A Mechanism in the Removal of Radioactive Materials from Aqueous Solutions by Clay Slurry**

It is well known that suspensions of clay materials are effective in removing many radioisotopes from solutions. If the process of removing radioactive materials from water by clay slurry is similar to true surface adsorption and follows a Freundlich-type reaction, then the log-log plot of the amount of adsorption per unit weight of adsorbent (clay) vs. the nonadsorbed portion (radioactivity) should be a straight line.

To investigate this phenomenon, a jar-test procedure was followed in which "spiked" distilled water and local montmorillonite clay were used. Samples were taken for counting, and a log-log plot of the results obtained are shown in Fig. 15. From these results it can be concluded that the process of surface adsorption appears to be the major mechanism involved in the removal of certain fission products from water by clay slurry.

If this same procedure is used, an approximate idea of the capacity of a unit quantity of clay at 0% salt concentration (distilled water) can be obtained. Extreme dilutions of clay material were necessary (10 to 20 ppm) in order to approach saturation of the clay surface. This limits the accuracy of the results. It was calculated from the test results that about 10 mc of mixed radio-

active fission products can be adsorbed on 1 g of montmorillonite clay from a distilled-water solution under the conditions of these tests.

**SURVEYS AND EVALUATIONS – FIELD AND LABORATORY**

- |                     |                               |
|---------------------|-------------------------------|
| T. W. Brockett, Jr. | R. J. Morton                  |
| M. J. Cook          | O. R. Placak                  |
| K. E. Cowser        | C. P. Straub                  |
| J. M. Garner        | H. J. Wyrick                  |
| B. Kahn             | R. M. Richardson <sup>1</sup> |

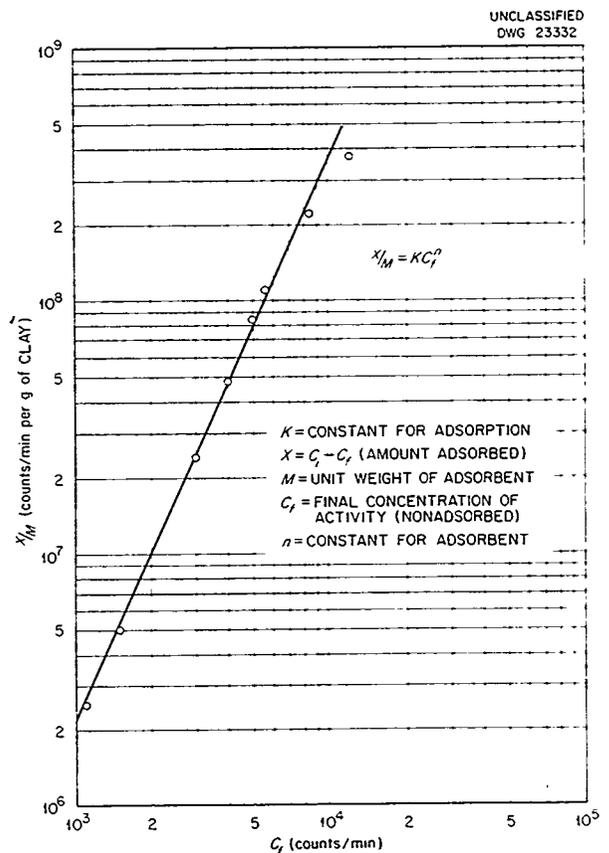
NOTE

**Continued Study of Waste-Storage Pit No. 2**

The construction and observation of waste-storage pit No. 2 have been summarized previously.<sup>2</sup> Up to January 1, 1954, a total of 278,000

<sup>1</sup>U.S. Geological Survey, part time.

<sup>2</sup>T. W. Brockett et al., *H-P Quar. Prog. Rep.* Oct. 20, 1952, ORNL-1420, p. 1.



**Fig. 15. Adsorption Isotherms for Montmorillonite Clay with 90 min Contact Time in a Mixed-Fission-Product Solution.**

## HEALTH PHYSICS PROGRESS REPORT

gal of liquid radioactive waste containing 8700 curies of activity had been transferred to the pit. Grab samples taken from the three wells adjacent to the pit and counted at approximately 10% geometry have shown a maximum activity of 72,700 counts/min/ml in well No. 52 and 15,400 counts/min/ml in well No. 54. Insofar as can be determined, well No. 53 has remained uncontaminated. Radiochemical analyses continue to indicate that the contamination reaching the wells from the pit is entirely Ru<sup>106</sup> and its daughter product Rh<sup>106</sup>. Liquid levels in the pit have a definite and moderately rapid influence on water levels in the two contaminated wells.

To obtain information relative to the amount, location, and entrance point of radioactive contamination with respect to these and other test wells, radiologging equipment was developed. Essentially, it consists of a thin-walled G-M tube and preamplifier encased in a suitable water-tight housing, connected to a count-rate meter and Esterline-Angus recorder. The probe is lowered in the well at a rate of  $\frac{1}{2}$  ft/min by means of a motor-driven cable reel which may be set to cut off at any desired depth. Figure 16 shows the continuous type of radiolog that is obtained. Calibration of the probe by means of analyzed water samples collected from specific depths will allow use of the radiolog charts to determine the total radioactivity in the well, if it can be assumed that most of the radioactive contaminant is contained in the water rather than the walls of the well at the points of measurement.

Definition of the underground pollution stream originating at the pit will necessitate additional test wells. To facilitate the installation of these wells, special equipment has been made available by the U.S. Geological Survey.

Additional work proposed in connection with the pit study includes the following:

1. electric logging of wells Nos. 52, 53, and 54,
2. radiologging of existing and future wells,
3. controlled sampling of the wells,
4. drilling of additional wells in areas adjacent to the pit,
5. permeability studies of prospective pit sites,
6. a controlled study of a pit of pilot-plant dimensions.

<sup>3</sup>J. M. Garner *et al.*, *H-P Semiann. Prog. Rep. July 31, 1953*, ORNL-1596, p. 28.

### Radioactivity in River-Bottom Sediments

A limited resurvey of radioactivity in bottom sediments in the Clinch River from White Wing Bridge to the mouth of the River and in the Tennessee River downstream to Chattanooga was made during the summer of 1953. The detector (Flounder) used in the surveys<sup>3</sup> of 1951 and 1952 was used in this resurvey. The weighted averages of the readings at various cross sections of the river are plotted in Fig. 17, in order to compare the results of the three surveys (1951, 1952, and 1953).

As shown in Fig. 17, the levels of activity observed in sediments in the Clinch River were lower than those found in 1952 but higher than in 1951. In the Tennessee River the 1953 levels were essentially the same as in 1952. Definitive data relative to the conditions of river flow and to the quantities and half lives of radioactive materials discharged during 1953 are insufficient to afford an explanation of the observed decrease in the levels of activity found in the Clinch River sediments for this one year.

Five mud samples from bottom deposits, two from Clinch River, two from Watts Bar Reservoir, and one from Chickamauga Reservoir, were collected to supplement the data from mud samples taken during the 1952 survey. The purpose of the work with mud samples was to develop methods of analysis, to identify and determine the amounts of fission products present, and to obtain information concerning the radioactivity in bottom sediments that originated from natural sources. Measurable amounts of fission products were found in the mud from Clinch River and in Watts Bar Reservoir below the mouth of the Clinch River. The techniques and results of mud analyses are summarized in the following section.

### INSTRUMENTATION AND TECHNIQUES

J. M. Garner                      B. Kahn

#### Determination of Radioactive Nuclides in River-Bottom Sediments

A method is being developed to determine the amount of radioactive nuclides adsorbed by muds of the Clinch and Tennessee Rivers. Such techniques of analysis are also needed in studies of the movement of radioisotopes through soils, for example, in the vicinity of waste-storage pits. The radioactive nuclides present in the river muds are believed to be some of the major long-lived

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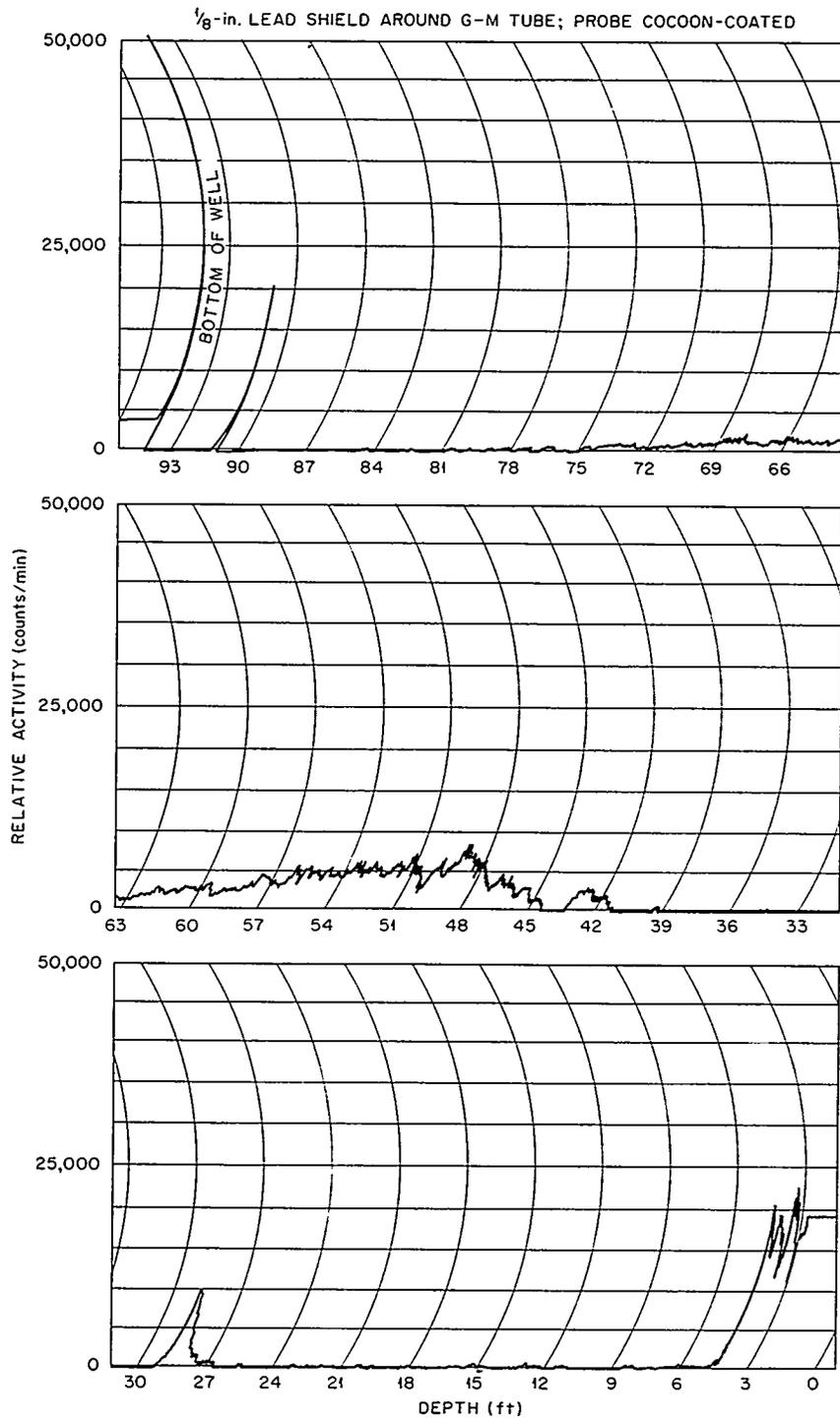


Fig. 16. Radiolog Obtained in Well No. 52 on January 13, 1953.

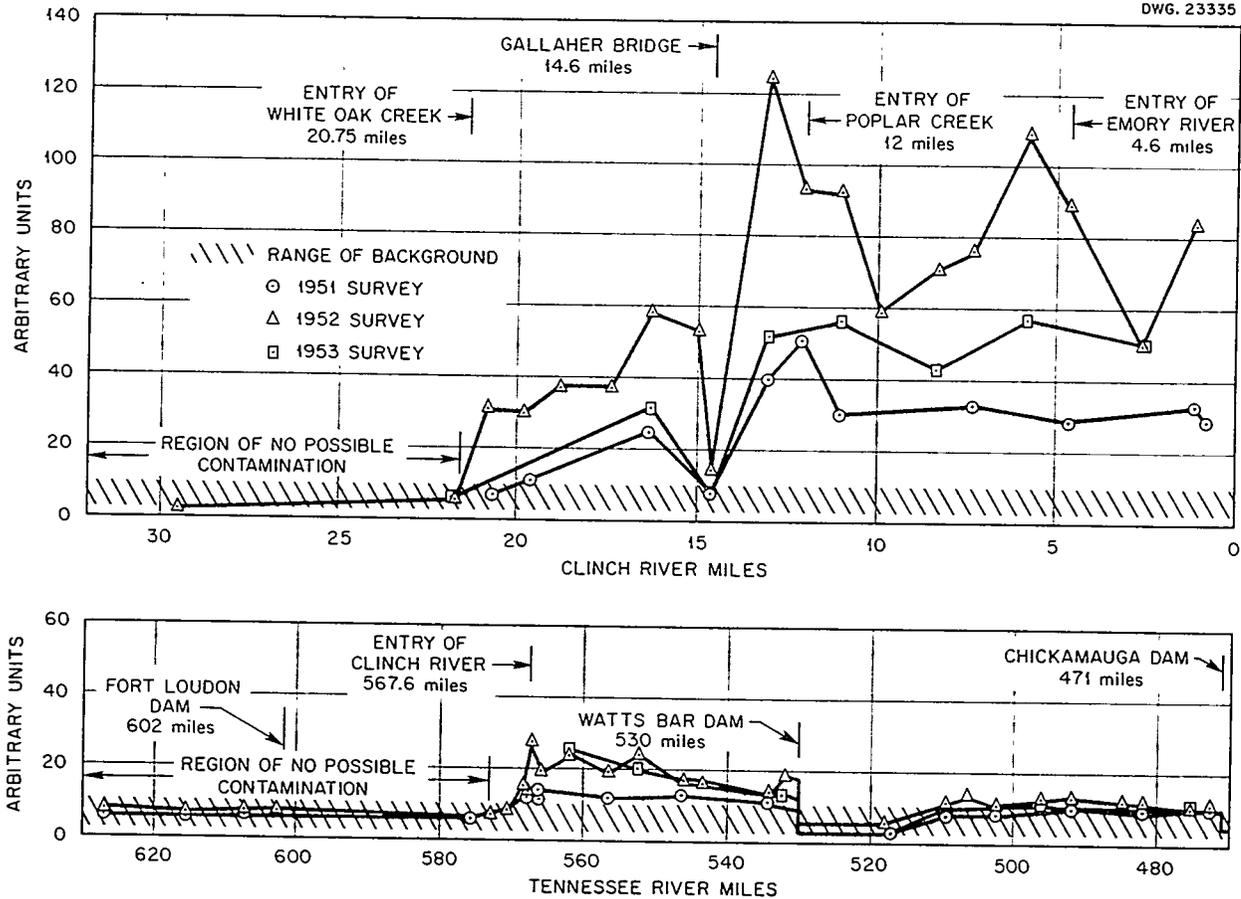


Fig. 17. Weighted Average Concentration of Radioactivity in River Sediments.

fission products -  $Sr^{89}$ ,  $Sr-Y^{90}$ ,  $Y^{91}$ ,  $Zr-Nb^{95}$ ,  $Cs-Ba^{137}$ ,  $Ce-Pr^{144}$ , and  $Pm^{147}$ . The procedure consists in leaching the mud, followed by chemical separation of the radionuclides.

The radionuclides, together with large amounts of solids, are leached from the mud by refluxing with a total of 3 ml of aqua regia per gram of moist mud for three consecutive 12-hr periods. Tracer studies of the efficacy of leaching were made by adsorbing about  $1.0 \mu c$  of each of the radionuclides listed in Table 5 on 15-g samples of Tennessee River mud (containing almost no radioactivity) in a slightly basic solution, washing the mud with tap water, and then leaching as just described. The efficacy of removal of radionuclides from mud is shown in Table 5.

In order to determine the amount of natural radioactivity which may be ascribed to radium at various

points in the Tennessee River, samples from Duck River and from Wilson Dam were analyzed for radon (Rn) by A. Gabrysh of the Experimental Radiation Measurements Section, Health Physics Division. The results, listed in Table 6, indicate no unusual radon activity in the analyzed samples.

#### Compilation of Radiochemical Methods

Abstracts of unclassified methods for the chemical separation of radionuclides have been compiled.<sup>4</sup> The collection consists of approximately 275 methods for the separation of 85 nuclides. Each abstract contains a summary of the procedure and the associated time, yield, and decontamination factor (when these are reported), as well

<sup>4</sup>B. Kahn, *Separation of Radionuclides—Abstracts of Unclassified Methods*, unpublished.

as references to the original papers. The compilation has been distributed to persons who are developing and using radiochemical methods, in order to obtain their criticisms, corrections, and suggestions for changes and additions. It is

planned to revise and bring the abstracts up to date according to the suggestions received.

Portable Well-Logging Instrument for Beta Measurements

A portable instrument has been designed and constructed for the detection and measurement of radioactivity, particularly beta activity, in the earth walls above water level and in the water of test wells. This instrument was devised for convenient use in the radiologging of multiple test wells to be drilled in order to determine the underground travel of radioactive contaminants from the two existing ORNL chemical waste pits and from future experimental waste-pit installations. The detector is a commercially available 30- to 35-mg/cm<sup>2</sup> stainless-steel-walled G-M tube. The G-M tube is attached by means of a watertight plug-in connector to the preamplifier housing to which, in turn, is attached 53 ft of five-conductor, shielded rubber-covered cable. This cable leads to a battery power supply and to a modified portable survey meter.

A portable well-logging instrument is essential for use in relatively inaccessible locations. Advantages of the present design are its beta sensitivity, the ease of replacing the G-M tube, the ease of changing types of detectors so as to cover a wide range of activity levels in the test wells, and the ability to protect the detector against contamination by covering it with a watertight disposable thin rubber sheath. One limitation of the present design is that the detector will not withstand water pressures caused by submergence to depths greater than 17 feet.

TABLE 5. LEACHING OF RADIONUCLIDES FROM TENNESSEE RIVER MUD

RADIONUCLIDE	PER CENT REMOVED BY LEACHING
Sr <sup>90</sup>	98
Y <sup>90</sup>	98
Zr <sup>95</sup>	76
Nb <sup>95</sup>	65
Ru <sup>106</sup>	96
Cs <sup>137</sup>	98

TABLE 6. SAMPLES ANALYZED FOR RADON ACTIVITY

SAMPLE	ACTIVITY
Duck River (water)	$0.56 \times 10^{-12}$ curie/liter
Duck River (solids in 1 liter of water)	$2.0 \times 10^{-12}$ curie/g
Wilson Dam (water)	$1.12 \times 10^{-12}$ curie/liter
Wilson Dam (solids in 1 liter of water)	$5.4 \times 10^{-12}$ curie/g

**HEALTH PHYSICS PROGRESS REPORT**

**ECOLOGICAL STUDY<sup>1</sup>**

L. A. Krumholz  
W. T. Helm

W. T. Miller  
E. R. Eastwood

Virtually the entire period has been spent in the preparation of the final report on the findings of the survey, and that report is nearly complete.

The extent to which migratory water fowl are using White Oak Lake as a resting and feeding area is still under study; thus the program for banding and releasing migratory waterfowl at the lake has been continued. Banding was begun in September 1953 in order to capture the resident and early migrant wood ducks. From that time through January 31, 1954, a total of 4881 waterfowl were caught in the eight traps designed for that

purpose. Of those, 1108 new individuals were banded; the remainder had been previously banded, either by this group or by others, and were recaptures.

The numbers of birds of each species that were banded or recaptured are listed in Table 7.

Of the waterfowl banded at White Oak Lake during the 1952-1953 season, a total of 30 individuals, which represents 5% of those banded, were recaptured at the same location during the current season, as follows: 16 mallards, 8 black ducks, 5 wood ducks, and 1 coot. Also, three birds banded at other stations, as yet unknown to us, were caught at White Oak Lake.

<sup>1</sup>In cooperation with the Tennessee Valley Authority.

**TABLE 7. BIRDS BANDED OR RECAPTURED FROM SEPTEMBER 1953 TO JANUARY 31, 1954**

	MALLARD	BLACK DUCK	WOOD DUCK	BALD-PATE	PIN-TAIL	GREEN-WINGED TEAL	GAD-WALL	COOT	TOTAL
Banded	800	118	142	10	4	8	1	25	1108
Recaptured	2787	637	255	28	28	8	0	30	3773
Total	3587	755	397	38	32	16	1	55	4881

## EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson  
M. F. Fair

M. R. Ford  
T. H. J. Burnett

K. Z. Morgan

## AEC FELLOWSHIP PROGRAM

The 1953-1954 group of 22 AEC Fellows in Radiological Physics, which reported to Vanderbilt University on September 28, completed the first quarter of the academic work with very creditable grade records. The 1952-1953 group completed their training in applied health physics at the Laboratory on August 29. Of this group, three fellows were granted extensions of their fellowships to complete work for the master's degree and chose research problems in the Health Physics Division. They have completed the experimental work and have accepted employment.

## OTHER TRAINING PROGRAMS

Two members of the Education, Training, and Consultation Section gave a three-week course in health physics in the Reactor School. In January, a 2 hr per week course in nuclear physics was started for members of the Applied Health Physics Section who have come to the Laboratory recently. The course will continue for approximately six months.

Lt. Elwood Lloyd, Army Chemical Center, Fort McClellan, Alabama, spent the month of January in training in the applied Health Physics Division.

## LECTURES

Lectures on radiation hazards and current practices in radiation protection were given at Virginia Polytechnic Institute and the University of Mississippi in conjunction with the ORINS-ORNL Travel-

ing Lecture Program, and two lectures on radiation protection were given at the Medical Military Symposium of the U.S. Navy Medical School. Seminars given during the reported period consisted of one on health physics for R. T. Overman's radioisotopes course at ORINS, one on radiological safety to the ORINS advanced medical course, one on nuclear physics and one on radiation protection of the Fifth Annual Nuclear Science Seminar of the Naval Research Reserve Group.

## CONSULTATION

The relative toxicity of  $U^{233}$  was investigated to determine the extent to which the hazards associated with handling  $U^{233}$  would influence the costs of manufacturing fuel elements. Chiefly because of its greater specific activity and also because of differences in energies, the hazard in the processing of  $U^{233}$  would be 133 times that of  $U^{235}$  for the same loss in mass. However, preliminary tests indicate that the additional precautions required for  $U^{233}$  will lead to only a 20% increase in costs. In the course of this study<sup>1</sup> the effective energy (that is, the sum of the energies of the radiations of the parent and the daughters weighted for their relative biological effectiveness, normalized to the RBE of alphas) of radium, used as a reference for biological damage value, was recalculated and found to be 16.18 effective Mev.

<sup>1</sup>T. H. J. Burnett, ORNL CF-53-9-77 (Sept. 16, 1953).

## HEALTH PHYSICS PROGRESS REPORT

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- H. H. Abee, *Radioactivity in the Mud of White Oak Lake*, ORNL-1580 (Oct. 26, 1953).
- E. E. Anderson, "Education and Training of Health Physicists," *Radiology* **62**, 83 (1954).
- R. L. Bradshaw, *A Servomechanism for Measuring Aerosol Size and a Servomechanism for Controlling Particle Size in the Dioctyl Phthalate Aerosol Generator*, ORNL-1660 (Jan. 18, 1954).
- T. H. J. Burnett, *Reference Weighted Energy for Radium<sup>226</sup>*, ORNL CF-53-9-77 (Sept. 16, 1953).
- W. D. Cottrell, *Solid Aerosol Generation*, ORNL-1666 (Jan. 20, 1954).
- G. S. Hurst and R. H. Ritchie, "On Energy Resolution with Proportional Counters," *Rev. Sci. Instr.* **24**, 664-668 (1953).
- G. S. Hurst, J. A. Harter, P. N. Hensley, W. A. Mills, and R. H. Ritchie, ORNL-1671 (classified), to be published.
- B. Kahn and W. S. Lyon, "Decay of  $K^{42}$ ," *Phys. Rev.* **91**, 1212-1213 (1953).
- B. Kahn and W. S. Lyon, "Decay of  $Rh^{106}$ ," *Phys. Rev.* **92**, 902-903 (1953).
- B. Kahn and W. S. Lyon, "Use of a Scintillation Spectrometer in Radiochemical Analysis," *Nucleonics* **11**, No. 11, 61 (1953).
- F. Kalil and R. D. Birkhoff, "Straggling Contributions for Electrons in Passing Through Thin Foils," *Phys. Rev.* **91**, 505 (1953).
- L. A. Krumholz and A. H. Emmons, "Preparation of Fish Tissues for Gross Beta Radioassay," *Jour. Wildl. Mgt.* **17**, 456-460 (1953).
- W. J. Lacy, "Removing Radioactive Materials from Water by Coagulation," *Water & Sewage Works* **100**, 410 (1953).
- K. Z. Morgan, "Nuclear Reactors for Industry and Research. Part IV, Radiation Protection," *Instruments and Automation* **26**, No. 12, 1873 (1953).
- J. Neufeld and W. S. Snyder, *Track Width of Heavy Charged Particles*, ORNL-1594 (August 1954).
- B. G. Saunders, *Rotating Prism for Use with Cloud Chambers*, ORNL-1657 (Jan. 27, 1954).
- B. G. Saunders, *Electrostatic Precipitator for Measuring Particle-Size Distribution in Aerosol*, ORNL-1656 (Jan. 19, 1954).
- B. G. Saunders, *Cloud Chamber for Measuring the Particle Density of an Aerosol*, ORNL-1655 (Feb. 4, 1954).
- J. W. Thomas, *The Diffusion Battery Method for Aerosol Particle Size Determination*, ORNL-1648 (Dec. 14, 1953).

---

### PAPERS

- T. E. Bortner, *Range of  $P^{32}$  Betas in Different Atomic Number Absorbers*, Tennessee Academy of Science, Nov. 27, 1953, Oak Ridge, Tenn.
- G. S. Hurst, *Fast Neutron Dosimeters, Care and Breeding Of*, Shielding Meeting, Argonne National Laboratory, Nov. 12, 1953.
- W. S. Snyder, *On the Solution of Integral Equations*, American Mathematical Society, Aug. 31 to Sept. 4, 1953, Kingston, Ontario, Canada.
- I. H. Tipton, *Results of Spectrographic Analysis of Tissues of 40 Individuals*, Tennessee Academy of Science, Nov. 27, 1953, Oak Ridge, Tenn.
- B. Kahn and W. S. Lyon, *Gamma Ray Spectroscopy in Analytical Radiochemistry*, Southwest Region Meeting of American Chemical Society, Dec. 10 to 12, 1953.

LECTURES

E. E. Anderson, *Radiation Protection*, Sigma Delta Epsilon Honorary Women's Science Research Fraternity, Madison, Wis., Sept. 8, 1953.

E. E. Anderson, *Nuclear Physics Review*, 5th Annual Nuclear Sciences Seminar, Naval Research Reserve, Oak Ridge, Tenn., Dec. 2, 1953.

E. E. Anderson, *Radiological Safety*, Advanced Medical Course, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn., Sept. 25, 1953.

E. E. Anderson, *Radiation Hazards and Current Practices in Radiation Protection*, Virginia Polytechnic Institute, Blacksburg, Va., Jan. 25, 1954.

E. E. Anderson, *Radiation Hazards and Current Practices in Radiation Protection*, University of Mississippi, Oxford, Miss., Jan. 12, 1954.

K. Z. Morgan, *The Control of Radiation by the Health Physicist*, Naval Medical School, Bethesda, Md., Oct. 23, 1953.

K. Z. Morgan, *The Control of Radiation by the Health Physicist*, Nuclear Sciences Seminar, Oak Ridge, Tenn., Dec. 10, 1953.

D. A. Pecsok, *AEC Production Facilities - Effects on Watercourses; Water Decontamination; Water Monitoring*, Waterworks Training Course,

Environmental Health Center, Cincinnati, Ohio, Nov. 9 to 14, 1953.

B. G. Saunders and W. D. Cottrell, *The Spinning Top*, 8th Tripartite Meeting, Army Chemical Center, Edgewood, Md., Sept. 28, 1953.

B. G. Saunders, *The Continuous Action Cloud Chamber*, 8th Tripartite Meeting, Army Chemical Center, Edgewood, Md., Sept. 28, 1953.

E. G. Struxness, *Millipore Filter Sampling and Radioautography in the Study of Airborne Radio-particulates*, Air Cleaning Symposium at Los Alamos, N.M., September 1953.

J. W. Thomas, *Effectiveness of Air Filters for Containment of Radioactivity Following an Incident*, Tripartite Reactor Safety Conference, Chalk River, Canada, Oct. 12 to 14, 1953.

J. W. Thomas and E. E. Grassel, *Development of a La-Mer Type Aerosol Generator*, 8th Tripartite Meeting, Army Chemical Center, Edgewood, Md., Sept. 28, 1953.

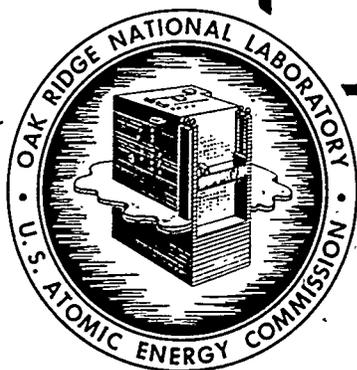
J. W. Thomas, *The Diffusion Battery*, 8th Tripartite Meeting, Army Chemical Center, Edgewood, Md., Sept. 28, 1953.

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FOR PERIOD ENDING JULY 31, 1954



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## CONTENTS

THEORETICAL PHYSICS .....	1
Passage of Charged Particles Through Plasma .....	1
Effect of Medium Density on Stopping of Moving Ions .....	1
PHYSICS OF NUCLEAR RADIATION .....	2
Applied Dosimetry .....	2
Electron-Drift Velocities .....	2
RADIATION MEASUREMENTS .....	4
RADIATION DOSE .....	4
Internal Dose .....	4
Spectrographic analysis of human tissue .....	4
Maximum-permissible-concentration experiments on mice .....	5
Radiochemical analysis .....	5
External Dose .....	6
Resonance-frequency variation of piezoelectric crystals .....	6
Measurement of ionizing radiation by high-frequency variation .....	6
Film dosimetry for fast neutrons .....	6
Energy losses of electrons in foils .....	6
Ion-recombination errors in pocket chambers .....	7
Film dosimetry .....	7
AIRBORNE RADIOPARTICULATE CONTAMINATION .....	8
Study of Radioparticulate Contamination at X-10 .....	8
Air Pollution Caused by Ground Disposal .....	8
Sand Entrainment Separators .....	8
RADIOACTIVE WASTE DISPOSAL .....	11
Liquid-Waste-Decontamination Processes .....	11
Flotation .....	11
Process-waste-treatment experimental plant studies .....	13
Chemical laboratory studies with reactor-waste solutions .....	13
Surveys and Evaluations – Field and Laboratory .....	14
Waste pit studies .....	14
Field explorations .....	16
EDUCATION, TRAINING, AND CONSULTATION .....	16
AEC Fellowship Program .....	16
Other Training Programs .....	16
PUBLICATIONS .....	17
PAPERS .....	18
LECTURES .....	19

# HEALTH PHYSICS DIVISION SEMIANNUAL PROGRESS REPORT

## THEORETICAL PHYSICS

J. Neufeld  
W. S. Snyder R. H. Ritchie

### PASSAGE OF CHARGED PARTICLES THROUGH PLASMA

When plasma problems are dealt with, the customary approach involving interactions of individual electrons can be replaced by a phenomenological approach in which the plasma is treated as a homogeneous dispersive medium. In conventional dispersive media the dielectric constant is an operator which operates on the time variable. In plasma, however, the dielectric constant is characterized by essentially different properties, since it operates not only on the time variable but also on the space variable. The representation of plasma as a dispersive medium is subject to certain validity criteria, which are satisfied for such typical cases as the ionosphere and electrical discharge through gases but are not satisfied for electrons in the conduction band of a metal. The passage of charged particles through plasma is investigated by means of straightforward application of Maxwell's equations for a dispersive medium. The Debye screening, which is applicable to the potential of an incident particle having velocity  $V \ll \langle v^2 \rangle^{1/2}$  (where  $\langle v^2 \rangle^{1/2}$  is the root-mean-square velocity of plasma electrons), loses its significance when  $V \gg \langle v^2 \rangle^{1/2}$ , and in the latter case the potential decreases with the distance in accordance with an inverse cube law. The stopping power has been calculated for incident charged particles having  $V \ll \langle v^2 \rangle^{1/2}$  and  $V \gg \langle v^2 \rangle^{1/2}$  in a plasma comprising electrons distributed in accordance with Maxwell-Boltzmann and Fermi-Dirac statistics.

### EFFECT OF MEDIUM DENSITY ON STOPPING OF MOVING IONS

Early experiments performed by Michl<sup>1</sup> and Philipp<sup>2</sup> and confirmed more recently by Appleyard<sup>3</sup> have established that water in the liquid state has

<sup>1</sup>W. Michl, *Sitzber. Akad. Wiss. Wien, Math. naturw. Kl.* 123, 1965 (1914).

<sup>2</sup>K. Philipp, *Z. Physik* 17, 23 (1923).

<sup>3</sup>R. K. Appleyard, *Proc. Cambridge Phil. Soc.* 47, 443 (1950).

a stopping power for alpha particles higher by 10 to 20% than that of water vapor. Consequently, the Bragg rule which claims additivity of atomic stopping power for all media is questioned. Several experiments have shown an anomaly in the stopping power which, for incident heavy particles, appears to be greater in condensed media than in gases. It is suggested that this anomaly is characteristic of incident ions, i.e., of particles that are not completely stripped of orbital electrons, and seems to be due to the reaction of the perturbed medium upon the moving ion having charge  $Ze$  resulting in a field  $F = (1/Ze)(dW/dz)$  acting against the motion of the ion ( $dW/dz$  is the energy loss per centimeter). Although  $F$  is relatively weak in gases, it is substantial in condensed media and may cause the spontaneous emission of electrons carried by the ion (autoionization), thus increasing the effective charge of the ion. The higher effective charge accounts for the higher stopping power in condensed media. When an incident helium atom passing through a liquid undergoes a collision and thus emerges in a singly ionized and excited state, it has been determined that it cannot exist in such a state since it becomes instantly doubly ionized. However, the same type of collision occurring in a gas leaves the atom singly ionized. The effective charge of the incident particle depends upon the values  $\phi_0$ ,  $\phi_1$ , and  $\phi_2$ , which represent the probability of the particle being neutral, singly ionized, and doubly ionized, respectively, where  $\phi_0 : \phi_1 : \phi_2 = \sigma_{10} : \sigma_{21} : \sigma_{01} : \sigma_{21} : \sigma_{01} : \sigma_{12}$  ( $\sigma_{if}$  represents the cross section for electron loss or capture;  $i$  and  $f$  represent the charge before and after the event, respectively). It has been shown that  $\phi_{if}$  is higher for a condensed medium than for a gas if  $i < f$  and lower if  $i > f$ .  $\sigma_{if}$  has been calculated for helium passing through argon gas at 400 keV, which gives, roughly,  $\phi_0 : \phi_1 : \phi_2 = 0.05 : 0.75 : 0.20$ ; the average square charge is thus  $\bar{\epsilon}^2 = 1.55e^2$ . When autoionization is taken into account,  $\sigma_{if}$  for helium in liquid argon gives, roughly,  $\phi_0 : \phi_1 : \phi_2 = 0.04 : 0.70 : 0.26$ , and thus  $\bar{\epsilon}^2 = 1.74e^2$ .

## PHYSICS OF NUCLEAR RADIATION

G. S. Hurst  
T. E. Bortner  
M. Slater

W. G. Stone  
W. A. Mills

## APPLIED DOSIMETRY

After additional investigations with the standard fast-neutron tissue dosimeter,<sup>1</sup> the gas amplification of the dosimeter was decreased from 150 to 25, which improved the resolution of the internal alpha source used for calibrating the dosimeter.

Figure 1 is a graph of the curves of integral count rate vs pulse height for the alpha source for the two amplification values: 150 for curve A and 25 for curve B. By differentiating curve B, the resulting width at half-maximum pulse height gives a resolution of 7%. The previous resolution was 20%. The operating conditions for curves A and B of Fig. 1 are listed in Table 1.

By using the standard fast-neutron dosimeter with the improvement in resolution, a polonium-beryllium (Po-Be) neutron source was calibrated in terms of rep per neutron per square centimeter. The measured value was  $4.65 \times 10^{-9}$  rep/neutron/cm<sup>2</sup> and agreed with the value of  $4.71 \times 10^{-9}$  rep/neutron/cm<sup>2</sup> calculated by using the Po-Be neutron spectrum as reported by Elliot *et al.*,<sup>2</sup> weighted against first-collision dose calculations.

<sup>1</sup>G. S. Hurst, *Brit. J. Radiol.* 27, No. 318, 353-357 (1954).

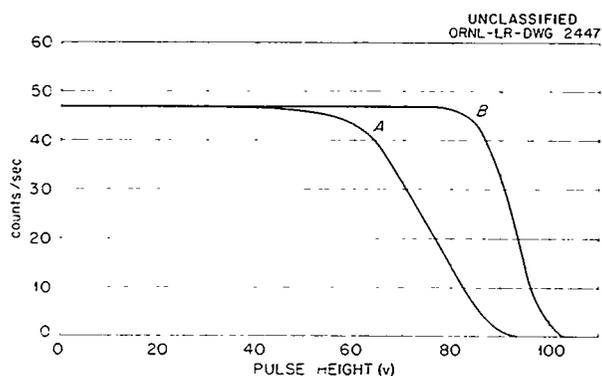


Fig. 1. Count Rate vs Pulse Height for Alpha Source for Two Amplification Values.

The value previously measured<sup>1</sup> for a Po-Be source was  $4.45 \times 10^{-9}$  rep/neutron/cm<sup>2</sup>.

A proportional counter suitable for use as a neutron dosimeter around cyclotrons has been developed. This counter is similar to the ethylene-polyethylene counter reported by Hurst.<sup>1</sup> However, the intensity of the neutron emission and the magnetic field present in a cyclotron necessitated certain changes in design. By decreasing the sensitive volume of the counter, the dosimeter has a sensitivity of  $2 \times 10^{-5}$  rep/count at the lowest integral pulse height, i.e., at the pulse height of maximum count rate. In addition, the magnetic field required that the stainless steel collecting wire be replaced by a platinum wire. The very successful design was achieved through the cooperation of R. K. Abele and E. Plasterer of the Instrumentation and Controls Division.

## ELECTRON-DRIFT VELOCITIES

The drift velocities of electrons in a few gases and in mixtures of gases have been obtained by using the method described previously. Drift velocities (cm/ $\mu$ sec) of electrons in argon and nitrogen as a function of  $E/P$  (v/cm/mm Hg) are shown in Fig. 2, and the velocities in mixtures of argon and methane are shown in Figs. 3 through 5.

<sup>2</sup>J. O. Elliot, W. I. McGarry, and W. R. Faust, *Phys. Rev.* 93, 1348-1349 (1954).

TABLE 1. OPERATING CONDITIONS FOR AMPLIFICATION VALUES SHOWN GRAPHICALLY IN FIG. 1

Curve	Preamplifier Gain	Linear-Amplifier Gain	Operating Voltage (v)
A	> 1	$32 \times 1$	3400
B	30	$8 \times 1$	2900

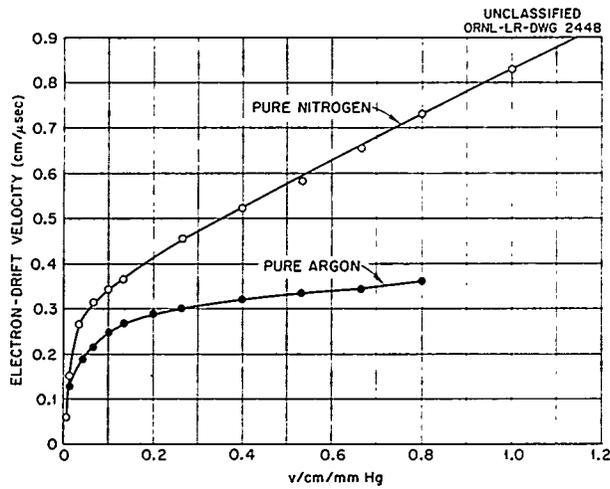


Fig. 2. Electron-Drift Velocity in Pure Nitrogen and Pure Argon.

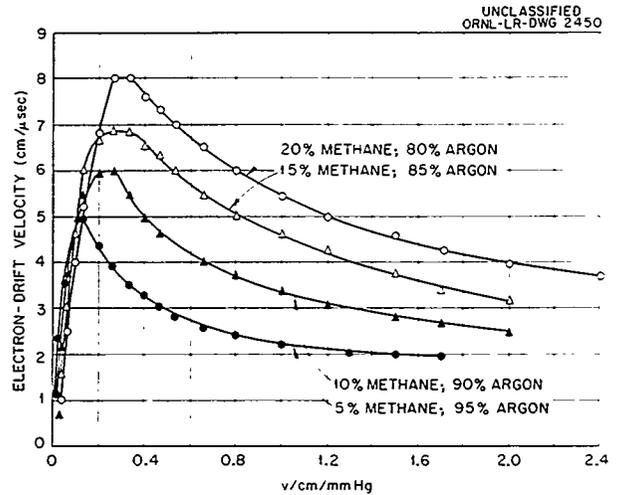


Fig. 4. Electron-Drift Velocity in Mixtures of Argon and Methane.

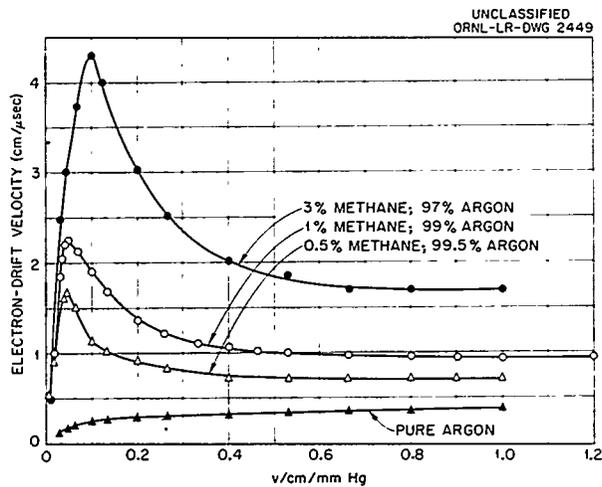


Fig. 3. Electron-Drift Velocity in Pure Argon and Mixtures of Argon and Methane.

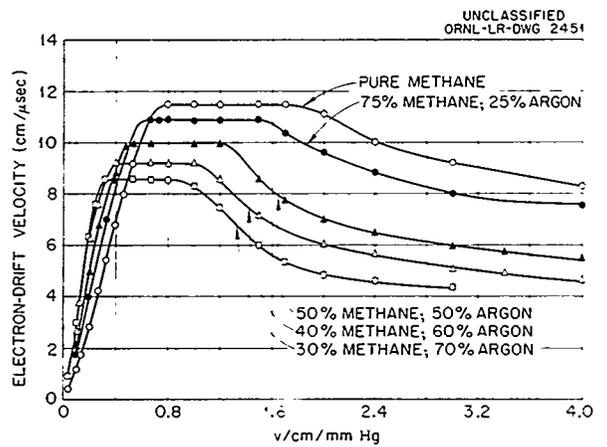


Fig. 5. Electron-Drift Velocity in Pure Methane and Mixtures of Argon and Methane.

## RADIATION MEASUREMENTS

F. J. Davis      P. W. Reinhardt  
 J. A. Harter

The small-aircraft scintillation equipment was supported in the crew compartment of the Tower Shielding Facility (TSF). Measurements were made at heights from 25 to 200 ft above the ground in order to determine the scattering and absorption in air of the gamma rays from Au<sup>198</sup> and radium. These data, now being analyzed, supplement measurements taken previously at higher levels by using aircraft.

In the joint program with the U.S. Geological Survey, aerial surveys for uranium prospecting were conducted in the vicinity of Cedar City, Utah. The efficiency of the survey was hampered by contamination, presumably the fall-out from the bomb tests in the Pacific. Survey flights in the vicinity of the TSF are planned for the near future.

Difficulty arises in the use of the scintillation counter equipment for measuring the spectral distribution of gamma rays of Co<sup>60</sup> scattered from concrete, since the NaI crystal and photomultiplier combination are exposed to variable outdoor temperatures. Thus a temperature-compensating control has been incorporated in the apparatus. A separate rate meter is introduced, and its discriminator is set at a voltage corresponding to a point on the steepest portion of the pulse-height distribution curve for the 1.33-Mev cobalt gamma. Through the use of a servomechanism, the output of this rate meter controls the high voltage (i.e., gain) in the photomultiplier tube so that the count rate remains constant during temperature changes.

## RADIATION DOSE

H. H. Hubbell

R. D. Birkhoff	L. B. Farabee
A. W. Blackstock	E. D. Gupton
J. L. Blankenship	G. R. Harrison
J. S. Cheka	H. K. Richards
M. J. Cook	I. H. Tipton

## INTERNAL DOSE

Spectrographic Analysis of Human Tissue<sup>1</sup>

During the six months from January 20 to July 20, 1954, the spectrographic laboratory for analysis of trace elements in human tissue has analyzed 326 samples of dry-ashed tissue from persons who were victims of an instantaneous accidental death. During this time considerable refinement of the spectrographic method has been achieved. As reported previously, the cathode layer of the d-c arc is used as the analytic source; however, the size of the sample burned has been increased to 4 mg. The method has been made more quantitative by the use of internal standards.

Since the concentrations of a large number of elements are desired simultaneously and since these elements have widely varying volatilization characteristics, two internal standards are employed, one for those elements which volatilize and burn out in the first 15 sec and one for those elements which volatilize at a slower rate. The separation of the two groups of elements is accomplished by the use of a modified Hartman diaphragm with two overlapping steps. Fifteen seconds after the arc is struck, the slide is shifted so that a 15- and a 130-sec exposure of the same sample are juxtaposed on the plates. Curves of concentrations vs intensities for 20 elements have been obtained by using indium as an internal standard for the short burn and palladium for the long burn.

A method for sample preparation which does not employ dry-ashing has been worked out. A device

<sup>1</sup>University of Tennessee research and development contract.

which reduces the tissue to a homogeneous mass has been built in the Health Physics Shop, and a vacuum system for quick-drying the ground tissue is being fabricated. A number of difficulties have been encountered, and this work is going more slowly than had been anticipated. To check the methods of sample preparation and spectrographic analysis, recovery and reproducibility studies have been made.

This laboratory is cooperating in an interlaboratory comparison of analyses for strontium and the strontium-to-calcium ratio in plants, milk, animal tissues, and soils. A special program of the determination of strontium in normal, fresh, human bone is in progress.

#### Maximum-Permissible-Concentration Experiments on Mice

The previously reported study<sup>2</sup> on continuous and single internal exposures of mice to Co<sup>60</sup> has been completed. The conclusions of this experiment are:

1. Single-exposure data can be used to obtain approximate maximum permissible values for continuous exposure.
2. The gastrointestinal tract should be taken as the first choice and liver as the second choice for the critical body organ receiving the greatest radiation dose from ingested Co<sup>60</sup>.
3. The percentage of ingested Co<sup>60</sup> retained in the liver is  $0.7 \pm 0.2$ .
4. Five days after a single oral dose of Co<sup>60</sup> the elimination rate follows an exponential curve which gives an effective half life of  $9.5 \pm 2$  days in the liver and in the total body minus the gastrointestinal tract.
5. Within the limits of error of this experiment this same effective half life of 9.5 days is applicable to the kidney, spleen, and gastrointestinal tract minus contents. At the end of 6 hr, 50% of the contents of the gastrointestinal tract has been eliminated.
6. The best estimate of the maximum permissible concentration of Co<sup>60</sup> in water for continuous exposure is  $1.4 \times 10^{-2}$   $\mu\text{c}/\text{ml}$  if the liver is the critical organ and  $3 \times 10^{-4}$   $\mu\text{c}/\text{ml}$  if the gastrointestinal tract is the critical organ. These values are in agreement (within the limits of error of this experiment) with those given in the report *Maximum Permissible Internal Dose*, to be published in 1954

<sup>2</sup>H. H. Hubbell *et al.*, *H-P Semiann. Prog. Rep.* July 31, 1953, ORNL-1596, p 4.

by the International Commission on Radiation Protection. Those values are  $2 \times 10^{-2}$   $\mu\text{c}/\text{ml}$  for the liver and  $4 \times 10^{-4}$   $\mu\text{c}/\text{ml}$  for the gastrointestinal tract.

An experiment similar to the Co<sup>60</sup> study is in progress in which Ru<sup>106</sup>-Rh<sup>106</sup> is administered orally to DBA strain mice. In one group of mice each mouse receives a single dose of 8  $\mu\text{c}$  of the radioisotope, and in a second group each mouse receives a single dose of 40  $\mu\text{c}$ . For the mice in a third group the drinking water contains the radioisotope in a concentration of 0.1  $\mu\text{c}/\text{ml}$ , and for the mice in a fourth group the drinking water contains 1.0  $\mu\text{c}/\text{ml}$ .

#### Radiochemical Analysis

An analytical procedure for the determination of radioactive strontium in urine specimens of approximately 1500-ml volume has been developed. The advantages of the method are that (1) it is specific for strontium and (2) the separation of strontium can be done on one resin column. More than 98% of the Sr<sup>89</sup> tracer can be recovered from a large urine specimen. The essential difference between this procedure and the one previously described<sup>3</sup> is that calcium and magnesium are removed from the Dowex-50 resin column with a solution of 1% Versene-1% sodium citrate at pH 5.0 instead of with ammonium citrate.

The essential steps in the new procedure are: (1) alkaline-earth phosphate precipitation to reduce the bulk of inorganic constituents, (2) destruction of organic material with HNO<sub>3</sub>, (3) chelation of alkaline earths with Versene (20% additional Versene is added to provide adequate chelation when the pH is reduced to 5.5; at this pH value the effective chelation for calcium is reduced by some 20%), (4) passing the solution at pH 5.5 over a column of Dowex-50 (sodium cycle) (some 4% of the calcium, 30% of the magnesium, and all of the radioactive strontium stays on the resin), (5) removal of extraneous calcium and magnesium with a solution of 1% Versene-1% sodium citrate at pH 5.0, (6) removal of sodium with 0.5 N HCl, and (7) elution of radioactive strontium with 6 N HNO<sub>3</sub>. Complete separation from magnesium and calcium can be achieved. Flow rates as fast as 5 ml/min per square centimeter of cross-sectional area can be used.

<sup>3</sup>H. H. Hubbell *et al.*, *H-P Semiann. Prog. Rep.* Jan. 31, 1954, ORNL-1684, p 13.

The advantage of using a mixture of Versene and sodium citrate at pH 5.0 is that the calcium and magnesium are removed simultaneously by the Versene and sodium citrate, respectively. Neither eluting agent alone is as effective in the removal of both calcium and magnesium.

#### EXTERNAL DOSE

##### Resonance-Frequency Variation of Piezoelectric Crystals

The same method of frequency measurement as that described previously<sup>4</sup> has been used to determine the frequency change of quartz crystals after exposure to gamma radiation and to fast neutrons.

Quartz crystals cut at an angle of plus 35 deg 15 min (AT-cut) with a resonance frequency from 5 to 9 Mc were gamma irradiated from a Co<sup>60</sup> source. The crystals were enclosed in commercially available metal holders which had been either evacuated or filled with a nonoxidizing gas. These crystals have been silver plated and cemented to their electrodes with silver cement. The dose varied from  $5 \times 10^7$  to  $2 \times 10^8$  rep.

Some disintegration of the cement under irradiation is possible; however, the silver surface should not be changed by irradiation. Frequency changes of 50 to 500 cps were observed at the dose level of  $2 \times 10^8$  rep. The frequency change was attributed to a change of the elastic constants. In a few cases no frequency change was found. Strong color changes were observed after irradiation. Measurement by X-ray diffraction showed no change in lattice constants. After heat treatment up to 200°C, the frequency returned approximately to its original value and the color disappeared. Further investigations designed to exclude any possible loading of the crystals by vapors which might be produced by the gamma radiation are in progress.

Since no conclusive results were obtained after irradiation with fast neutrons, the investigation will be continued.

##### Measurement of Ionizing Radiation by High-Frequency Variation

In continuing the work on the measurement of ionizing radiation by high-frequency variation,<sup>4</sup> improved barium titanate capacitances have been

made part of the frequency-determining network. The charge losses due to the finite resistance of the barium titanate capacitances produce a drift in the frequency of the circuit which will be reduced by the use of two oscillators, one of which is connected to the ionization chamber.

##### Film Dosimetry for Fast Neutrons

It has been found that the latent-image fading of nuclear emulsion exposed to gamma radiation is rapid but reproducible. This makes possible the use of such emulsions for high-range-gamma monitoring (10 to 200 r), provided the time elapsed between exposure and development is known so that a correction for fading can be made. A full report of this study has been accepted for publication in *Nucleonics*.

The possibility of suppressing gamma fog in nuclear emulsions in order to extend its range of usefulness for neutron measurements in a high-gamma field has been investigated. Some experiments which used surface oxidants on the exposed film before development in an attempt to differentiate between the images formed by different radiations, on the assumption that heavy particles formed "internal" latent images, gave negative results. A subsequent literature search indicated that such a method is not feasible.

The accelerator became available for use, and the NTA film response to several groups of monoenergetic neutrons was measured. These values were compared with the response calculated on the basis of hydrogen-atom content of the emulsion and surrounding media, neutron-scatter cross section of hydrogen with respect to energy, and the ranges of protons of various energies in the surrounding media.<sup>5</sup> It was found that the number of tracks counted was less than the number calculated and that the discrepancy increased with decreasing neutron energies. The deficiency of tracks counted is probably due to the greater proportion of very short tracks at low energies; such short tracks are easily missed during microscopic study. A 40- $\mu$  emulsion, rather than the present 30  $\mu$ , was suggested as a remedy, and the suggestion is being considered by the Eastman Kodak Company.

##### Energy Losses of Electrons in Foils

**Beta Spectrometer.** A new Geiger counter and filling system have been installed on the beta

<sup>4</sup>H. H. Hubbell et al., *H-P Semiann. Prog. Rep. Jan. 31, 1954*, ORNL-1684, p 14.

<sup>5</sup>J. S. Cheka, *Nucleonics* 12, No. 6, 40-43 (1954).

spectrometer; this should make possible the use of the instrument at energies down to approximately 100 kev. A mixture of two-thirds argon and one-third ethylene has been found to be the most suitable of several counter gases tried. Sources of  $\text{Cr}^{51}$ ,  $\text{Ru}^{106}$ - $\text{Rh}^{106}$ , and  $\text{Hg}^{203}$  were prepared and their conversion-line spectra determined. Of these, only the  $\text{Hg}^{203}$  will be suitable for the low-energy stopping-power measurements contemplated. However, the high carrier content of the mercury isotope available at ORNL makes it unsuitable, and it appears that only a sample of separated  $\text{Hg}^{202}$  irradiated in the MTR will have a sufficient activity per milligram to permit the measurements to be made.

The program for the beta spectrometer has been delayed by the increased use of the electron accelerator. The personnel requirements of the latter machine and defocusing of the beam of the accelerator by the fringe magnetic field of the spectrometer make the simultaneous operation of the two machines impossible.

**Accelerator.** The problem now under investigation with the accelerator appears to be of more current interest than the stopping-power data from the spectrometer, so that the major effort of the group has been directed toward obtaining the maximum amount of data from the accelerator in the minimum time. To this end the cathode-gun supply has been replaced with a newly designed unit which permits more careful control of gun potentials and enables the accelerator to be operated at energies up to 125 kev.

A paper on the operation of the accelerator was presented at the meeting of the Southeastern Section of the American Physical Society, and a second, more detailed, report has been submitted to the *Review of Scientific Instruments* for publication. Cross sections for the excitation of the electron plasma in aluminum as a function of the bombarding energy have been determined. Additional measurements of those elements for which the data do not appear to agree with the theory of Pines and Bohm are in progress.

A vacuum evaporator which enables faster preparation of thin foils and saves the expense of having such foils prepared elsewhere has been constructed and is in daily use.

Preliminary measurements of the distribution of dose as a function of depth for 100-kev electrons striking a slab of aluminum have been carried out.

Such measurements have previously been made for energies above 300 kev by a group at MIT but there appears to be no data in the literature for lower energies. It is planned that this program will be continued in the energy range from 10 to 250 kev with a more elaborate ion chamber, the design of which is partially completed.

#### Ion-Recombination Errors in Pocket Chambers

Pocket chambers of the widely used 200-mr type were exposed to small doses of X rays at dose rates which ranged from 100 to 8000 r/hr and at charging voltages which ranged from 35 to 450 v in order to determine the errors introduced in the chamber readings by ion recombination when the dose rate was high or the collecting field was low. It was found that for dose rates below 8000 r/hr and for initial charging potentials above 200 v the total effects due to recombination were not greater than the errors normally encountered (5 to 10%) in the use of these chambers. When the chamber is no longer saturated, the error increases approximately 5% for each tenfold increase in dose rate, and as the chamber voltage is decreased from 200 to 60 v, within the range of dose rates used, the error increases approximately 15%.

The results indicate that the pocket ion chamber as normally charged to 150 v for any readable exposure of 0.1 sec or more duration will be in error by less than 20% as a result of recombination effects. For exposures at a rate of 15 r/hr or lower, the error would be less than 5%.

#### Film Dosimetry

A nomograph technique has been developed which will permit reasonably rapid determination of the probable radiation exposures from film-badge-density readings with a probable error of about 30%. This represents some improvement over the possible error of from 200 to 2000% inherent in the usual method of interpreting all exposures in terms of a radium dose. Beta exposures can be separately estimated. The nomograph can be altered to cover combinations of filters other than those used in the present ORNL badge, and the same technique can then be applied to determine the doses and so forth.

An open-air ionization chamber of the Bureau of Standards design has been modified and is now in operation to serve as a laboratory primary standard of dose for X and gamma rays below 200 kev.

## AIRBORNE RADIOPARTICULATE CONTAMINATION

E. G. Struxness

R. L. Bradshaw

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J. W. Thomas

### STUDY OF RADIOPARTICULATE CONTAMINATION AT X-10

A one-year study of the radioparticulate air contamination at X-10, with the U.S. Weather Bureau Office, Oak Ridge, cooperating, has been concluded, and a report on the study has been written. Recommendations have been made for reducing the radioparticulate air contamination in the Laboratory area.

### AIR POLLUTION CAUSED BY GROUND DISPOSAL

A program for studying the air pollution associated with the ground disposal of radioactive wastes by means of pits has been initiated. Most of the period of time covered by this report has been spent in program planning and research on aerosol-entrainment separators.

### SAND ENTRAINMENT SEPARATORS

Boiling liquids evolve aerosol particles as a result of the breakup of bubbles as they reach the surface. The object of this work was to study sand beds as filters for evolved radioactive aerosols. The effectiveness of the bed may be expressed by an over-all decontamination factor, which is the ratio of the activity per unit volume in the boiling liquid to the activity per unit volume of the discharged condensed distillate.

It was desired to investigate entrainment separators having over-all decontamination factors up to about  $10^{12}$ . To measure decontamination factors of this magnitude directly, the use of multicurie levels of radioactivity in the boiling liquid is necessary. This work will be done outside the immediate ORNL area. However, it is feasible to determine decontamination factors approaching  $10^{12}$  in the laboratory by an indirect method. This method involves (1) determination of decontamination factors due to distillation effect alone, using no entrainment layer, and (2) determination of decontamination factors due to the sand-layer-filtration effect only, by generation of a concentrated aerosol and the measurement of influent and effluent concentrations.

Sodium-24 was used to tag a concentrated sodium aluminate solution, and the activity in the distillate was determined at boilup rates of 2 to 8 lb of water per square foot per hour, using no entrainment layers.

Decontamination factors of about  $10^5$  to  $10^7$  were obtained, depending on the amount of foaming present.

The sand-layer decontamination factor was measured by using ordinary river sand. The median diameter of the sand granules was 0.007 in. A dioctyl phthalate aerosol (particle radius  $\sim 0.1$  to  $0.4 \mu$ ) was supplied by a La Mer generator,<sup>1</sup> and particle sizes were measured with the diffusion battery<sup>2</sup> and the servc owl.<sup>3</sup> The sand column was 5 in. thick and 4 in. in diameter, supported on a 1-in. layer of "pea" gravel.

Figure 6 is a plot of the percentage of aerosol penetration as a function of superficial velocity. For the larger particle sizes, there is a maximum in the curves. At the low velocities, diffusion and/or settling are effective in permitting only low penetrations; at the very high velocities, inertial impaction of the aerosol on the sand granules becomes predominant, causing the penetration curve to turn downward.

Figure 7, a graph of the results plotted to show penetration as a function of particle size at different air velocities, shows the existence of an aerosol size for maximum penetration through the sand bed. At small particle sizes, rapid diffusion of the particles causes low penetration values; at larger sizes, interception, gravity settling, and inertial impaction are effective. The combination of these effects results in the existence of an aerosol size for maximum penetration through the sand bed.

<sup>1</sup>E. E. Grassell, *Construction of a La-Mer Type Thermal Aerosol Generator for Radioactive Compounds*, ORNL CF-54-3-46, April 13, 1954.

<sup>2</sup>J. W. Thomas, *The Diffusion Battery Method for Aerosol Particle Size Determination*, ORNL-1648, Dec. 14, 1953.

<sup>3</sup>R. L. Bradshaw, *A Servomechanism for Measuring Aerosol Size and a Servomechanism for Controlling Particle Size in the Dioctyl Phthalate Aerosol Generator*, ORNL-1660, Jan. 18, 1954.

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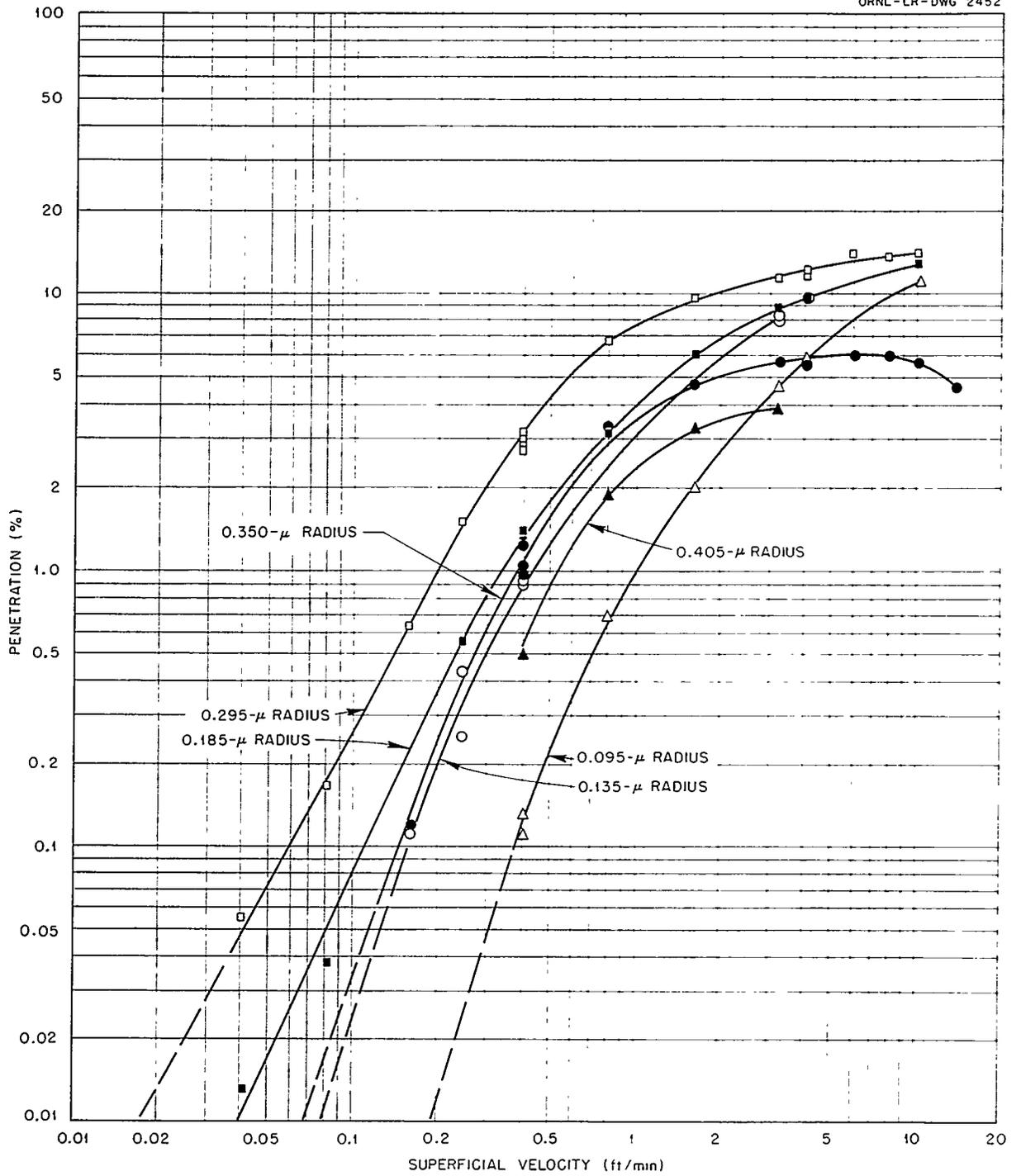


Fig. 6. Aerosol Penetration Through a Sand Bed. Penetration vs superficial velocity.

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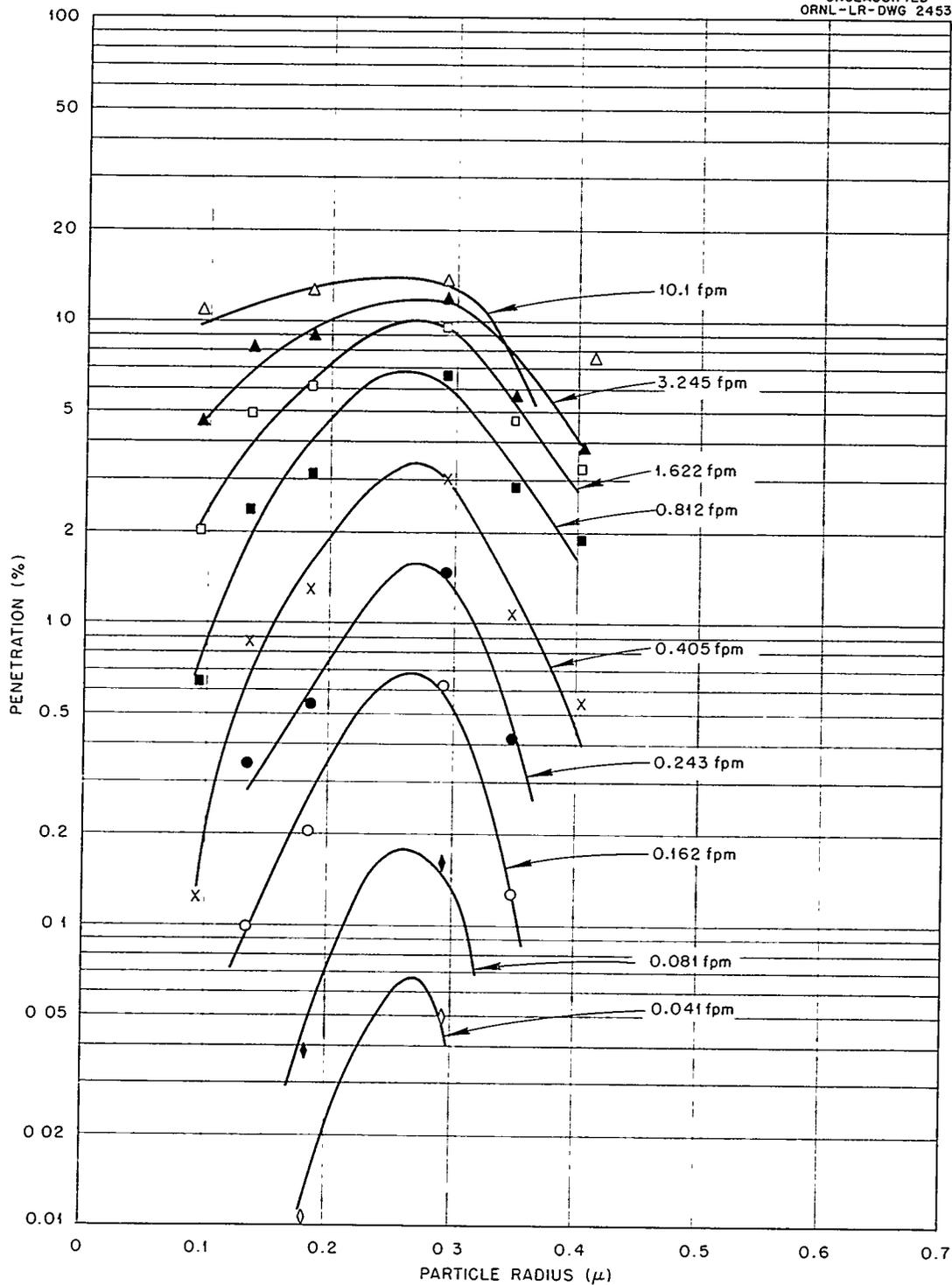


Fig. 7. Aerosol Penetration Through a Sand Bed. Penetration vs particle size.

The establishment of the size for maximum penetration is very important, since, if sand beds are tested against this size aerosol, it is assured that the beds will have a better performance in filtering aerosols of any other size, larger or smaller. The possibility that the penetration curves may turn upward again at some other value of particle size seems remote; however, further work is necessary to confirm the present results and to extend the range of the investigation.

Figures 6 and 7 show that at a superficial linear flow rate of 0.4/ft/min through the bed (equivalent to about 0.1 lb of water vapor per square foot per hour) the decontamination factor was better than

$10^3$  for the most penetrating particle size. This gives an over-all decontamination factor of at least  $10^8$  for the combined distillation effect and filtration effect for a 5-in. sand bed at this flow rate. At the present time, it seems quite likely that less than 3 ft of sand will be required to obtain decontamination factors of  $10^{12}$ , at a superficial velocity corresponding to 0.1 lb of water vapor per square foot per hour.

The above conclusions are valid only for dry sand. If large amounts of water exist in the sand bed in the liquid phase, it is anticipated that a much thicker layer will be required to achieve a decontamination factor of  $10^{12}$ .

## RADIOACTIVE WASTE DISPOSAL

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On March 15, the Radioactive Liquid Waste Research and Development Section was reorganized and integrated into the over-all Reactor Waste Disposal Project directed by E. G. Struxness. Field investigations, hydrologic and geologic explorations, and instrumentation are under the immediate direction of R. J. Morton, and the laboratory studies of chemical and engineering problems are directed by C. P. Straub. The fixation and fusion of clays and other materials and of radioactive wastes into insoluble glasses or compounds with a view to fixing waste products will be investigated by the Ceramics Group, Metallurgy Division, ORNL. The activities of the Section are concerned with three general problems: (1) liquid and solid wastes associated with the nuclear-power-reactor program, (2) the disposal of wastes from operations and research projects at ORNL, and (3) other general associated problems.

During this period the participation by cooperating agencies in liquid-waste studies has been increased. The effort of the assignees of the Public Health Service has been shifted almost entirely to the problems of power-reactor wastes. The U.S. Army Corps of Engineers (ERDL) group has been increased by the assignment of three

additional workers (A. L. Donahew, L. M. Lawless, P. B. Pruett) for a three-month period. This was done to facilitate the operation of the Process-Waste-Treatment Experimental Plant.<sup>1</sup> The U.S. Geological Survey has increased and has planned further expansion of its joint program with ORNL, particularly in geologic and hydrologic studies pertinent to disposal of wastes in surface pits.

Two research participants, Marvin L. Granstrom, University of North Carolina (full-time), and Richard B. Hahn, Wayne University (part-time), have joined the Section for the summer.

## LIQUID-WASTE-DECONTAMINATION PROCESSES

### Flotation

Flotation processes may be effective in the removal of suspended or colloidal radioactive materials from water. The particular surface-active agent chosen for study was a cyclic amine - cetylpyridinium chloride. It is reported<sup>2</sup> to have worked very well for water clarification under many chemical conditions.

<sup>1</sup>R. J. Morton et al., *H-P Semiann. Prog. Rep. Jan. 31, 1954*, ORNL-1684, p 19.

<sup>2</sup>S. H. Hopper and M. C. McCowen, *J. Am. Water Works Assoc.* 44, 719-726 (1952).

A sufficient amount of the radioactive material under investigation was added to tap water to give approximately  $10^{-2}$   $\mu\text{c}/\text{cc}$  (2220 counts/min/ml). One liter of this solution was placed in each of five 1-liter graduates. Kaolinite clay  $(\text{Al}_4)(\text{Si}_4\text{O}_{10})(\text{OH})_8$  was added to four of the graduates to give 25, 50, 100, and 200 ppm, respectively. The fifth cylinder, containing no clay, was used to evaluate the process without turbidity. To each graduate was added 15 ppm of the surface-active reagent. These solutions of surface-active

reagent, radioisotope, and clay were aerated at a rate of 1.5 to 2 liters of air per minute for 5 min.

As the air bubbles formed, they collected clay particles on their surfaces and were swept over the top of the beaker in the foam. After 5 min of aeration the surface-active agent had been exhausted; another 15 ppm of the surface-active reagent was added, and the solution was aerated again. After this second aeration, samples were taken, prepared, and counted. The results listed in Table 2 indicate that this is a rather favorable

TABLE 2. REMOVAL OF RADIOISOTOPES BY FLOTATION

Radioisotope	Raw Water			Treated Water		Radioactivity Removed (%)
	Radioactivity (counts/min/ml)	pH	Turbidity (ppm)	Radioactivity* (counts/min/ml)	Turbidity (ppm)	
$\text{Ba}^{140}\text{-La}^{140}$	2620	7.3	0	1990	0	24
			25	1600	4	39
			50	1080	5	59
			100	1000	6	62
			200	590	6	78
$\text{Cs}^{137}\text{-Ba}^{137}$	2590	7.2	0	1620	0	38
			25	1000	4	59
			50	582	4	77
			100	786	3	80
			200	387	3	85
$\text{Ru}^{106}\text{-Rh}^{106}$	1230	7.3	0	841	0	43
			25	834	7	56
			50	836	8	61
			100	817	9	64
			200	765	10	74
$\text{Sr}^{90}\text{-Y}^{90}$	2430	7.4	0	1410	0	42
			25	1290	6	47
			50	898	6	63
			100	842	6	65
			200	775	9	68
$\text{Zr}^{95}\text{-Nb}^{95}$	3020	7.4	0	1520	0	50
			25	1360	6	55
			50	958	7	68
			100	707	9	77
			200	698	8	77
$\text{I}^{131}$	3220	7.4	0	2040	0	37
			25	2080	4	36
			50	2110	5	35
			100	2020	7	37
			200	2030	7	37

\*After second aeration.

TABLE 3. REMOVAL EFFICIENCIES OBTAINED IN PROCESS-WASTE-TREATMENT EXPERIMENTAL PLANT

Treatment	Range of Removal (%)		
	Accelerator	SR Accelerator	Erdlator
(1) Ferric chloride, limestone, and clay	9-46		13-43
(2) Alum, limestone, and clay	32-50	0-28	34-56
(3) Lime and soda ash			
Stoichiometric amounts	27-55	26-48	47-54
100% excess	29-42	22-52	60-74
200% excess	34-53	36-47	66-82
(4) Trisodium phosphate, lime, and sodium hydroxide (pH control)	29-87	23-79	33-87

process for water clarification. However, it is slightly inferior to other methods for removing radioactive materials. The process does not affect the pH of the water, and the amount of surface-active material remaining in solution is not harmful to man. Results also indicate a 99% reduction in the number of bacteria. Further investigation is necessary to ascertain the optimum procedure for removing radioactive contaminants by this process.

#### Process-Waste-Treatment Experimental Plant Studies

The ORNL-ERDL-PHS study group has completed several runs with the Process-Waste-Treatment Experimental Plant using the effluent from the settling basin. Removal efficiencies obtained in these preliminary runs, indicated in Table 3, are not entirely adequate. Additional runs following modifications in the process may show higher removals.

#### Chemical Laboratory Studies with Reactor-Waste Solutions

Procedures for the removal of fission products from 1.6 M  $\text{Al}(\text{NO}_3)_3$  solution, 0.2 M in  $\text{HNO}_3$  and containing weighable amounts of fission products, are under investigation. The radioisotopes used as tracers are  $\text{Cs}^{137}$ ,  $\text{Sr}^{90}$ - $\text{Y}^{90}$ ,  $\text{Ru}^{106}$ - $\text{Rh}^{106}$ ,  $\text{Zr}^{95}$ - $\text{Nb}^{95}$ , and in some cases  $\text{Ce}^{144}$ - $\text{Pr}^{144}$ .

**Precipitation of the Fission Products.** The addition of the above solution to one-half its volume of 18 M NaOH caused the precipitation of a majority of the fission products without precipitating the aluminum. More than 90% of the cerium-

praseodymium, zirconium, and niobium tracers were removed, as well as some of the strontium and cesium tracers. The strontium removal could be increased by the addition of calcium, strontium, or barium carrier, plus phosphates or carbonates. The results obtained with this procedure are shown in Table 4.

Since the addition of large volumes of NaOH is rather costly, decontamination of the acid solution is being attempted. Specific precipitating agents are used for each radioisotope, so that most radioisotopes may be removed by a combination of reagents. Best results have been obtained with the use of the reagents listed in Table 5.

TABLE 4. REMOVAL OF RADIOISOTOPES FROM REACTOR-WASTE SOLUTION

(25 ml of 18 M NaOH, 50 gpg of  $\text{Na}_2\text{CO}_3$ , and 50 mg of  $\text{Ca}^{++}$  added to 50 ml of boiling solution; solution filtered)

Radioisotope	Total in Initial Solution (%)	Removal (%)
Ce-Pr	37.2	99.97
Sr	18.7	97.7
Ru	9.8	99.0
Nb	18.6	95.6
Zr	8.6	96.3
Cs	7.1	52.2
Total over-all	100.0	95.0

TABLE 5. REMOVAL OF RADIOISOTOPES FROM REACTOR-WASTE SOLUTION

Precipitating Agent	Removal (%)					
	Cs	Sr	Y	Ru-Rh	Zr-Nb	Total
150 mg $K_4Fe(CN)_6$ + 130 mg $FeCl_3$	94	0	0	31	46	24
$H_2S$ , then 100 mg $Pb^{++}$	10	7	5	78	48	17
5 ml $H_2SO_4$ + 200 mg $Ba^{++}$	14	83	7	12	17	
10 ml HF + 500 mg $Ca^{++}$	15	65	85	10	15	
20 g silica gel (column)	43	0	5	9	97	

**Soil Sorption.** The waste solution, made basic by its addition to one-half its volume of 18 M NaOH, was passed through columns containing 5 g of local soil. Virtually complete removal of cesium, strontium, yttrium, zirconium, and niobium was obtained, while some ruthenium-rhodium was found in the effluent, and no  $^{131}I$  was retained by the soil. After the passage of 45 to 50 ml of waste solution, a white precipitate formed in the soil, clogged the soil, and prevented further passage of the waste solution.

The filtrate from the treatment indicated in Table 3 was passed through a 5-g soil column, which resulted in the removal of more than 75% of the remaining radioactivity.

In another series of tests, 50 ml of the acid waste solution was shaken with two types of local clay soils in amounts up to 5 g. The results are given in Table 6 and show that even for a specific isotope the percentage removal varies over a wide range of values.

Cesium tracer and carrier were brought into contact with acid and basic solution, both in the presence and absence of aluminum. The results indicate that the presence of aluminum does not decrease the adsorption of cesium on soil.

A procedure for recovering the major fission products fixed to clay soils has been developed and consists in shaking the soils with the solutions listed in Table 7 and then separating soil and solution by centrifugation. Ten grams of local clay soil was leached with three successive 25-ml portions of the solutions by shaking for 20-min periods in 50-ml, rubber-stoppered, lusteroid centrifuge tubes. The results of a recent series of tests are given in Table 7.

TABLE 6. REMOVAL OF RADIOISOTOPES FROM REACTOR-WASTE SOLUTION

(50 ml of acid solution shaken 16 hr with 5 g of local soil)

Radioisotope	Removal (%)	
	Soil No. 1	Soil No. 2
Cs	0-8	0-4
Sr		1-12
Y		10-23
Ru	2-12	2-18
Zr	0-62	5-47
Nb	0-37	48-99

#### SURVEYS AND EVALUATIONS - FIELD AND LABORATORY

##### Waste Pit Studies

**Waste Storage Pit No. 2.** Prior to June 15, 1954, a total of 505,857 gal of liquid wastes containing 11,628 curies of radioactivity has been transferred to the pit. Wells Nos. 52 and 54 continue to show the same order of magnitude of radioactivity due to radiochemical contamination by  $Ru^{106}$  and its daughter product  $Rh^{106}$ . While Well No. 53 has previously been reported as uncontaminated, it now appears that  $Ru^{106}$ - $Ru^{106}$  has reached this well, as evidenced by grab-sample analyses, the latest showing 275 counts/min/ml. Surface breakthrough of  $Ru^{106}$ - $Rh^{106}$  and nitrates has been observed 400 to 500 ft southwest of the pit in a

TABLE 7. REMOVAL OF CARRIER-FREE RADIOISOTOPES FROM CLAY SOIL BY LEACHING\*

Leaching Agent	Removal (%)					
	Cs <sup>137</sup>	Sr <sup>90</sup>	Y <sup>90</sup>	Ru <sup>106</sup>	Zr <sup>95</sup>	Nb <sup>95</sup>
0.5 N HCl	2.8	98.6	97.6	90.8	3.5	0.9
55 g/liter H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	1.4	1.1	2.2	4.0	93.5	93.0
Concentrated HCl	74.9	0.3	0.1	3.0	2.3	4.4
Remainder	20.9	0	0.1	2.2	0.7	1.7

\*Isotopes in the form received from Operations Division, ORNL, adsorbed from dilute solution onto clay soil following approximately 5 min of shaking.

marshy area and creek. The possibility of a hazard created by this condition is being evaluated.

**Experimental Unlined Pit.** An earthen pit 30 ft in diameter and 5 ft deep in the shape of a right cone was installed in the Conasauga shale. Nineteen auger holes ranging from 12 to 19 ft deep and one core hole 61 ft deep were spaced around the pit. Where possible, the inner ring of wells is 35 ft and the outer ring of wells 65 ft from the center of the pit. Because of the limestone encountered during the drilling of the auger holes, it was necessary to offset several of these test wells in order to obtain maximum depth. Samples from each well were analyzed for uranium and nitrates by the Analytical Chemistry Division. Background readings in the well water were taken with a portable beta probe. Seven hundred and forty-one gallons of a solution containing uranium, nitric acid, and aluminum nitrate were obtained from the Chemical Technology Division and have been discharged to the pit. By routine, field nitrate determinations and by periodic uranium analyses of the well water, it is hoped that the length, breadth, and rate of movement of any resulting pollution stream can be defined and that a decontamination factor for uranium in the soil can be obtained. It is also hoped that the vertical dimensions of any resulting pollution stream within the depth limits of the observation wells can be defined with a beta probe. It is expected that, if uranium is removed by the soil, the fission products Ce<sup>141</sup>, Pr<sup>143</sup>, Ce<sup>144</sup>-Pr<sup>144</sup>, Nd<sup>147</sup>-Pm<sup>147</sup>, Y<sup>90</sup>, Y<sup>91</sup>, and La<sup>140</sup> will be removed to the same extent.

**Experimental Lined Pit.** This pit, having dimensions similar to the unlined experimental pit,

has a bituminous liner which was sprayed on in an average thickness of approximately  $\frac{3}{8}$  in.; over this liner, 6 in. of tamped earth was applied. The pit was filled with sand and partially filled with water. A roof was provided over the pit to prevent the access of rainfall. Evaporation cans have been sunk in the sand, and the evaporation from these cans will be compared with the evaporation from the pit in an attempt to determine the water-tightness of the applied bituminous liner under the hydrostatic head available.

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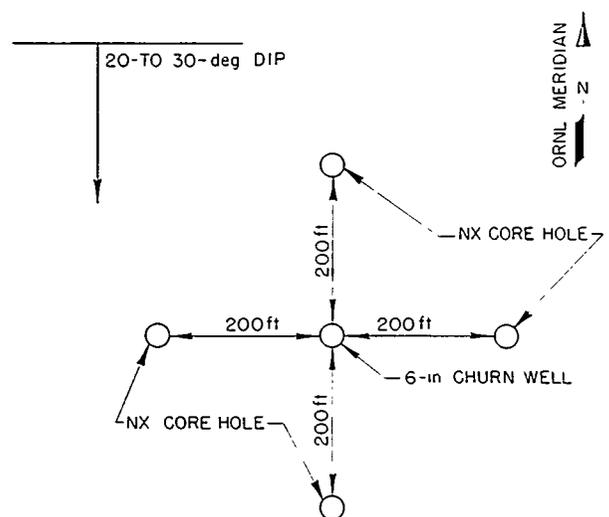


Fig. 8. Layout of NX Core Hole and 6-in. Churn Well.

### Field Explorations

Core drilling in a general area selected for possible pit disposal was completed by a U.S. Army Corps of Engineers drilling rig utilized in connection with a special project. Drilling logs and a geological report including specific conclusions and recommendations for additional study were received. On the basis of this information

an area of approximately 4 acres situated in the lower regions of the exposed Conasauga shale was selected for a concentrated geologic and hydrologic exploration. For these studies it has been proposed to locate four NX core holes, each 200 ft deep, and a churn well 300 ft deep and 6 in. in diameter as shown in Fig. 8. At present, the ORNL drillers have completed two of the 200-ft NX core holes.

---

## EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson  
M. F. Fair      M. R. Ford

### AEC FELLOWSHIP PROGRAM

The 1953-1954 group of 21 AEC Fellows in Radiological Physics completed the year of academic work at Vanderbilt University on June 6 and reported to the Laboratory for training in Applied Health Physics on June 8. From February 1 until the close of the school year, members of the Health Physics Division of ORNL gave a 6-credit graduate course in radiation physics at Vanderbilt University.

### OTHER TRAINING PROGRAMS

Six officers from AFSWP spent six weeks at the

Laboratory in the Health Physics Division during the period from February 16 to April 30. The period was devoted to lectures, discussions, and observation of Health Physics practices.

The course in atomic and nuclear physics for 14 members of the Applied Health Physics Section which began in January will be completed in two weeks.

Miss Lois Wehrmann, General Electric Company, Cincinnati, Ohio, spent two weeks with the Personnel Monitoring Section learning the techniques of neutron film dosimetry.

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<sup>1</sup>Tennessee Valley Authority.

<sup>2</sup>Veterinary Corps, U.S. Army.

<sup>3</sup>U.S. Geological Survey.

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T. E. Bortner and G. S. Hurst, *Ionization of Pure Gases and Mixtures of Gases by 5-Mev Alpha Particles*, American Physical Society Meeting, April 29–May 1, 1954, Washington, D. C.

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D. M. Davis, *Portable Equipment and Health Physics*, ORINS Advanced Instrumentation Course, June 28–July 2, 1954.

M. F. Fair, *Personnel and Area Monitoring*, Region III Radiological Defense Conference (FCDA), Georgia Institute of Technology, July 8–9, 1954.

W. J. Lacy and F. L. Cobler, *Surface Adsorption: A Mechanism of Removal for Radioactive Material from Aqueous Solution by Clay Slurry*, Second AEC Sanitary Engineering Conference, April 15–16, 1954, Baltimore, Md.

W. J. Lacy, *Food and Water Monitoring Techniques and Decontamination*, Region III Radiological Defense Conference (FCDA), Georgia Institute of Technology, July 8–9, 1954.

C. E. Melton, G. S. Hurst, and T. E. Bortner, *Measurements of Ionization Produced by 5-Mev Alpha Particles in Argon Mixtures*, Southeastern Section, American Physical Society, April 3, 1954, Knoxville, Tenn.

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W. G. Stone and L. W. Cochran, *Energy Per Ion Pair for Recoil Atoms in Methane*, Southeastern Section, American Physical Society, April 3, 1954, Knoxville, Tenn.

C. P. Straub, *Progress Review of Accomplishments at ORNL Since September 1952*, Second AEC Sanitary Engineering Conference, April 15–16, 1954, Baltimore, Md.

## LECTURES

E. E. Anderson, *Principles and Practices of Health Physics*, ORINS Radioisotope Techniques Course (February, March, June, and July, 1954).

M. F. Fair, *Health Physics*, MIT Practice School, ORNL, July 29, 1954.

M. F. Fair, Five Orientation Courses in Health Physics for the Summer Research Participants (June–July 1954).

G. S. Hurst, *Neutron Measurements*, Advanced Instrument Course at ORINS, July 2, 1954.

W. A. Mills, *Recent Neutron Dosimetry Experiments*, Fifth Conference on Radiation Cataracts, Washington, D. C., March 1954.

K. Z. Morgan, *MPE to Ionizing Radiations*, University of Alabama, February 26, 1954.

K. Z. Morgan, *MPE to Ionizing Radiations*, Mississippi State College, February 25, 1954.

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K. Z. Morgan, *Peacetime Developments in Atomic Energy*, North Carolina Bankers Association, Conover, North Carolina, March 11, 1954.

K. Z. Morgan, *Relative Biological Effectiveness*, Radiation Cataract Conference, Washington, D. C., March 26, 1954.

K. Z. Morgan, *Instruments for Measuring Radiations*, University of Michigan, Ann Arbor, Michigan, May 26, 1954.

R. J. Morton, *A Balanced Local Sanitation Program*, Meeting of Sanitation Section, Tennessee Public Health Association, Nashville, Tennessee, May 14, 1954.

R. H. Ritchie, *Passage of Charged Particles Through Plasma*, Physics Seminar, University of Tennessee, March 30, 1954.

W. S. Snyder, *On the Approximate Solution of an Integral Equation Relating to Radiation Damage*, University of Tennessee Mathematics Colloquium, April 21, 1954.

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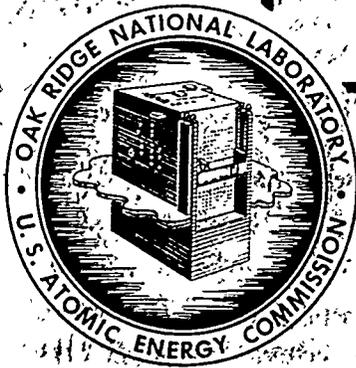
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## CONTENTS

APPLIED RADIOBIOLOGY .....	1
Distribution and Excretion of Uranium in Man .....	1
Ecology .....	4
Urinalysis Research .....	5
Distribution of Radioisotopes in Animal Tissue.....	7
Isotopic Distribution in Man.....	9
SANITARY-ENGINEERING RESEARCH .....	13
Field Investigations and Explorations (Liquid-Waste Disposal) .....	13
Chemistry and Soils Engineering.....	19
Airborne Radioactivity Studies .....	20
RADIATION DOSIMETRY .....	22
Experimental Physics of Dosimetry .....	22
Theoretical Physics of Dosimetry .....	25
Dosimetry Applications.....	26
EDUCATION, TRAINING, AND CONSULTATION .....	27
AEC Fellowship Program .....	27
Other Training Activities .....	27
PUBLICATIONS .....	28
PAPERS .....	28
LECTURES .....	29

# HEALTH PHYSICS DIVISION SEMIANNUAL PROGRESS REPORT

## APPLIED RADIOBIOLOGY

E. G. Struxness

### DISTRIBUTION AND EXCRETION OF URANIUM IN MAN

S. R. Bernard	B. L. Harless
J. C. Gallimore	J. R. Muir
C. S. Banks	G. J. Dodson
G. W. Royster, Jr.	N. L. Gillum

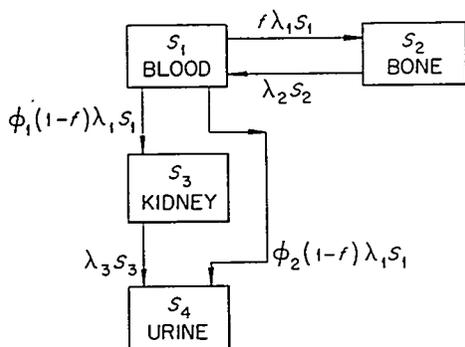
A study of the metabolism of uranium in humans after a single intravenous injection of uranyl nitrate hexahydrate is under way. This is a cooperative

study with Dr. W. H. Sweet of the Massachusetts General Hospital. It has a dual purpose: (1) to determine the feasibility of employing enriched uranium in the treatment of brain tumors by the recent technique of neutron-capture therapy and (2) to test the relationship between excretion and distribution theoretically described by a mathematical model.

The model of the distribution and excretion shown in Fig. 1 employs systems of linear differential

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THE MODEL:



THE DIFFERENTIAL EQUATIONS:

BLOOD

$$\frac{dS_1}{dt} = \lambda_2 S_2 - \lambda_1 S_1$$

BONES

$$\frac{dS_2}{dt} = f\lambda_1 S_1 - \lambda_2 S_2$$

KIDNEY

$$\frac{dS_3}{dt} = \phi_1(1-f)\lambda_1 S_1 - \lambda_3 S_3$$

URINE

$$\frac{dS_4}{dt} = \phi_2(1-f)\lambda_1 S_1 + \lambda_3 S_3$$

THE INTEGRATED EQUATIONS:

BLOOD

$$S_1(t) = \frac{I}{\mu_2 - \mu_1} \left[ (\mu_2 - \lambda_1) e^{-\mu_1 t} + (\lambda_1 - \mu_1) e^{-\mu_2 t} \right]$$

BONES

$$S_2(t) = \frac{f\lambda_1 I}{\mu_2 - \mu_1} \left[ e^{-\mu_1 t} - e^{-\mu_2 t} \right]$$

KIDNEY

$$S_3(t) = \frac{\phi_1(1-f)\lambda_1 I}{\mu_2 - \mu_1} \left[ \frac{\mu_2 - \lambda_1}{\lambda_3 - \mu_1} e^{-\mu_1 t} + \frac{\lambda_1 - \mu_1}{\lambda_3 - \mu_2} e^{-\mu_2 t} + \frac{(\lambda_2 - \lambda_3)(\mu_2 - \mu_1)}{(\lambda_3 - \mu_1)(\lambda_3 - \mu_2)} e^{-\lambda_3 t} \right]$$

URINE

$$S_4(t) = I - \frac{(1-f)\lambda_1 I}{\mu_2 - \mu_1} \left[ \frac{(\mu_2 - \lambda_1)(\lambda_3 - \phi_2 \mu_1)}{\mu_1(\lambda_3 - \mu_1)} e^{-\mu_1 t} + \frac{(\lambda_1 - \mu_1)(\lambda_3 - \phi_2 \mu_2)}{\mu_2(\lambda_3 - \mu_2)} e^{-\mu_2 t} + \frac{\phi_1(\mu_2 - \mu_1)(\lambda_2 - \lambda_3)}{(\lambda_3 - \mu_1)(\lambda_3 - \mu_2)} e^{-\lambda_3 t} \right]$$

Fig. 1. A Model for the Distribution and Excretion of U(VI).

equations. Its design<sup>1</sup> is based on the considerations of small-animal data available in the literature. The excretion equation contains three exponential terms and requires a fit by an exponential series having no more than three terms. The values of the parameters contained in the coefficients are unknown but may be determined by fitting a curve to the excretion data and equating this to the theoretical equation. After some manipulation the following equations permit solutions to be obtained for the unknowns:

$$(1) \left\{ \begin{array}{l} \phi_2^2(\mu_1 \times \mu_2) - [(\mu_1 + \mu_2)\lambda k \\ - M(\lambda k - \mu_2)\mu_1 - N(\lambda k - \mu_1)\mu_2]\phi_2 \\ + \lambda k[\lambda k - M(\lambda k - \mu_2) - N(\lambda k - \mu_1)] = 0, \\ \phi_1 = 1 - \phi_2, \\ \lambda_2 = \frac{\phi_1 \mu_1 \mu_2 \lambda k}{\phi_1 \mu_1 \mu_2 - O(\lambda k - \mu_1)(\lambda k - \mu_2)}, \\ \lambda_1 = \mu_1 + \mu_2 - \lambda_2, \\ 1 - f = \frac{\mu_1 \mu_2}{\lambda_1 \lambda_2}, \end{array} \right.$$

where

$$\begin{array}{l} M \sim \text{coefficient of } \epsilon^{-\mu_2 t}, \\ N \sim \text{coefficient of } \epsilon^{-\mu_1 t}, \\ O \sim \text{coefficient of } \epsilon^{-\lambda_3 t}, \end{array}$$

$$\mu_1 \ll \lambda_{3=k} < \mu_2$$

or

$$\lambda_{\text{bone}} \ll \lambda_{\text{kidneys}} < \lambda_{\text{blood}}.$$

The numerical solutions of these equations, when substituted into the integrated equations for bones, blood, and kidneys, yield estimates of the contents of these organs.

To date, six brain-tumor patients at Massachusetts General Hospital have received injections of uranyl nitrate hexahydrate. All but one have succumbed to the effects of the neoplasm. All fluids and tissues taken at biopsy and autopsy have been analyzed for uranium.

Typical excretion data are shown in Fig. 2. The counts per minute excreted per hour are plotted vs the time of void (corrected for decay). The excretion rate is seen to decrease through 3 orders of magnitude and shows spurious fluctuations from sample to sample.

The application of the model can be illustrated after fitting a curve to the excretion data. Difficulties arise when a graphical method of fitting data as a sum of exponentials is employed. It appears that three terms will not yield a good fit. This, however, is not an adequate test for the number of exponentials required, since it relies upon a free choice of the region described by a single component. The fluctuations in the data also influence the graphical procedure. Consequently, analytical methods have been employed.

Householder's modification<sup>2</sup> of Prony's method<sup>3</sup> affords some help in the solution of this problem. The data in Fig. 2 were interpolated at 50-hr intervals, thus providing the elements of the matrix of linear difference equations required by the Prony method. This is the *W* matrix, which appears below:

	<i>W</i> <sub>0</sub>	<i>W</i> <sub>1</sub>	<i>W</i> <sub>2</sub>	<i>W</i> <sub>3</sub>	<i>W</i> <sub>4</sub>	<i>W</i> <sub>5</sub>
<i>W</i> =	1420608	10687	2871	1412	1291	1123
	10687	2871	1412	1291	1123	797
	2871	1412	1291	1123	797	723
	1412	1291	1123	797	723	557
	1291	1123	797	723	557	462
	1123	797	723	557	462	270

When *W* is orthogonalized as prescribed by the Householder procedure, the vector column *V*<sub>3</sub> of the *V* matrix is seen to contain the smallest elements. This signifies that only three terms are necessary to fit the data.

<sup>1</sup>S. R. Bernard and E. G. Struxness, unpublished report.

<sup>2</sup>A. S. Householder, "Analyzing Exponential Decay Curves," *Proceedings of the Seminar on Scientific Computation*, International Business Machine Corp., New York, 1949.

<sup>3</sup>Cited by E. T. Whittaker and G. Robinson, *The Calculus of Observations*, 4th ed., Blackie and Son Ltd., London and Glasgow, 1946.

	$V_0$	$V_1$	$V_2$	$V_3$	$V_4$	$V_5$
$V =$	1420608	-26.709145	1.8193559	-0.0594230	-11.104810	9.3739431
	10687	2790.402531	-415.0656693	-3.6305357	1159.634151	-980.3519978
	2871	1390.347962	385.6309315	86.4600498	571.894343	-466.4129972
	1412	1280.351209	291.7617557	-114.1674027	532.096176	-412.3131088
	1291	1113.263747	74.1108537	50.0849149	475.910446	-389.9031366
	1123	788.530742	210.5499037	-24.9372761	333.835010	-369.8452503

This offers some encouragement for representing the data with three terms even though limited data are employed. This procedure will be programmed for the Oracle in order to permit rapid manipulation of larger matrices.

In the application of the model, the data are bounded by two curves. The equations and curves superimposed upon the data are shown in Fig. 3.

Solving Eqs. 1 and substituting in the integrated equations yield an estimate of the uranium present

in blood, bone, and kidney as a function of time. The agreement between such estimates and the observed results is shown in Fig. 4. The best agreement occurs in the period immediately following injection. The estimating functions appear to decrease too rapidly, which indicates that the  $\lambda$ 's determined from the excretion curve are too large.

Among the several analytical methods available with which to determine the  $\lambda$ 's, two have been tried and found to be unsuccessful. The method

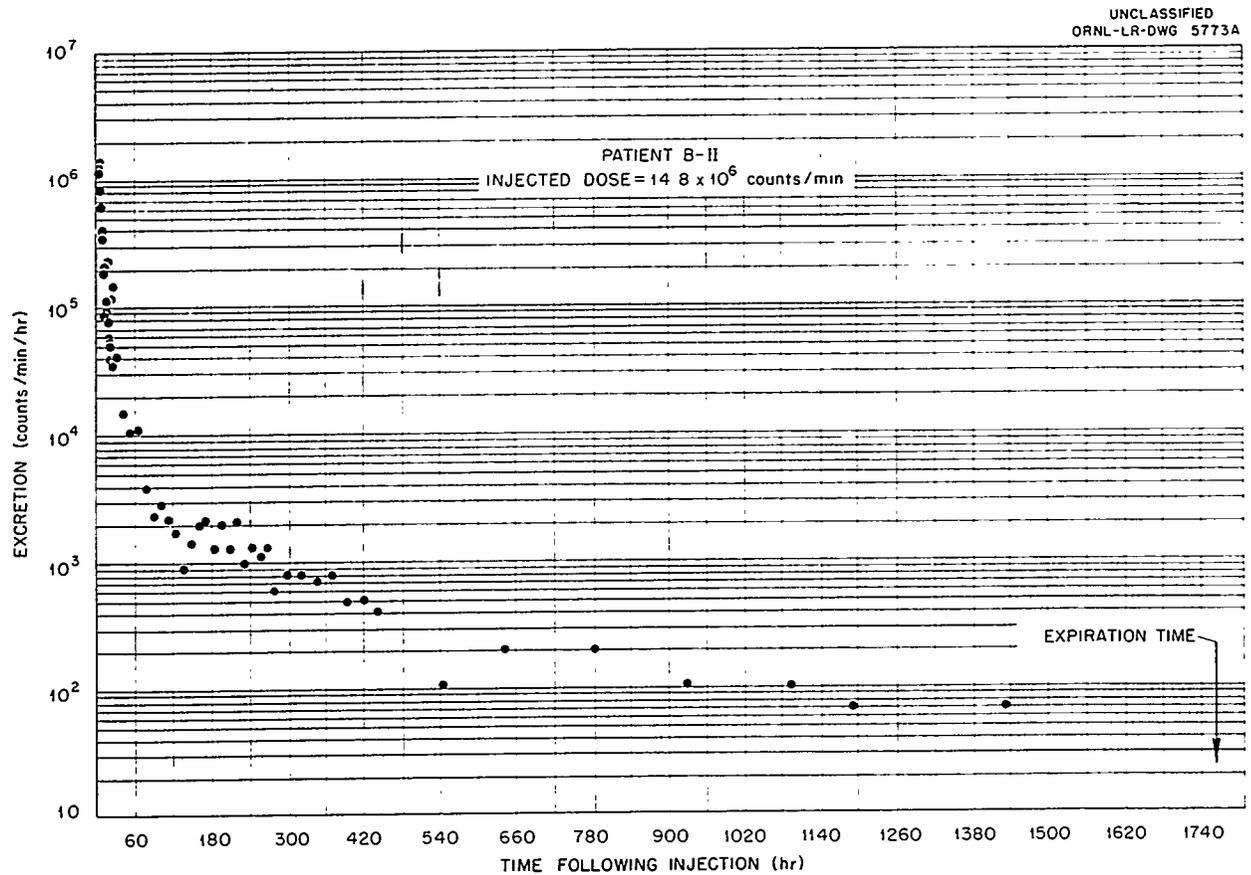


Fig. 2. Excretion of Uranium by a Terminal Brain-Tumor Patient Following an Intravenous Injection of U(VI).

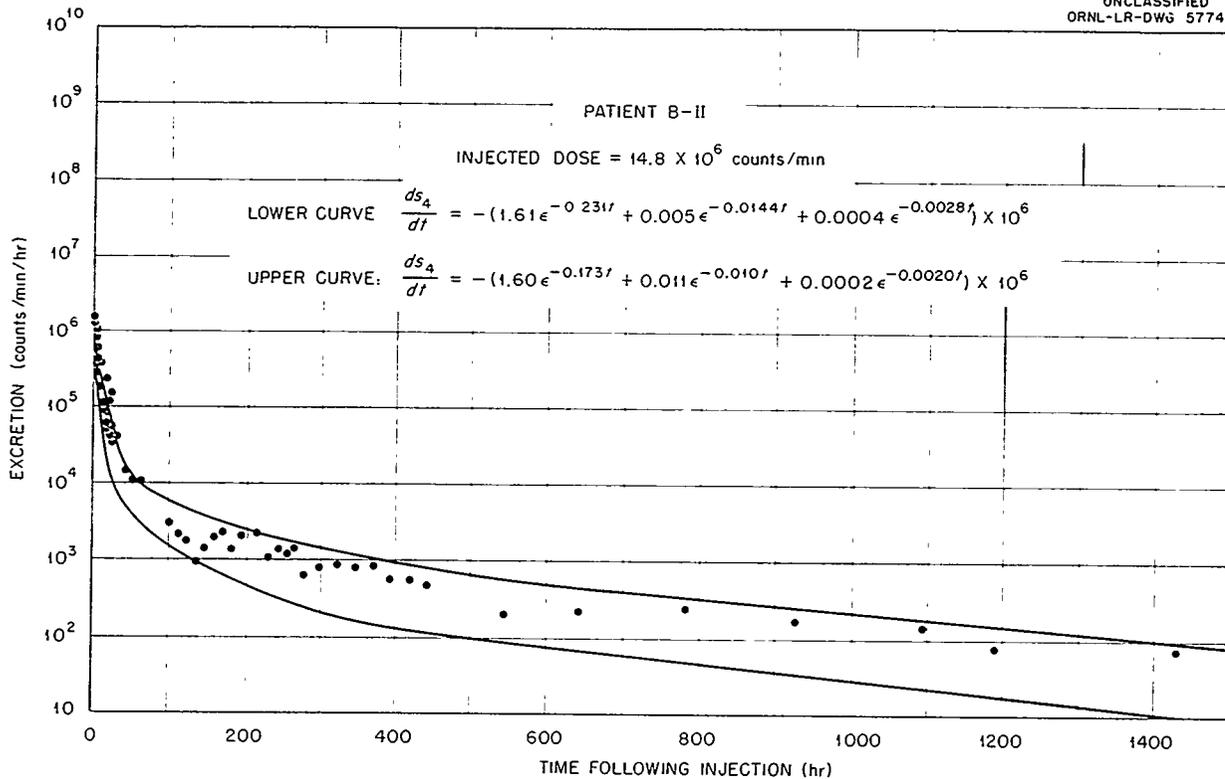


Fig. 3. Excretion Data (Fig. 2) Bounded by Two Multiple Exponential Curves.

of Deming<sup>4</sup> for the treatment of nonlinear functions by a least-squares technique has failed. This method requires initial estimates of the  $\lambda$ 's. An iterative procedure described by Householder<sup>5</sup> has been programmed for the Oracle and is employed in conjunction with the Prony method. The program can handle only a limited number of data. A critical factor governing its use is the variance level associated with the data. With the limited number of data points it appears that the variance in the excretion data is too large.

Other methods for the treatment of nonlinear functions are being considered. When a good fit of the excretion curve is obtained, the usefulness of the model can be established.

#### ECOLOGY

S. I. Auerbach      E. G. Struxness  
O. Park              J. Lynch

Seven samples of tree-hole mold and one sample of log mold with their contained arthropod popula-

tions were subjected to various doses of gamma radiation from a  $\text{Co}^{60}$  source. The tree species utilized were *A. saccharum*, *Q. alba*, *U. fulva*, *L. styraciflua*, *F. grandifolia*, and *T. americana*. The samples were subdivided into series consisting of several 50- or 100-g fractions. Each of these fractions was irradiated at one of the following doses (in roentgens):  $(1.5, 2.5, 5, 7.5) \times 10^4$ ;  $(1, 1.25, 1.5, 1.75, 2, 3.5, 5, 7.5, 8.6) \times 10^5$ ; and  $1 \times 10^6$ .

The immediate mortality of the contained arthropods was determined by extracting the surviving individuals in Berlese funnels, counting them, and comparing them with controls. Mortality was caused by all doses. It ranged from less than 10% in the lower doses to over 99% at  $1 \times 10^6$  r. Figures 5 and 6 show the immediate mortality, expressed

<sup>4</sup>W. E. Deming, *Statistical Adjustment of Data*, 1st ed., Wiley, New York, 1943.

<sup>5</sup>A. S. Householder, *On Prony's Method of Fitting Exponential Decay Curves and Multiple-Hit Survival Curves*, ORNL-455 (Sept. 19, 1949).

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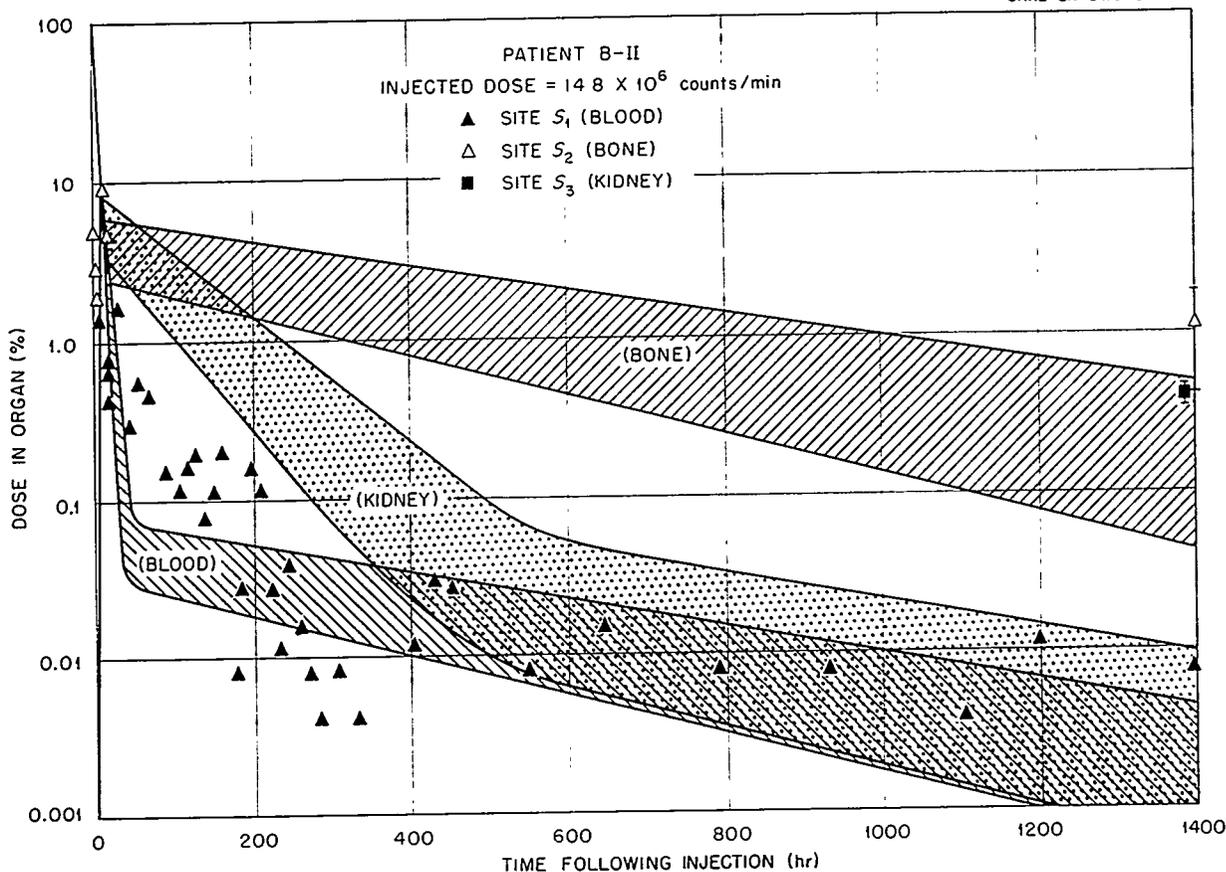


Fig. 4. Comparison Between Estimated and Observed Organ Content.

as per cent of survival, produced by the different doses. Figure 5 shows the curves for the first four series of experimentals, and Fig. 6 shows them for the last four series. In terms of steepness of slope of the curve of per cent survival vs dose, the increments of dose that appeared to be most effective in causing immediate lethality were in the range 50,000 to 200,000 r.

The total arthropod population mortality curve for each tree sample had its own slope. Furthermore, within each sample the curves were not linear. This is not surprising in view of the differences in substrate, the heterogeneity of the species populations within each sample, and the interspecific and intraspecific differences with respect to radiosensitivity.

It is suggested that there is a level of radiation in the range 50,000 to 150,000 r which is of critical biologic significance with regard to the community.

If this level is exceeded, the community will undergo breakdown. This hypothetical level has been designated the Manifest Radiation Threshold (MRT).

#### URINALYSIS RESEARCH

L. B. Farabee

Work continued on the development of an analytical procedure for the determination of radioactive strontium in urine specimens of approximately 1500 ml volume. The essential steps in this procedure were described in a previous progress report.<sup>6</sup> Further studies have been made in order to evaluate the usefulness of the procedure in routine urine analyses. Previous studies at high Sr<sup>89</sup> tracer levels showed over-all losses of about 2%. The

<sup>6</sup>H. H. Hubbell et al., H-P Semann. Prog. Rep. July 31, 1954, ORNL-1763, p 5.

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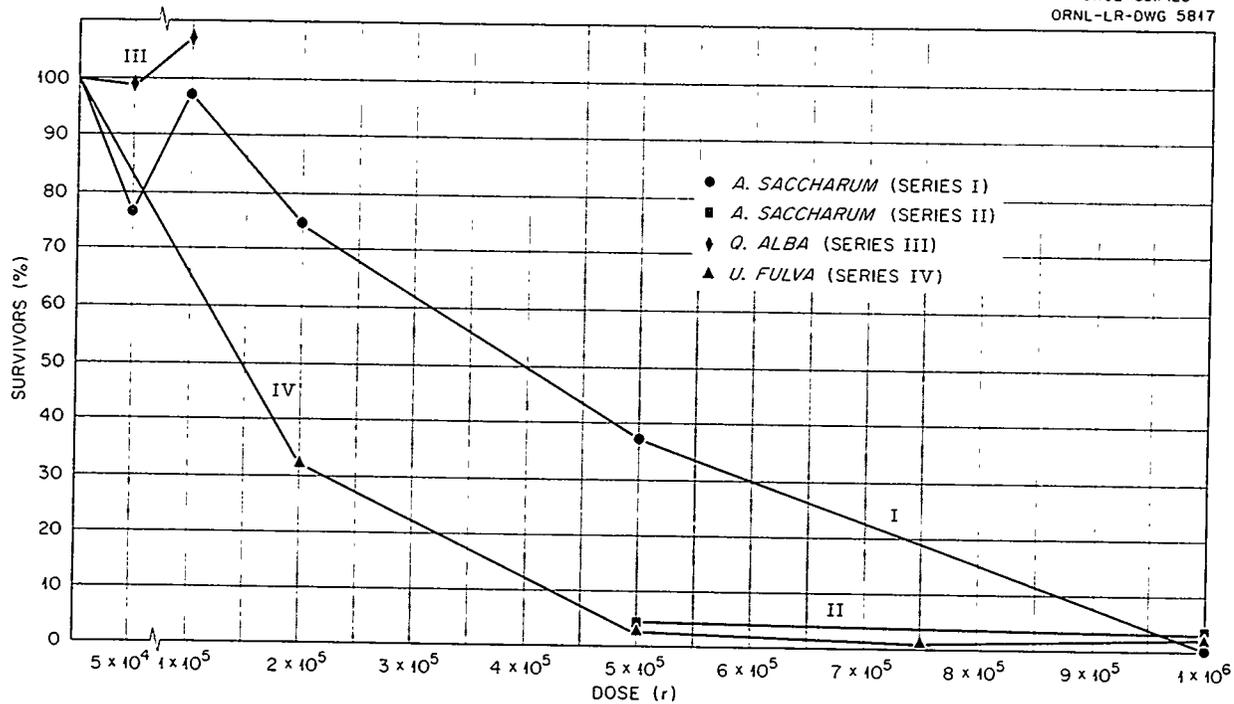


Fig. 5. Mortality of Arthropods Contained in Tree-Hole and Log Mold When Subjected to Various Doses of Gamma Radiation (Series I-IV).

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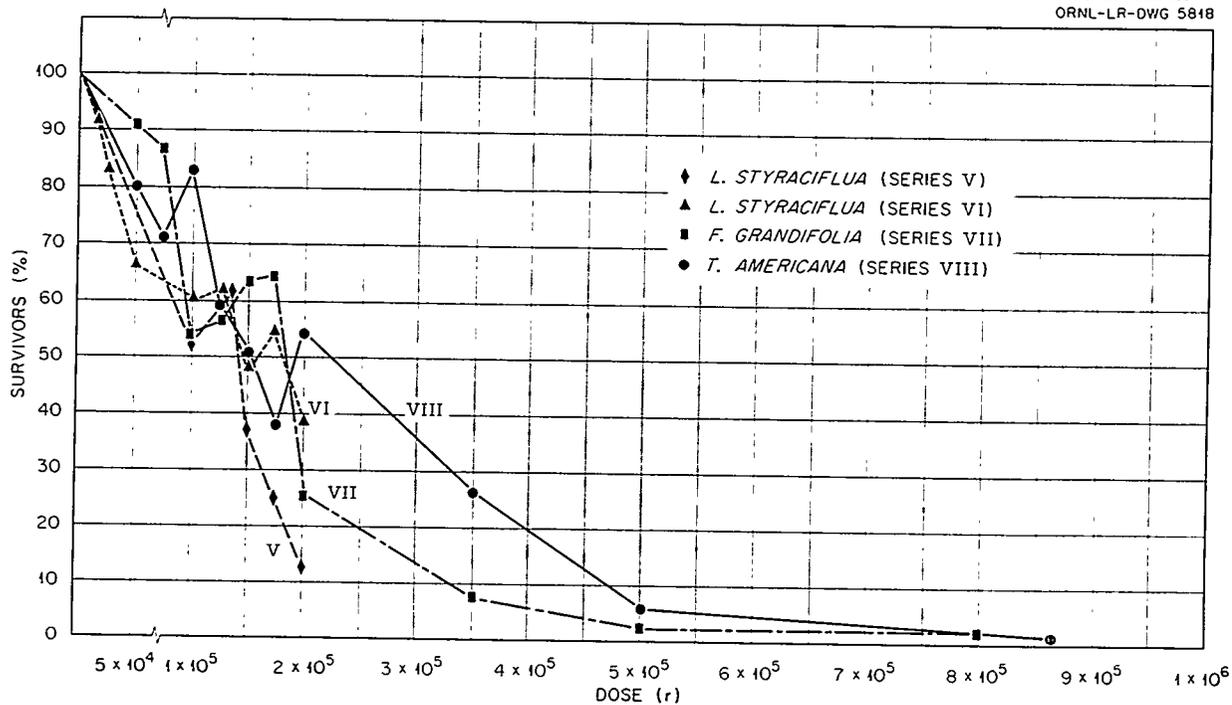


Fig. 6. Mortality of Arthropods Contained in Tree-Hole and Log Mold When Subjected to Various Doses of Gamma Radiation (Series V-VIII).

procedure has been further tested at low tracer levels of approximately 70 counts/min (at 25% geometry) to determine the efficiency at levels that might be expected in some samples in routine analyses. Recovery of added  $\text{Sr}^{89}$  tracer in urine samples from 22 persons gave an average of 93.3%  $\pm$  3.1% (statistical error in counting, 3 counts/min).

Since there is appreciable beta activity from the  $\text{K}^{40}$  in urine, adequate separation from potassium must be provided by any procedure for analysis for radioactive fission products in urine. This procedure was checked for decontamination from  $\text{K}^{40}$  by analyses made on 17 urine samples (1500 ml volume) from persons not exposed to radiostrontium. The average beta activity of these samples was 0.73 count/min (25% geometry), with a range of 0.1 to 1.7 counts/min.

This procedure has been used at ORNL since Dec. 1, 1954, for routine analysis for strontium in urine. Although the procedure is not so short as might be desired, the over-all efficiency in routine operations is enhanced by the fact that one operator can carry out eight to ten analyses simultaneously. Since very small amounts of solids are present in the final eluent, which is evaporated and mounted directly for counting, no weighing of the final residue is necessary. Self-absorption of beta activity due to the solids is nil. The procedure provides easy identification of the strontium isotope, since  $\text{Y}^{90}$ , if present, is separated from  $\text{Sr}^{90}$  and subsequent counting of the sample will indicate the fraction  $\text{Sr}^{90}/(\text{Sr}^{90} + \text{Sr}^{89})$  present by the growth of the daughter  $\text{Y}^{90}$ . A detailed report of this procedure will be published soon.

#### DISTRIBUTION OF RADIOISOTOPES IN ANIMAL TISSUE

M. J. Cook    A. G. Barkow<sup>7</sup>  
K. Z. Morgan

##### Description of the Experiment

Single-exposure data are currently used to calculate continuous-exposure values for maximum permissible concentrations of radioisotopes in water. A preliminary experiment to test the validity of this practice has been completed.

Male and female C-57 strain mice were divided at random into three principal groups, and all were

<sup>7</sup>Summer research participant, Marquette University, Milwaukee, Wis.

given  $\text{Co}^{60}$  as the chloride. The first two groups were treated identically, except for the amount of  $\text{Co}^{60}$  administered. Each mouse in the first two groups was given a single gavage dose consisting of 0.5 ml of solution. The solution administered to the first group contained 7.2  $\mu\text{c}$ , and that given to the second group contained 32.7  $\mu\text{c}$ . At specified times, ten mice from each group were sacrificed.

The value<sup>8</sup> for maximum permissible concentration in water for  $\text{Co}^{60}$ ,  $2 \times 10^{-2}$   $\mu\text{c}$  of  $\text{Co}^{60}$  per milliliter, has been estimated to result in a dose rate of 0.3 rep per week to the liver after extended use of the contaminated water. On this basis,  $2.25 \times 10^{-2}$   $\mu\text{c}$  of  $\text{Co}^{60}$  per milliliter was added to the drinking water of the third group. The water was present in the cage at all times in order that the mice might drink *ad libitum*. During a nine-week period these mice were sacrificed — ten at a time — at specified time intervals.

After the animals were sacrificed, they were weighed in tared Lusteroid tubes. Each tube containing a mouse was then placed in a high-pressure ionization chamber, and readings for the total-body burdens of  $\text{Co}^{60}$  were obtained before the mice were dissected.

Since disagreement exists as to the critical organ for  $\text{Co}^{60}$ , the organs chosen for investigation were the spleen, liver, kidneys, and gastrointestinal tract with its contents. Each organ was weighed in tared Lusteroid tubes, and the number of microcuries per organ was obtained in the same manner as for the total body. If the amount of  $\text{Co}^{60}$  in a single organ was too small to be determined, all ten like organs from a sacrificed group were combined to obtain a measurement.

#### Results of the Experiment

The results of the single-exposure experiments are plotted in Fig. 7. Each point for the total body, liver, and gastrointestinal tract with contents represents the average of ten readings of the per cent of administered dose present in the individual organs. Each point for the spleen and kidneys represents the average reading obtained from a single observation on ten spleens or ten pairs of kidneys.

<sup>8</sup>United States National Bureau of Standards, *Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water*, Handbook 52, Superintendent of Documents, Washington 25, D.C.

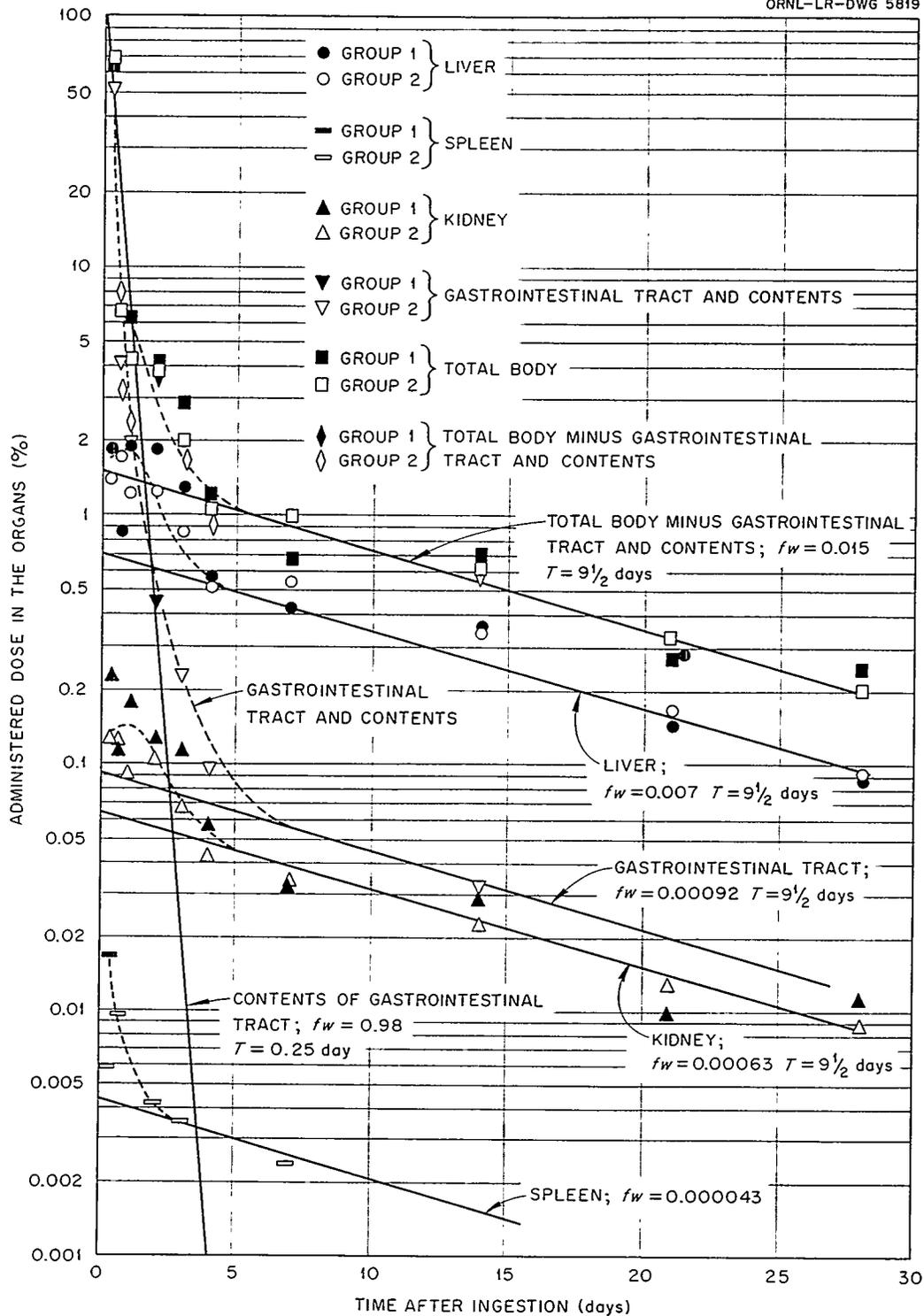


Fig. 7. Distribution of  $Co^{60}$  in the Various Organs as a Function of Time After Ingestion. Data from both groups are combined to give the indicated curves.

In Fig. 8 are presented both the experimental points from the continuous-exposure experiments (third group of mice) and the curves calculated by substituting the single-exposure values of  $f_w$  and  $T$  in the following equation:

$$(1) \quad qf_2 = \frac{CRTf_w(1 - e^{-0.693t/T})}{0.693},$$

where

- $q$  = microcuries in total body,
- $f_2$  = fraction in the organ of the quantity in the total body,
- $C$  = concentration of radioisotope in water ( $2.25 \times 10^{-2} \mu\text{c}$  of  $\text{Co}^{60}$  per milliliter),
- $R$  = rate of water intake (2 ml/day in this experiment),
- $f_w$  = fraction of the radioisotope that reaches the organ after ingestion,
- $t$  = period of exposure, days,
- $T$  = effective half life, days.

The continuous-exposure curves calculated from single-exposure data show that after 63 days of exposure only 0.000026  $\mu\text{c}$  or about 0.1% of the  $\text{Co}^{60}$  in the total body is deposited in the spleen. Since the lowest reading obtainable with the high-pressure ionization chamber was about 0.002  $\mu\text{c}$ , the ten spleens combined would not be expected to give a reading. This proved to be the case; no data could be obtained for the spleens in the continuous-exposure experiment. The continuous-exposure data that are plotted in Fig. 8 for the total body, kidney, liver, and gastrointestinal tract plus contents are in agreement, within the limits of error, with the values calculated from the single-exposure data and substantiate the current practice of calculating the maximum permissible values from single-exposure data. The greatest deviation occurred in the case of the liver, for which the values differed by a factor of 2.

The second objective was to determine the critical organ of the body. The liver is recommended as the first choice for  $\text{Co}^{60}$  in Handbook 52 (ref. 8) and in the 1951 report by the International Commission,<sup>9</sup> but in the 1954 report by the International Commission<sup>10</sup> the gastrointestinal tract is considered to be the critical organ. The maximum permissible concentration in water is  $2 \times 10^{-2} \mu\text{c}/\text{ml}$  for the liver and is  $4 \times 10^{-4} \mu\text{c}/\text{ml}$  for the gastrointestinal tract, respectively, indicating that

the gastrointestinal tract is more critical by a factor of 50. In this experiment the best estimate of the maximum permissible concentration of  $\text{Co}^{60}$  in water for continuous exposure is  $1.4 \times 10^{-2} \mu\text{c}/\text{ml}$  for liver as the critical organ and  $3 \times 10^{-4} \mu\text{c}/\text{ml}$  for the gastrointestinal tract as the critical organ. These data are in agreement within the limits of error with the two ICRP values of maximum permissible concentration.

A most striking observation is the large fraction of administered  $\text{Co}^{60}$  which localizes in the liver. After a five-day period following administration of the dose and during the remainder of the experiment, about 50% of all the administered  $\text{Co}^{60}$  remaining in the body continued to be in the liver. Figure 9 indicates that the concentration decreases in the following order: gastrointestinal tract with contents, liver, kidneys, and the rest of the body.

The third objective of this experiment was to eliminate the discrepancies between the 1951 report of the International Commission,<sup>9</sup> in which  $f_w = 1.00$  and  $T = 20$  days for  $\text{Co}^{60}$  in the liver, and the values given in Handbook 52 (ref. 8), in which  $f_w = 0.004$  and  $T = 8.4$  days. In this experiment the single-exposure values are  $f_w = 0.007 \pm 0.002$  and  $T = 9.5 \pm 2$  days.

It is concluded that single-exposure data can be used to obtain continuous-exposure values for approximate maximum permissible concentrations of  $\text{Co}^{60}$ . This experiment should be repeated for other radioisotopes in order to establish the general validity of using single-exposure data to calculate continuous-exposure values.

#### ISOTOPIC DISTRIBUTION IN MAN

I. H. Tipton      M. J. Cook  
D. K. Bowman    J. C. Gallimore

#### Spectrographic Analysis of Human Tissue

The spectrographic laboratory in the Physics Department of the University of Tennessee analyzed

<sup>9</sup>International Congress of Radiology, "Recommendations of the International Commission of Radiological Protection," *Brit. J. Radiol.* 24, 46-53 (1951) or Handbook 47, Superintendent of Documents, Washington 25, D.C. (The meeting of the International Congress of Radiology was held in London, England, July 1950.)

<sup>10</sup>International Congress of Radiology, *Maximum Permissible Internal Dose*, final report of the Congress, December 1954. (This meeting of the International Congress of Radiology was held in Copenhagen, Denmark, July 1953.)

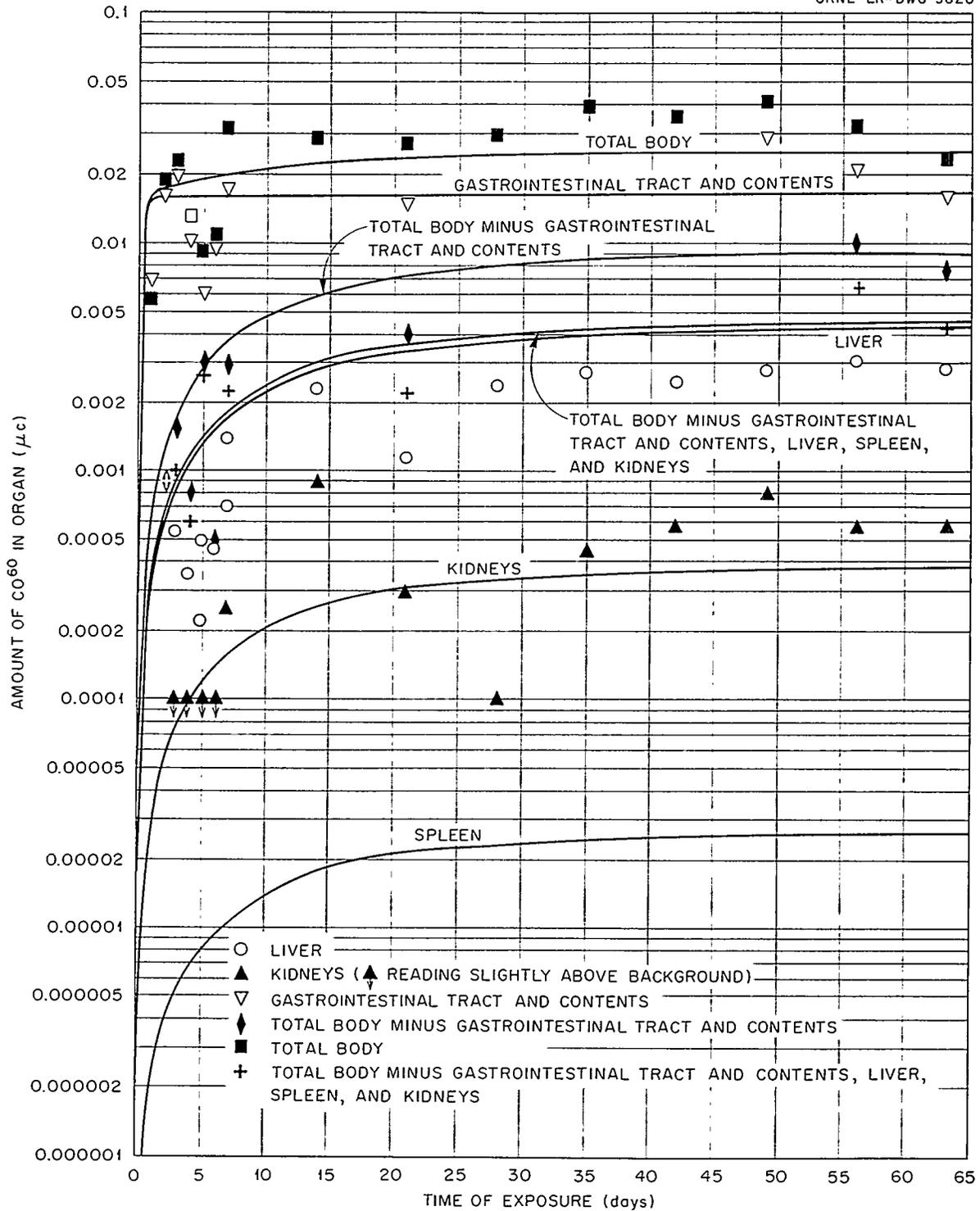


Fig. 8. Relation Between the Amount of  $Co^{60}$  Found in the Organs After Continuous Exposure and the Amount Calculated by Use of Eq. 1. The solid lines represent results computed by inserting values of  $f_w$  and  $T$  as found from single-exposure data (Fig. 7) for various organs in Eq. 1.

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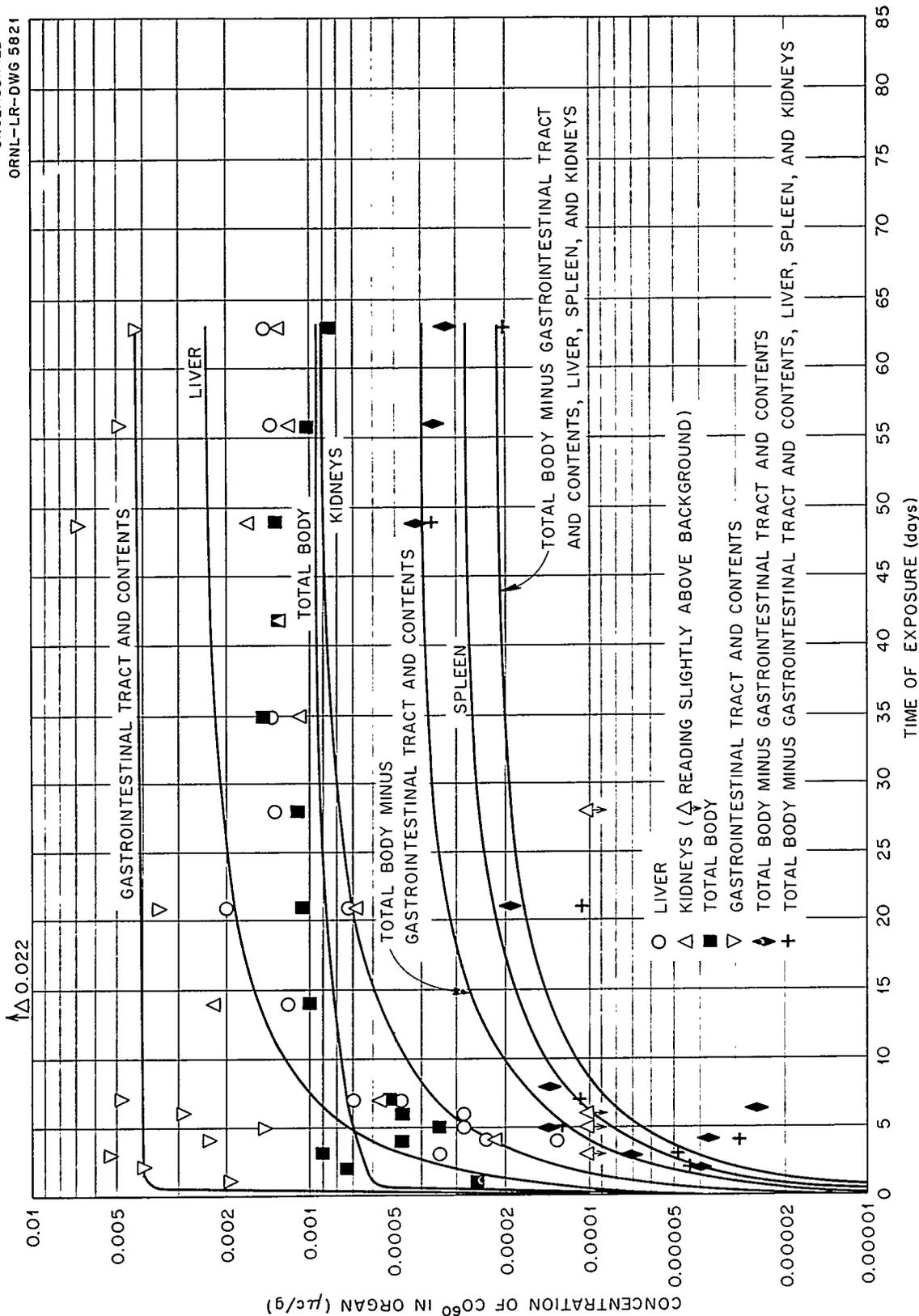


Fig. 9. Relation Between the Amount of Co<sup>60</sup> Found in the Various Organs Based on Continuous Exposure and the Amount Computed from Single-Exposure Data.

## HEALTH PHYSICS PROGRESS REPORT

260 samples of wet-ashed tissue from persons who were victims of an instantaneous accidental death, 100 samples of bone and cartilage, and more than 200 other samples of various tissues. Quantitative spectrographic methods for the simultaneous analysis of 21 elements were developed, and a sensitive method for the determination of dilute concentrations of strontium in various biological materials was established.

Since it is desirable to analyze a large number of samples from representative geographical locations and since the collection of accidental-death tissue is tedious and involved, it was decided that the responsibility for collecting and preparing

samples should be assumed by the Applied Radiobiology Section. The University was not able to handle this difficult problem, except at the expense of the spectrographic work. A tissue-preparation laboratory has been established, and arrangements with appropriate medical authorities for collection of samples in Boston, New York, Chicago, St. Louis, Denver, Seattle-Tacoma, Los Angeles, Dallas, New Orleans, Miami, and Richmond have been initiated. Samples have been, or are being, received from Boston, New York, Chicago, and Denver. It is hoped that reliable figures for concentrations of more than 20 elements in "standard man" can be established this year.

SANITARY-ENGINEERING RESEARCH

E. G. Struxness

FIELD INVESTIGATIONS AND EXPLORATIONS  
(LIQUID-WASTE DISPOSAL)

R. J. Morton	E. R. Eastwood
K. E. Cowser	R. Richardson (USGS)
P. Guinn	W. J. Lacy (ERDL)
H. J. Wyrick	Pfc. L. M. Lawless (ERDL)
W. D. Laguna (USGS)	M/Sgt. R. R. Rollins (ERDL)

Serial Coagulation Equipment

The ERDL group studied the additive effect of successive coagulations on the removal of radioactive materials from water. Enough radioactive material was added to 2 liters of tap water to give about  $1.3 \times 10^{-2}$   $\mu\text{c/ml}$ . Then 500 ml of this solution was added to each of four 1-liter beakers, the pH was adjusted by the use of either HCl or NaOH, and enough of the desired chemical coagulant combination was added to give 25-25, 50-50, 100-100, and 200-200 ppm. The three coagulant combinations studied were (1)  $\text{FeCl}_3\text{-CaCO}_3$ , (2)  $\text{Al}_2(\text{SO}_4)_3\text{-Na}_2\text{CO}_3$ , and (3)  $\text{Na}_3\text{PO}_4\text{-Ca(OH)}_2$ . Hereafter these will be referred to as

Fe, Al, and Na, respectively. The pH range used with each coagulant combination was (1) 7.2 to 8.0, (2) 6.2 to 7.0, and (3) 10.2 to 11.0, respectively. After the coagulant was added, the beaker contents were rapidly mixed for 3 min, slowly mixed for 10 min, and then allowed to settle for 20 min. Samples of the supernatant were taken, placed in counting dishes, dried, and counted. Other samples of the supernatant were first filtered and then dried and counted. The remaining liquid was decanted into a 2-liter beaker, the pH was readjusted to the range for the next coagulant pair, and the above procedure was repeated for the second and third coagulants on the same sample. The procedure was repeated with the use of all six possible orders of addition of the chemical coagulants on each of the solutions of the seven radioactive substances.

Table 1 shows the total per cent removal of the radioactivity from the filtered sample for only the 100-100 ppm dosage. Per cent removal was calculated as follows:

$$\text{Per cent removal} = \frac{(\text{activity before first coagulation}) - (\text{activity after final coagulation})}{\text{activity before first coagulation}} \times 100$$

TABLE 1. REMOVAL OF RADIOACTIVE MATERIAL BY SERIAL COAGULATION

All removal values are for filtered samples treated with the 100 ppm concentration of chemicals

Radioactive Material	Initial Activity ( $\mu\text{c/ml}$ )	Total Removal (%)					
		Method 1 Fe-Al-Na	Method 2 Fe-Na-Al	Method 3 Al-Fe-Na	Method 4 Al-Na-Fe	Method 5 Na-Al-Fe	Method 6 Na-Fe-Al
Ru <sup>106</sup> -Rh <sup>106</sup>	0.011	99.8	99.9	99.6	99.7	99.0	99.9
Zr <sup>95</sup> -Nb <sup>95</sup>	0.013	99.9	99.9	99.8	99.7	99.9	99.9
Ce <sup>144</sup> -Pr <sup>144</sup>	0.013	99.9	99.9	99.9	99.9	99.9	99.9
Ba <sup>140</sup> -La <sup>140</sup>	0.012	91.0	90.7	97.1	92.3	89.2	91.5
Sr <sup>90</sup> -Y <sup>90</sup>	0.012	80.8	69.8	80.7	82.6	79.0	73.7
MFP-1*	0.013	96.4	97.0	96.4	97.3	97.6	97.0
MFP-2*	0.014	70.5	74.0	73.2	72.5	72.0	69.8

\*MFP-1 and -2 are fission-product mixtures.

It will be noticed that the per cent removals agree very closely. However, per cent removals after each coagulation indicated that some radioisotope solutions were as effectively treated by one particular coagulant combination as by the series of coagulations. The serial treatment method was more effective on  $\text{Ru}^{106}$ - $\text{Rh}^{106}$ ,  $\text{Zr}^{95}$ - $\text{Nb}^{95}$ , and  $\text{Ce}^{144}$ - $\text{Pr}^{144}$  than was a single treatment. With certain radioisotopes, for example radiostrontium, repeated treatment with the same chemical combination [ $\text{Na}_3\text{PO}_4$ - $\text{Ca}(\text{OH})_2$ ] at high pH (11.0) was found to be most effective. Results reported by McCauley *et al.*<sup>1</sup> have indicated that coprecipitation is the method of removal for radiostrontium when this technique is used.

#### Field Explorations

Four NX core borings 200 ft deep and one 6-in.-dia churn-drilled well 300 ft deep have been completed at the 4-acre site previously selected for geologic and hydrologic exploration in anticipation of its use for possible disposal of radioactive liquid wastes.<sup>2</sup> Water-level recorders have been installed on the wells to obtain information of the configuration and elevation of the water table in this area. To determine the vertical distribution and degree of interconnection of permeable zones in the rock, each well has been pressure tested, and analysis of the data is in progress.

A deep-well pump and associated equipment have been ordered to conduct pumping tests in this area. The purpose of these tests is to investigate quantitatively the ability of the rocks to transmit fluids.

Single-point electric logging of all wells at this site has been completed. These data will be compared with the recovered cores and with the logs recorded during drilling of the wells to determine whether useful information can be obtained by electric logging.

Preparation of a geologic and hydrologic base map of the Oak Ridge area is in progress.

#### Experimental Lined Pit

The evaporation study<sup>2</sup> to determine the watertightness of the asphalt-tamped clay liner was completed after a 44-day observation period. This experiment is being conducted as part of a program to develop more effective and economical methods of impoundment of radioactive waste. The data<sup>3</sup>

indicate that the liner is leaking at a mean rate of about  $0.021 \pm 0.017$  gal/ft<sup>2</sup>/day, amounting to a mean loss of  $8.4 \pm 6.8$  gal/day. Nonuniformity in thickness of the asphalt liner and puncturing of the liner by the tamped shale are deemed responsible for its nonwatertightness and the decrease in its retentive qualities by a factor of approximately  $10^2$  as compared with the value obtained by laboratory studies. After additional bituminous-membrane studies are completed, it is proposed that the pit be used for confirmation of the studies on a pilot-plant scale.

#### Experimental Unlined Pit

Another promising method of radioactive-waste disposal involves the use of unlined pits. Prior to the discharge of wastes to one of the experimental unlined pits,<sup>2</sup> water-table contour drawings were developed from the water-level measurements made in the observation wells surrounding the pit. Figure 10 shows the contours before rain accumulated in the pit, and Fig. 11 shows the results of this localized ground-water recharge. From these drawings it is concluded that the movement of waste in the direction of wells U-4 and U-16 would be pronounced, while toward well U-2 it would be less.

The movement of chemical pollution was followed by field nitrate tests (diphenylamine spot-plate method) and by quantitative nitrate and uranium analysis on samples obtained from the wells. A plot of the pit and the direction of travel of nitrates and uranium, as shown in Fig. 12, confirm the direction of travel implied by the rainfall recharge effect on the ground-water table. Uranium in amounts above normal was found in several of the wells and was always associated with a pH less than that of the normal ground water. This is in agreement with the effect of pH on the removal of isotopes by clay as reported in laboratory studies.<sup>4</sup>

<sup>1</sup>R. F. McCauley, R. A. Lauderdale, and R. Eliassen, *A Study of the Lime-Soda Softening Process as a Method for Decontaminating Radioactive Waters*, NYO-4439 (Sept. 1, 1953).

<sup>2</sup>R. J. Morton *et al.*, *H-P Semann. Prog. Rep.* July 31, 1954, ORNL-1763, p 15-16.

<sup>3</sup>K. E. Cowser, R. J. Morton, and T. W. Bendixen, *Evaluation of the Watertightness of an Asphalt-Tamped Clay Pit Liner*, ORNL CF-55-3-128 (to be published).

<sup>4</sup>T. W. Brockett, B. Kahn, and C. Straub, *Removal of Radioactive Cations from Solutions by Local Clay-Type Soils*, ORNL CF-54-12-145 (Dec. 17, 1954).

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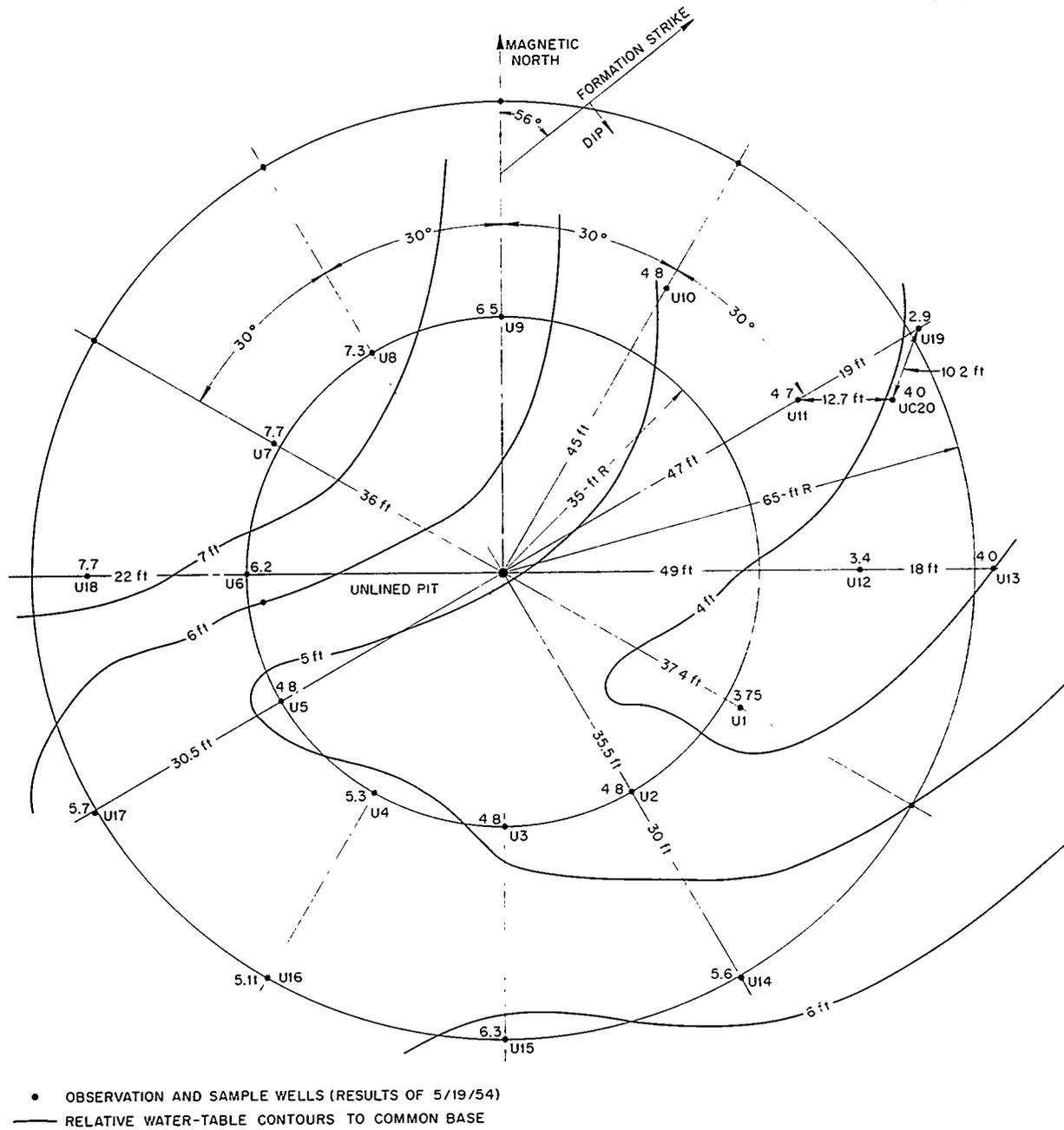


Fig. 10. Water-Table Contours Before Rain Accumulated in Experimental Unlined Pit.

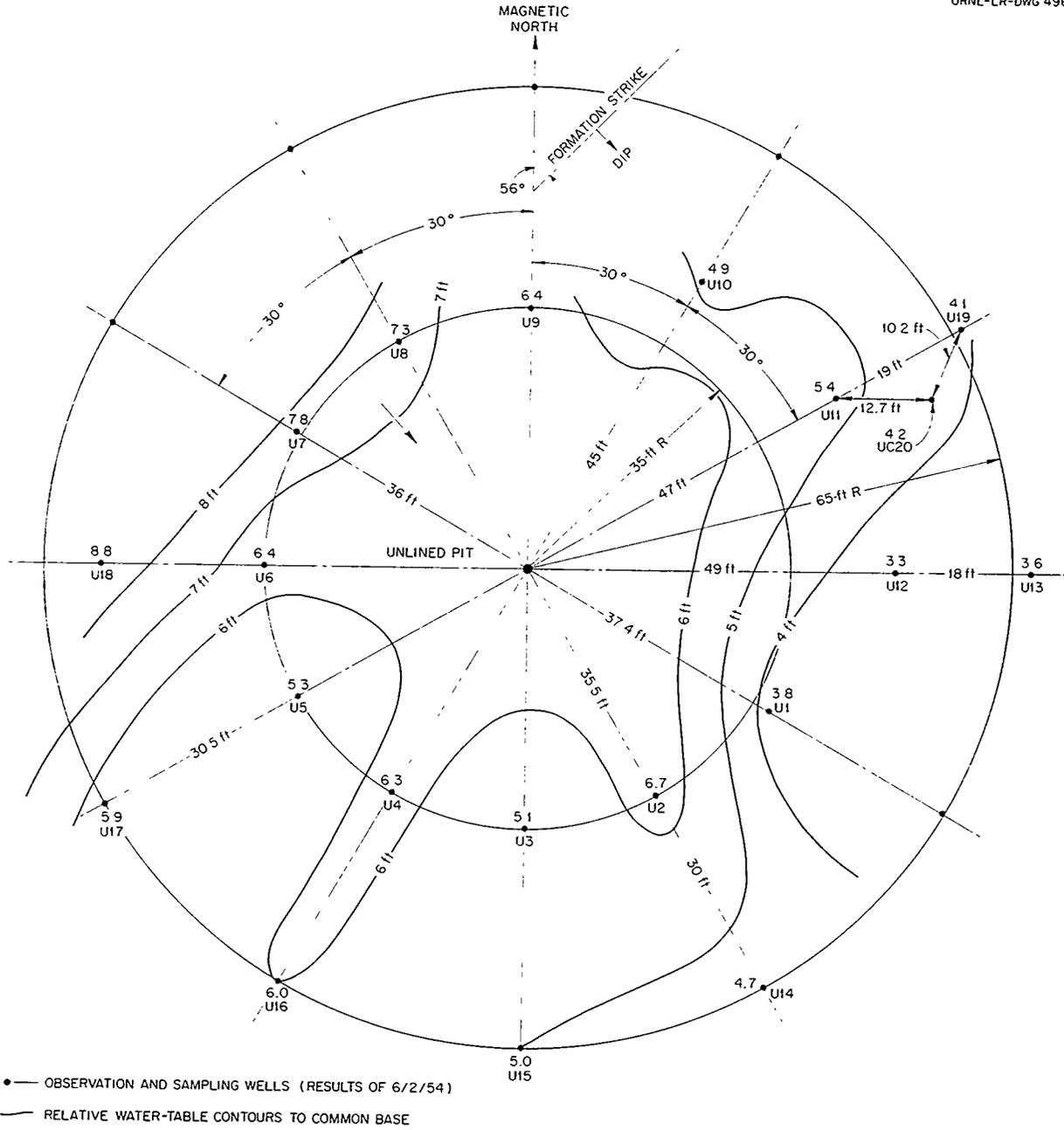


Fig. 11. Results of Localized Ground-Water Recharge on Water-Table Contours.

NITRATE AND URANIUM ANALYSIS

ALL RESULTS IN PARTS PER MILLION)

LABORATORY	9/14/54 - LABORATORY		9/13/54 FIELD NITRATE
	URANIUM	NITRATES	
1.8	12.0	1.0	10+
1.1			DRY
1.8			+
0.5	1600	0.6	10+
1.4	214	0.7	10+
0.9			DRY
0.8			+
0.8			DRY
1.4			DRY
1.4			DRY
0.9			+
0.4			+
0.4			+
0.9			+
0.9			+
0.4	1990	9.0	10+
0.4			+
0.9			+
0.9			+
1.8			+
	<1.0	1.1	5-
	1.0	1.0	5-
	<1.0	1.3	5-
	55.0	0.5	10+
	<1.0	0.8	5-
	19,210	31.0	10+
	1.0	2.0	5-
	13,000	2.3	10+
	17.0	0.6	10+

Uranium.



Two core borings are being made in order to define down-dip movement, to locate a potential main stream of chemical pollutant, and to provide samples for uranium analyses.

#### Waste-Storage Pits

A new operational radioactive-waste pit (No. 3) adjacent to waste pit No. 2 was completed and placed into service January 24, 1955. Four wells located around the pit will be used initially for observing the direction and rate of movement of chemical and radiochemical pollution. To detect any down-dip movement of the waste, one well was located normal to the formation strike and drilled to a depth of 172 ft; this depth was necessary to intercept the bedding planes exposed in the pit bottom.

Water samples for chemical analysis have been collected from the four wells. The wells have also been radiologged for background determinations by use of a trailer-mounted G-M probe.

A remote-registering water-stage recorder has been installed to give a continuous record of liquid levels in the waste pit.

To estimate the volume of seepage from the pit, an evaporation pan and a rain gage have been located adjacent to the pit. The difference between the liquid gain by waste input and rainfall and the liquid loss by evaporation will indicate the approximate volume of seepage.

#### CHEMISTRY AND SOILS ENGINEERING

C. P. Straub (USPHS)    E. R. Eastwood  
B. Kahn                    T. W. Bendixen (USPHS)  
T. W. Brockett            M. I. Goldman (USPHS)  
                                 H. L. Krieger (USPHS)

#### Chemical Laboratory Studies

Procedures have been developed for determining the quantities of cesium, strontium, yttrium, rare earths, ruthenium, zirconium, and niobium radioisotopes adsorbed on soils. The soil is leached repeatedly with the appropriate acid (nitric for strontium, yttrium, and the rare earths; hydrochloric plus oxalic for zirconium and niobium; and sulfuric for cesium and ruthenium), carriers are added, and the radioisotopes are separated and identified by radiochemical methods.

The adsorptive behavior of local soils with respect to the major long-lived fission products was studied. It was found that little adsorption

of the isotopes named above occurred on soils saturated with carrier solutions of these isotopes, with the exception of zirconium and niobium, from the 0.2 M  $\text{HNO}_3$  and 1.6 M  $\text{Al}(\text{NO}_3)_3$  solution; but in aqueous solutions ( $\text{pH} > 3$ ) removal (with the exception of cesium) followed that predicted from the Hofmeister lyotropic series. For the  $\text{H}^+$  saturated soil, for example, the order of removal was  $\text{Nb}^{95} = \text{Zr}^{95} < \text{Cs}^{137} < \text{Ru}^{106} < \text{Y}^{90} < \text{Sr}^{90}$ . The adsorptive capacity of soils for cesium as a function of the cesium concentration was determined in an effort to explain the greater tenacity of cesium retention by soils when cesium is in lower concentrations.

Because of the high cost of making basic the nitric acid-aluminum nitrate solution described above and because of the excessive volume of  $\text{Al}(\text{OH})_3$  precipitated during neutralization, methods were studied for precipitating in acid solution the various radioisotopes present. It was found that cesium could best be coprecipitated with cold copper ferrocyanide, ruthenium with hot copper ferrocyanide, strontium with cold barium sulfate, and yttrium and the rare earths with cold cerium oxalate from a diluted solution; zirconium and niobium could be carried down by several precipitates. More than 90% of each of the radioisotopes was removed by the designated process.

A study of cesium in low concentrations showed no radiocolloidal properties of cesium. It was found that filter paper had the capacity to adsorb cesium and that this capacity depended on the ionic form of the solution with which the paper is saturated and also on the ionic strength of the cesium solution. This capacity was determined for Whatman No. 40 paper.

Standard radiochemical methods for the determination of barium and strontium were adapted for use in the analysis of low concentrations of these radioisotopes in natural waters and sewage. The sewage is digested with perchloric acid and nitric acid. The strontium and barium radioisotopes are carried on small amounts of strontium and barium carriers and on the calcium normally found in water and sewage, the precipitation being that of the carbonates in basic solution. The strontium and barium are separated from the calcium by treatment with anhydrous acetone.

#### Soils and Engineering Studies

The use of Tennessee ball clay as a liner material was investigated. With an alkaline waste

solution the permeabilities of the plastic limit pack and dry pack apparently stabilized at  $k_{20}$  values of  $5 \times 10^{-9}$  and  $1 \times 10^{-8}$  cm/sec, respectively. As the construction of Lagoon No. 3 progressed, various soil and core samples were collected and tested. Preliminary test results on these samples indicate a permeability coefficient of  $3 \times 10^{-3}$  cm/sec for vertical samples and of about  $4 \times 10^{-3}$  and  $1 \times 10^{-3}$  cm/sec for samples parallel and normal to the dip, respectively. Permeability studies of asphalt liner materials were undertaken, and, after 61 days of testing, these materials were found to have a  $k_{20}$  value of about  $5 \times 10^{-11}$  to  $10^{-10}$  cm/sec in either acid or alkaline aluminum nitrate solution.

Field evaluation of some of the liner materials is under way; sections of these liners and other equipment for their study have been built into Lagoon No. 3.

#### AIRBORNE RADIOACTIVITY STUDIES

J. W. Thomas	F. M. Empson
R. L. Bradshaw	R. E. Yoder

The use of open pits, provided with impermeable liners, has been proposed as a means of impounding radioactive waste. The pits would be filled with gravel and covered with a bed of sand to prevent contamination of the atmosphere with radioactive aerosols formed by evaporation from the pit. To study the feasibility of this system, a type 347 stainless steel tank, 20 ft long and 3 ft in diameter, equipped with 20 kw of electric heat, has been installed in the ground at a site near the laboratory area. This "entrainment well" will be half filled with coarse gravel, and a radioactive solution will be introduced into the gravel layer. The solution will be brought to a boil by the electric heaters.

The sand will be added in increments so that its effectiveness as an entrainment separator can be determined. Radioactivity will be added initially in the form of short-lived tracers, followed by high-level activity in the form of waste or dissolver solution.

The accessory equipment required for operation of the well consists of a dissolver tank (installed), condenser and cold trap, sampler, air compressor, water tank and pump, refrigeration machine, air

filter, and vacuum pump. Installation of this accessory equipment is now in progress.

#### ORNL-Area Air Contamination

Studies of the distribution of air contamination in the Laboratory area during various hot chemical operations revealed that the vent from a waste storage tank was a source of contamination. Installation of a Fiberglas filter on this vent during the summer of 1954 resulted in a reduction in area-wide ORNL air contamination by a factor of at least 2 during the last two special isotope-recovery operations, in which the tank is used. Air contamination in the immediate vicinity of the tank was reduced by a factor of 100 to 1000. To make and install the Fiberglas filter cost less than \$100.

#### Packed-Bead-Column Method of Particle-Size Determination

Present methods of particle-size determination (owl, diffusion battery, Tyndall effect, gravity settling, etc.) are inconvenient to use for routine measurements over a wide range of particle size, 0.1 to 1.0  $\mu$  in radius. To provide a rapid and convenient method of particle-size determination in this range, a glass column, 89 cm long and 3.81 cm in diameter, was filled with 1.47-mm-dia lead beads, and aerosol penetration was determined as a function of particle size by using the standard methods listed above. The results are shown in Fig. 13 for spherical di-2-ethylhexyl particles (DOP). In about 5 min a particle-size determination may be made with an accuracy of about  $\pm 10\%$ .

The existence of an aerosol size for maximum penetration through a packed column, reported previously,<sup>5</sup> is confirmed by these data. When the air stream is directed down the column, gravity impingement of the suspended particles is assisted by the flow direction; when the flow is directed upward, gravity settling is hindered by the flow direction. As the particle size becomes smaller, the up- and down-direction curves come closer together; this is due to the decreasing influence of gravity. Finally, at about 0.15  $\mu$  radius the curves come together and rapidly fall off; diffusion is the important mechanism of particle removal at and below this size.

<sup>5</sup>E. G. Struxness *et al.*, *H-P Semian. Prog. Rep.* July 31, 1954, ORNL-1763, p 8-11.

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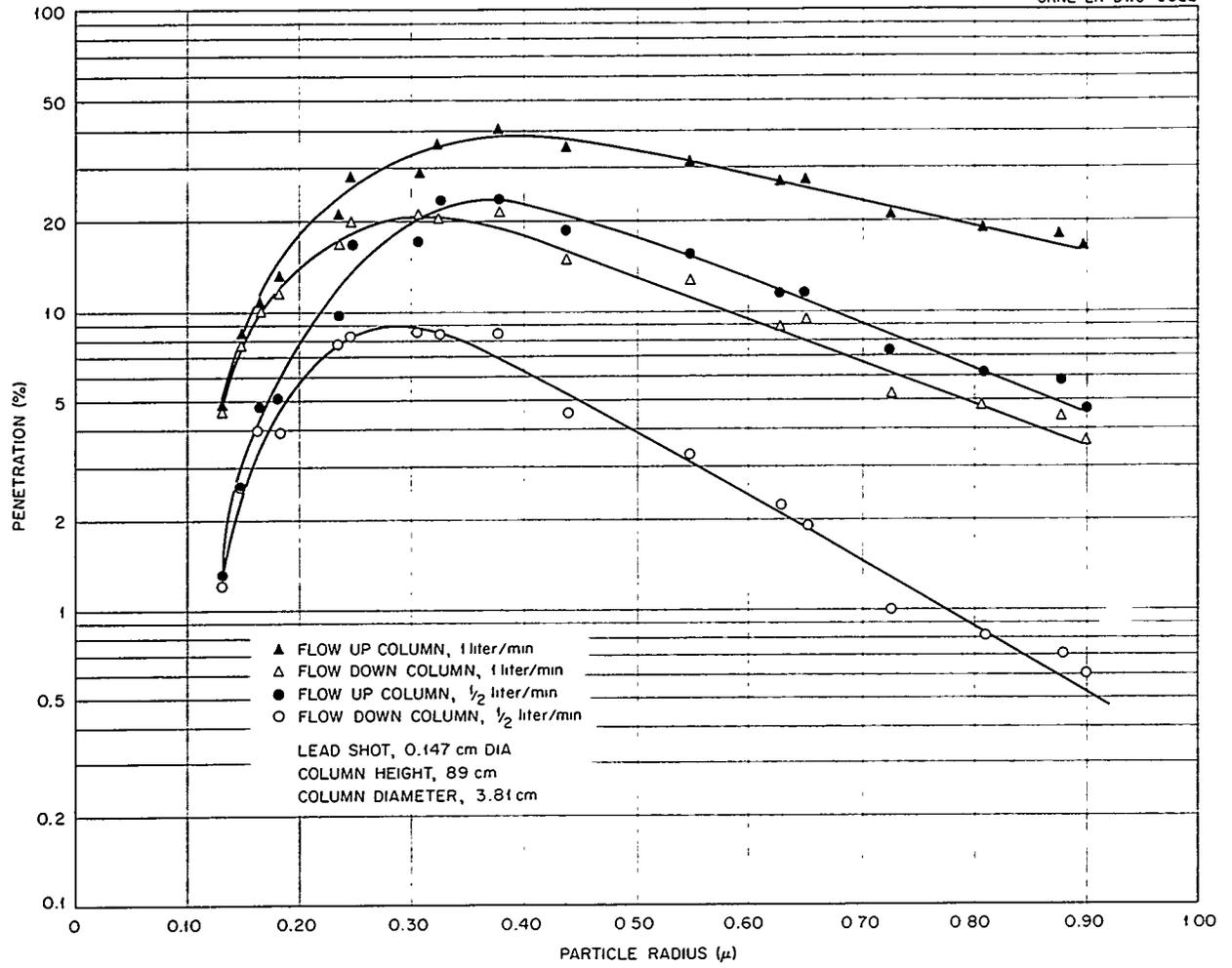


Fig. 13. Aerosol Penetration Through Lead-Shot Column.

## RADIATION DOSIMETRY

G. S. Hurst

## EXPERIMENTAL PHYSICS OF DOSIMETRY

R. D. Birkhoff    H. K. Richards  
 T. E. Bortner    B. G. Saunders  
 J. S. Cheka      W. G. Stone  
 H. H. Hubbell    F. W. Sanders<sup>1</sup>  
 W. F. Patton<sup>1</sup>

## Measurement of Attachment Coefficient

Apparatus has been developed whereby the attachment coefficient for electrons in various gases can be determined. The method involves measuring the decrease in pulse height in an electron-collection pulse chamber with the addition of an electron-attaching gas. Figure 14 shows the effect on the pulse height when oxygen is added to argon in the chamber. It may be shown that the pulse height is a function of electron drift velocity and attachment coefficient. To obtain a unique relation between pulse height and attachment coefficient, the electron drift velocity is measured simultaneously with the pulse height. A very important detail of the experiment is to maintain proper gas purification, especially with such electronegative gases as water vapor and oxygen. Mass spectrographic analyses (performed in the

Mass Spectrometry Laboratory) show that the equipment is now capable of holding gas purity to less than 1 ppm of oxygen or water vapor. Under these conditions, since the attachment coefficient for argon is essentially zero, it was found that the variation of pulse height with electron drift velocity agreed with that predicted on theoretical grounds.

The method may be applied to such counting gases as methane, ethylene, nitrogen, and argon, in which oxygen is present in small amounts. In such cases the average agitation velocity of electrons is determined by the main constituent of the mixture. Thus the coefficient for attachment of electrons to oxygen may be determined for electrons in the range from very low energies up to 8 ev. Even though the data on attachment coefficients are obtained with a parallel-plate chamber, they will apply to the high fields that are encountered with most typical proportional or Geiger counters.

*W* Value of 5-Mev Alpha Particles in Water Vapor<sup>2</sup>

Because of its importance in radiobiological studies, the ionization produced by 5-Mev alpha particles in water vapor has been measured. For this purpose a special parallel-plate ionization chamber was constructed in such a way that it could be held at elevated temperatures, thus maintaining a high water-vapor pressure. The ionization current produced was measured as a function of voltage, and, since water is electronegative, the value for the saturation current was determined by means of the Jaffé recombination theory. The *W* value for water vapor was determined by comparison with the ionization produced in nitrogen and ethylene, for which the *W* values had been previously determined. Both methods of calibration gave a *W* value for 5-Mev alpha particles in water vapor equal to  $37.6 \pm 0.2$  ev per ion pair.

To determine the mechanism for the increased ionization and the lowering of the value of *W* of argon due to slight added impurities,<sup>3</sup> two lines of

<sup>1</sup>AEC Fellows in Radiological Physics.

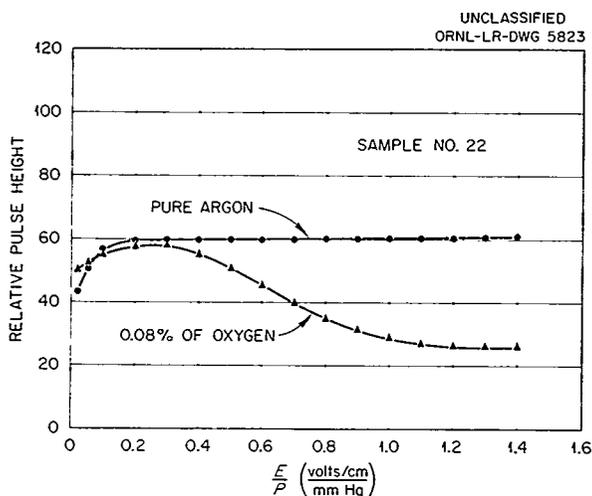


Fig. 14. Pulse Height in Pure Argon and in Argon-Oxygen Mixture.

<sup>2</sup>Thesis work done under AEC Radiological Fellowship, 1953-1954.

<sup>3</sup>C. E. Melton, G. S. Hurst, and T. E. Bortner, *Phys. Rev.* 96, 643-645 (1954).

investigation are being followed. A large parallel-plate ionization chamber with an internal plutonium alpha source is being used to determine the effect of adding various gases to argon at pressures ranging from 750 down to 25 mm Hg. Ethane additions of 1 and 3% have been used, and the increased ionization effect has been found to be non-pressure-dependent. The ionization of argon and of the mixtures is constant down to the pressure at which the alpha particles begin to escape from the sensitive area of the chamber. Below this pressure the amount of ionization drops rapidly. The relative increase due to the added impurity remains fairly constant in the pressure range used. Other impurities will be tested in the same manner.

A spectrometer is used to determine whether any lines of the argon spectrum are attenuated or removed by the addition of the impurity. If either of these occurs, it would indicate that some energy formerly given off as radiation is being expended in ionizing collisions.

#### Energy Losses of Electrons in Foils

**Beta Spectrometer.** A technique for making thin gold-ring sources has been developed. Such sources are now irradiated weekly in the LITR and have made possible a study of the internal conversion spectrum from the  $\text{Hg}^{198}$  gamma ray. Tentative conversion ratios are  $K:L:M:N$  of 32.2:11.9:3.2:1 and  $L_I + L_{II}:L_{III}$  of 5.9. A report describing the spectrometer and its automatic control features has been written and will be submitted to *The Review of Scientific Instruments*.

Data have been taken on the straggling of the  $K$  conversion electrons from  $\text{Hg}^{198}$  in aluminum and silver. Additional foils of lead and copper have been made in thicknesses useful for measurements in these metals. The automatic controls permit the spectrometer to gather data continuously around the clock.

**Accelerator.** Experimental work on the excitation of the conduction electron plasma in metals has been completed. Foils of aluminum, magnesium, and copper have been inserted in the electron beam of the accelerator, and the resulting discrete energy losses have been investigated with an energy resolution of 2 in  $10^5$  for bombarding energies from 15 to 115 keV. The energy necessary to excite the plasma has been measured, and the cross section has been determined as a function of the incident

energy of the electrons. Evaluation of data is under way.

Measurements made previously on the distribution of dose as a function of depth for 100-keV electrons striking a slab of aluminum have been continued for very small depths, where the dose is greatest, and for large depths comparable to the range of the incident electrons. When these present measurements on aluminum are completed, the new higher precision ion chamber which has been constructed will be installed. Dose distributions in a variety of materials and at incident electron energies from 10 to 250 keV will then be determined.

#### X-Ray Exposure Facility

The x-ray exposure facility, mentioned previously, built around a commercial 250-kV constant-potential x-ray machine is now complete and calibrated. The machine can be quickly set for routine exposures at dose rates varying from a few milliroentgens per hour up to several hundred thousand roentgens per hour, at x-ray energies from 5 or 10 kV up to 250 kV. The energy spectrum is accurately known at seven different voltages and can be quickly determined at other voltages by means of a complete set of calibrated filters of aluminum, copper, tin, and lead. Broad or narrow spectral distributions can be easily obtained by the use of these filters.

A standard free-air ionization chamber with its controls, in addition to a large set of Victoreen condenser r-meters, permits quick and accurate dose measurements. A dose-rate meter assists in setting the machine for any dose rate obtainable with the improved x-ray controls, which stabilize the current at any value from 20  $\mu\text{a}$  to 20 ma.

Exposures have been made in the past six months for other members of this section, for the Applied Health Physics Section, and for visitors from the Electric Boat Div. and the U.S. Army.

#### Film Dosimetry

A series of exposures to x and gamma rays has been made on Eastman type K and Blue Brand x-ray films to determine how the variation in sensitivity of the films with radiation energy compares with that of other types tested previously. A report on all this work is being prepared for publication.

#### Ion-Recombination Errors in Pocket Chambers

Apparatus has been constructed to determine whether the errors observed by measuring current

flow through an irradiated pocket chamber are the same as those measured by the discharge method mentioned previously.<sup>4</sup>

A study of the theory, carried out with the aid of the Theoretical Physics Group of this section, indicates that the results obtained by the discharge method do not agree with the theory or with results obtained by current-flow methods elsewhere, although the process is too complex for accurate theoretical treatment.

**Detection of Ionizing Radiation by Frequency Variation with the Use of the Ferroelectric Effect**

In the work on the detection of ionizing radiation by frequency variation, the ion chamber has been replaced by a Geiger counter (Fig. 15).  $V_1$  is a subminiature tube in a Clapp circuit, the frequency of which is controlled by a series-resonance quartz crystal. The circuit contains the ferroelectric capacitance  $C_F(l)$  as another frequency-controlling element. The capacitance is connected at one side to the 600-v tap of the voltage supply of the Geiger counter. The other side of  $C_F(l)$  is connected over

$R_2$  and  $R_1$  to the 900-v outlet of the voltage supply. Therefore the polarization voltage at  $C_F(l)$  is 300 v, producing a capacitance reduction and a frequency increase over the values at zero voltage. When ionizing radiation enters the counter, the current pulses will produce a voltage drop across  $R_1$  and thereby reduce the voltage at  $C_F(l)$ . By adding a capacitance across a portion of  $R_2$ , the pulses can be integrated and produce a nearly constant voltage decrease at  $C_F(l)$  and a frequency increase. The leakage of the ferroelectric material becomes unimportant in this construction, and the only undesirable feature remaining is the temperature dependence of barium titanate. New materials with zero temperature coefficient will eliminate this limitation. This circuit is shown in Fig. 15.

**Exposure of Quartz Crystals to Neutrons and  $Co^{60}$  Gamma Rays**

Quartz-crystal blanks without plating or cement were used exclusively in tests on the exposure of quartz crystals to neutrons and  $Co^{60}$  gamma rays, since it was suspected that previous results were produced, at least partially, by decomposition of the cement or by oxidation of the silver plating.

<sup>4</sup>H. H. Hubbell *et al.*, *H-P Semiann. Prog. Rep.* July 31, 1954, ORNL-1763, p 7.

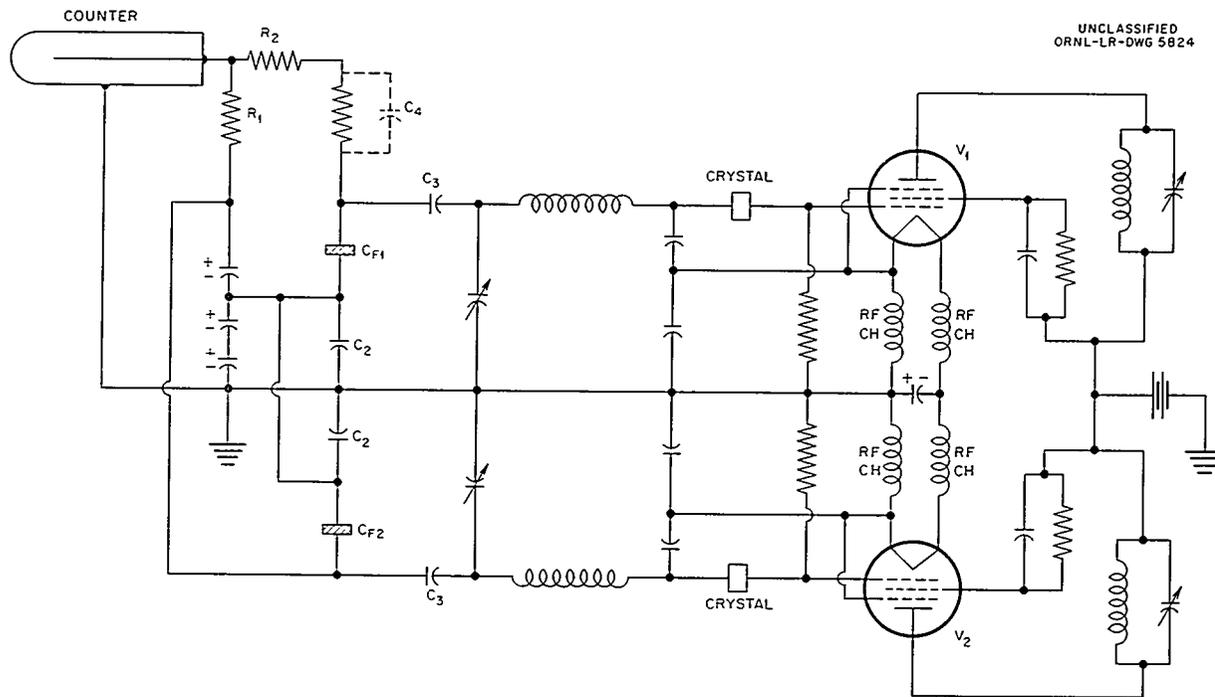


Fig. 15. Frequency-Variation Circuit for Detection of Radiation by Use of the Ferroelectric Effect.

The crystals were placed in a jig between two air-gap electrodes, and a slight pressure was exerted on this assembly and controlled by a positioning screw, thus keeping the pressure constant.

Eight crystals were exposed in the reactor to  $1.55 \times 10^{17}$  fast neutrons,  $3.45 \times 10^{17}$  thermal neutrons, and  $10^8$  r of gamma rays. All crystals showed a darkening in color. Usually there were certain striated spots which were darker than the rest of the surface. The frequency of all the crystals increased by approximately 300 cps. The lattice constants did not change within the limits of measurement. The optical density [ $\log(1/T)$ , where  $T$  = transparency] increased by a factor of 2 to 3. Exposure of the crystals to an ultraviolet lamp did not change the transparency.

After the crystals were annealed at  $200^\circ\text{C}$ , the frequency decreased again by 10 to 50 cps. At  $250^\circ\text{C}$  another slight annealing effect was found. At  $420^\circ\text{C}$  the crystal frequencies returned to approximately their original values.

Another exposure of quartz crystals to  $3.9 \times 10^{17}$  fast neutrons and  $2.15 \times 10^8$  r of gamma rays resulted in frequency increases of 500 to 600 cps. This time the equivalent resistance was also measured, and an increase of from 30% to more than 100% was found.

Experiments with gamma rays from  $\text{Co}^{60}$  up to  $5.5 \times 10^8$  r did not show the significant frequency change of the quartz crystals expected from previous measurements with mounted and silverplated crystals. The experiments are being continued.

#### THEORETICAL PHYSICS OF DOSIMETRY

J. Neufeld R. H. Ritchie  
W. S. Snyder

#### Path-Length and Energy Distribution for Slowly Moving Ions

The problem of the distribution in path length and energy of heavy, slowly moving atoms or ions [ $v \ll (c/137)$ ] in matter has been treated under the idealized assumption of constant cross section and uniform scattering in relative coordinates. Using the Boltzmann transport equation and assuming that many collisions have occurred, it is found that the flux of particles  $\psi$  in  $ds$  at  $s$  and in  $du$  at  $u$  is

$$\psi ds du = \frac{ds du}{4M} \sqrt{\frac{3l}{2\pi s}} \exp \left[ -\frac{3l}{8s} \left( \frac{u}{2M} - \frac{s}{l} \right)^2 \right],$$

where

$M$  = ratio of the mass of the stopping atom to that of the incident atom ( $M \ll 1$ ),

$s$  = path-length variable,

$l$  = mean free path,

$u = \ln(E_0/E)$ ,

in which  $E_0$  is the energy of the particle at the beginning of its path.

An assumption which is more realistic at somewhat greater energies of the incident particle is that the mean free path for collision varies inversely with the energy. This case may be treated by an immediate generalization of the above equation, if the mean free path does not vary greatly over the collision interval. The results do not differ greatly from those of Bohr<sup>5</sup> for this case. The results have been compared with range-energy data in the literature, and good agreement has been obtained in view of the assumptions made. A program to compute more exact values of the differential cross section for elastic collision of slowly moving ions is planned.

#### Columnar Recombination

The problem of columnar recombination when diffusion predominates over recombination has been treated by Jaffé.<sup>6</sup> A variational scheme is proposed which gives Jaffé's results with the use of a one-term trial function. The Lagrangian density  $\mathcal{L}$ , which yields the partial differential equation describing the density of ions  $n(\bar{r}, t)$ , is

$$\mathcal{L} = \frac{\alpha}{3} n^3 + n \frac{\partial n}{\partial t} + \frac{\kappa}{2} (\bar{\nabla} n)^2,$$

where  $\alpha$  and  $\kappa$  are the recombination and diffusion constants, respectively. The process of extremizing the Lagrangian is carried out on the assumption that  $\partial n / \partial t$  has its correct value.<sup>7</sup> Numerical work on more accurate trial functions is planned.

#### Passage of Charged Particles Through a Dispersive Medium

Exact calculations have been made to corroborate the validity of some assumptions made by

<sup>5</sup>N. Bohr, *Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd.* 18, No. 8, 138 (1948).

<sup>6</sup>G. Jaffé, *Ann. Physik* 42, 303 (1913).

<sup>7</sup>P. M. Morse and H. Feshbach, *Methods of Theoretical Physics*, McGraw-Hill, New York, 1953.

Bohr<sup>8</sup> on the basis of some quantitative and intuitional considerations. These assumptions are as follows:

1. The energy loss of the incident particle due to the transverse electromagnetic field surrounding the particle is identical with the energy dissipated as Cerenkov radiation.

2. For an incident particle of relativistic velocity, the electrostatic effect of the surrounding electrons is negligible, and the main factor in the screening is due to the electromagnetic interactions which limit the impact parameter to a value  $c/\Omega$ , where  $\Omega = (4\pi ne^2/m)^{1/2}$  and  $n$  is the electron density in the medium.

The calculations substantiate the assumptions made by Bohr.

#### Neutron-Damage Estimates with RBE Considered as a Function of Linear Energy Transfer

A program has been prepared for computing on the Oracle neutron damage to tissue where the RBE values used are based on the concept of specific ionization or linear energy transfer. The use of these RBE assignments is in accord with the recommendations of the National Committee on Radiation Protection in its Handbook 59, and the project to estimate the damage on the basis of these recommendations has been undertaken at the request of the Committee. The program, as presently constituted, will use the Monte Carlo method of computing the neutron histories and would seem to require about 150 hr of computing time to give estimates of damage for neutrons of energies from 10 Mev to thermal energies.

#### Depth-Dose Curves in Tissue for Neutrons of Intermediate Energies

Depth-dose curves in a tissue slab irradiated by a normally incident broad beam of neutrons have been computed for neutron energies of 100, 20, 5, and 0.1 kev. The slab thickness was taken as 30 cm, and the RBE factors used to convert from absorbed energy to biological damage were taken as 1 for energies absorbed from gamma rays, as 10 for energies absorbed from recoil protons, and as 20 for energies absorbed from recoil carbon, nitrogen, or oxygen atoms. The maximum damage

<sup>8</sup>A. Bohr, *Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd.* 24, No. 19, 1-52 (1948).

was found to be  $7.2 \times 10^{-9}$ ,  $2.2 \times 10^{-9}$ ,  $1.2 \times 10^{-9}$ ,  $1.4 \times 10^{-9}$  rem/neutron for the respective energies. This maximum damage occurred at the irradiated surface for the 100- and 20-kev beams and at a depth of about 3 cm for the 5- and 0.1-kev beams. A report containing a more detailed analysis of the data is being written.

#### DOSIMETRY APPLICATIONS

F. J. Davis                      J. A. Harter  
J. M. Garner                     W. A. Mills  
P. W. Reinhardt

The Division has developed two methods of measuring the fast-neutron tissue dose. The first one of these, employing the proportional counter designed with the Bragg-Gray principle, has been sufficiently described.<sup>9</sup> A later method measures the fast-neutron spectrum, from which tissue-dose interpretation may be made by means of a first-collision curve. This method uses activation and threshold detectors and is described elsewhere.<sup>10</sup>

Recent comparisons of the two methods at ORNL and at LASL indicate that the two methods of dosimetry give dose measurements which are in excellent agreement. The proportional counter is a fundamental instrument which may be designed to fit any application ranging from the measurement of dose rates less than the maximum permissible flux of neutrons to give 0.3 rem per 40 hr to applications in measuring the dose in radiobiological experiments, even with the cyclotron or other high-intensity neutron sources. The threshold-detector method in its present form can be applied with great advantage to extremely high bursts of neutrons — for example, weapons testing — where other methods of fast-neutron dosimetry fail. An additional advantage of the threshold-detector method is that spectral measurements are obtained which permit not only a calculation of the dose but also an interpretation of the energy-distribution function vs specific ionization or linear energy transfer (LET).<sup>11</sup>

<sup>9</sup>G. S. Hurst, *Brit. J. Radiol.* 27, 353-357 (1954).

<sup>10</sup>G. S. Hurst *et al.*, ORNL-1671 (March 30, 1954) (classified).

<sup>11</sup>J. W. Boag, *Radiation Research* 1, No. 4, 323 (1954).

**EDUCATION, TRAINING, AND CONSULTATION**

E. E. Anderson

**AEC FELLOWSHIP PROGRAM**

M. F. Fair                      M. R. Ford

The 1953-1954 group of 21 AEC Fellows in Radiological Physics completed their training in applied health physics at the Laboratory on August 27, 1954. Two of the fellows, who were granted six-month extensions of their fellowships, remained at the Laboratory to engage in research to fulfill the requirement for a master's degree. W. F. Patton has completed his problem, on the  $W$  values in water vapor; F. W. Sanders is working on the problem of determining the mechanism by which the value of  $W$  of argon is lowered when slight impurities are added.

The new group of 21 AEC Fellows (1954-1955) began their training under the fellowship program at Vanderbilt University on September 27, 1954.

**OTHER TRAINING ACTIVITIES**

M. F. Fair                      M. R. Ford

One member of the Education, Training, and Consultation Section is conducting two courses

(each 1 hr per week) for nine months in apprentice mathematics for the Training Division.

The weekly and special orientation lectures in health physics are the responsibility of the Education, Training, and Consultation Section of the Division.

Two courses of five weeks each in internal dose were given for members of the Health Physics Division.

Special lecture and discussion periods in health physics were held for: (1) members of the Chemical Technology Division, (2) a group of aircraft engineers, and (3) representatives from Bendix Aviation Corp., Detroit.

A two-week advanced course in health physics was held for three members of the Nautilus crew, one member of the Health Physics Staff of Electric Boat Div., and one U.S. Army officer from Fort McClellan, Alabama.

One laboratory experiment on health physics instrumentation was conducted for ORSORT.

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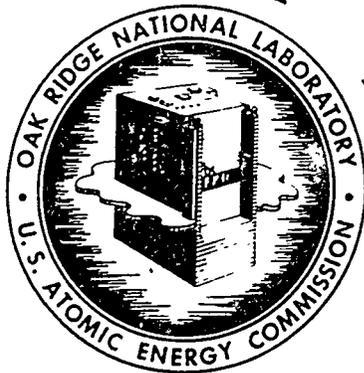
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## CONTENTS

APPLIED RADIOBIOLOGY .....	1
Distribution and Excretion of Uranium in Man .....	1
Ecology .....	7
Urinalysis Research.....	10
Distribution of Radioisotopes in Animal Tissue .....	10
Isotopic Distribution in Man .....	10
SANITARY-ENGINEERING RESEARCH .....	12
Field Investigations and Explorations (Liquid-Waste Disposal).....	12
Chemistry and Soils Engineering .....	16
Airborne Radioactivity Studies.....	19
RADIATION DOSIMETRY .....	20
Experimental Physics of Dosimetry.....	20
Theoretical Physics of Dosimetry .....	20
Dosimetry Applications .....	26
EDUCATION, TRAINING, AND CONSULTATION.....	31
AEC Fellowship Program .....	31
Other Training Activities .....	31
PUBLICATIONS .....	32
PAPERS .....	33
LECTURES .....	34

# HEALTH PHYSICS DIVISION

## SEMIANNUAL PROGRESS REPORT

### APPLIED RADIOBIOLOGY

E. G. Struxness

#### DISTRIBUTION AND EXCRETION OF URANIUM IN MAN

S. R. Bernard                      J. R. Muir  
J. C. Gallimore                  G. J. Dodson  
G. W. Royster, Jr.                N. L. Gillum  
C. S. Banks

The intravenous administration of fissionable uranium in man for its possible application to neutron-capture therapy<sup>1-3</sup> has continued during the period of this report. To date, eight terminal brain-tumor patients have been studied, seven of which have died. Blood, cerebrospinal fluid, urine, and fecal samples were collected at Massachusetts General Hospital in accordance with established routine and sent to ORNL for analysis. Autopsy tissue samples were obtained in six of the seven terminations. Table 1 summarizes the pertinent injection data.

The data which have been collected on the first six patients have been tabulated and plotted. Figure 1 shows graphs of the disappearance of uranium from the blood. On an average, 99% of the injected dose is removed from the circulation in about 20 hr, assuming uniform distribution at injection time and a blood volume of 7.14% of body weight. Once reduced, the blood values remain relatively constant until time of expiration. Figure 2 shows the urinary excretion data obtained in this study. These data are presented as log-log plots to compare the excretion rates on an identical time scale. Most of the excretion takes place in the first 24 hr after administration. Essentially all the uranium is excreted in the urine, since less than 1% of the injected dose is found in the feces.

Table 2 lists the autopsy and biopsy findings in terms of per cent of injected dose per gram of tissue. This method of reporting values was necessary because it was impossible to obtain weights of all the organs and tissues sampled. If the weight values of standard man<sup>4</sup> are assumed, and if these values are converted to per cent of injected dose per organ or per tissue, it is evident that all soft tissues, excluding kidney, contain approximately 20% at 60 hr postinjection and less

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<sup>1</sup>W. H. Sweet and M. Javid, *J. Neurosurg.* 9, 200-209 (1952).

<sup>2</sup>M. Javid, G. L. Brownell, and W. H. Sweet, *J. Clin. Invest.* 31, 604-610 (1952).

<sup>3</sup>L. E. Farr *et al.*, *Am. J. Roentgenol., Radium Therapy Nuclear Med.* 71, 279-291 (1954).

<sup>4</sup>S. Kinsman *et al.*, *Radiological Health Handbook*, NP-4071, p 127 (Sept. 1952).

TABLE 1. SUMMARY OF INJECTIONS IN THE DISTRIBUTION AND EXCRETION STUDY

Patient	Expiration Time (days)	Injection Compound	Injection Dose ( $\mu$ c)	Autopsy Samples Obtained
I	2 1/2	UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	12.2	Yes
II	74	UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	9.8	Yes
III	566	UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	10.1	Yes
IV	136	UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	33.4	No
V	139	UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	47.2	Yes
VI	18	UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	3.3	Yes
VII		UCl <sub>4</sub>	2.6	
VIII	21	UCl <sub>4</sub>	3.1	Yes

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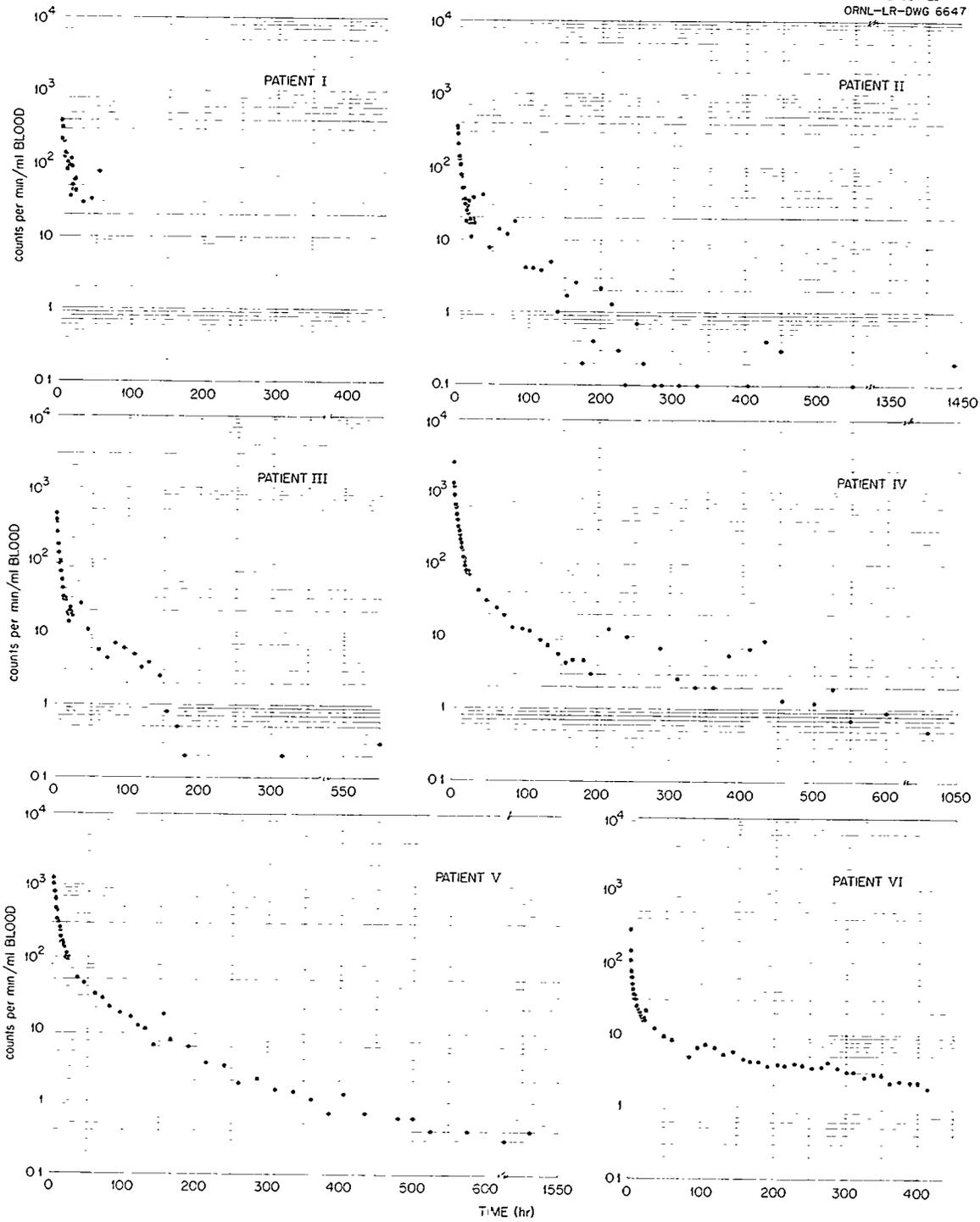


Fig. 1. Uranium Disappearance from Blood.

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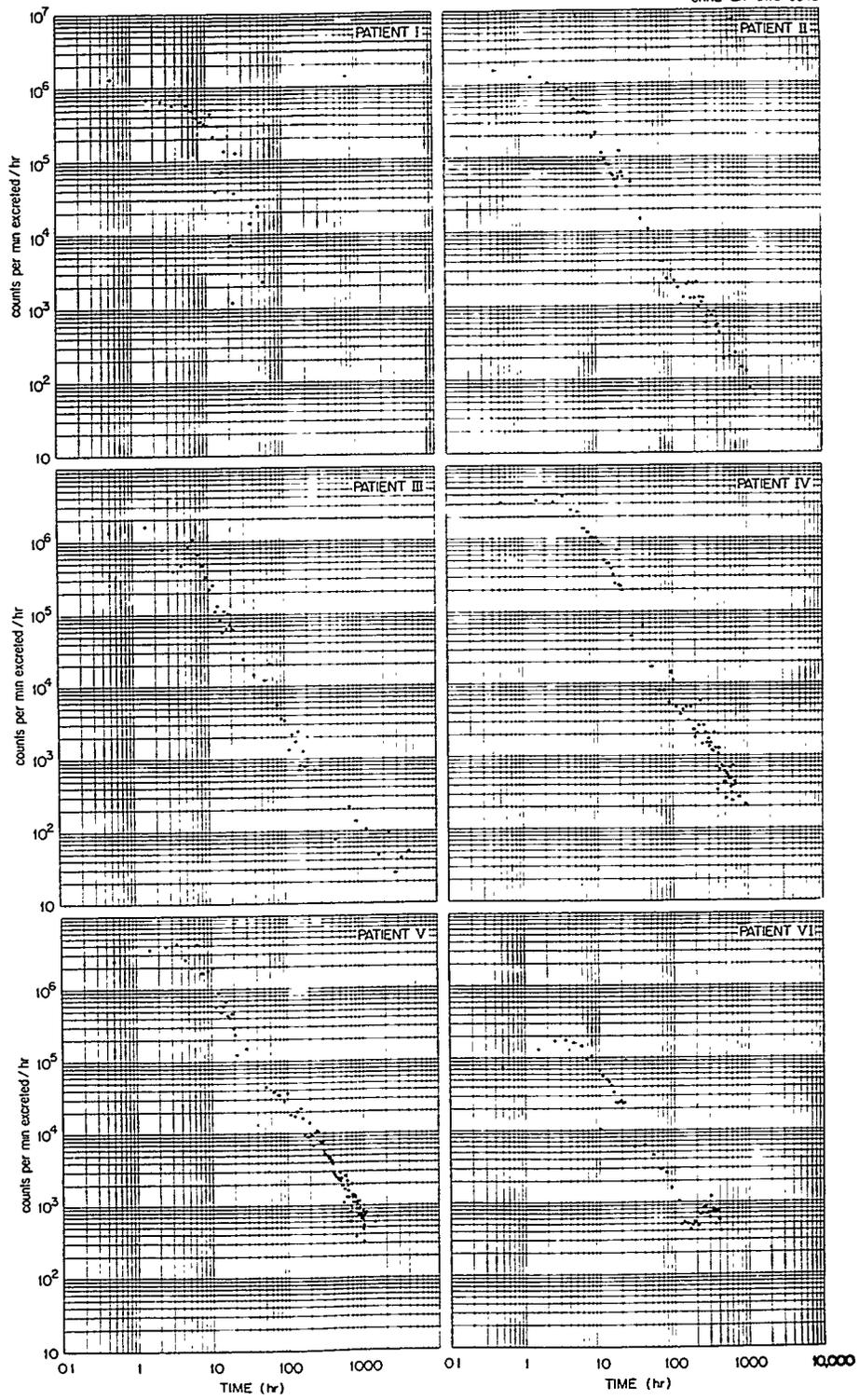


Fig. 2. Urinary Excretion of Uranium.

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than 1% at 3100 hr. These residual percentages are shown in Fig. 3.

cumulating the per cent of injected dose in urine and subtracting from 100, is shown in Fig. 4 and is seen to be slightly different for each patient.

Total body content of uranium, determined by

TABLE 2. BIOPSY AND AUTOPSY RESULTS FOR PATIENTS INJECTED WITH U(VI)  
PER CENT OF INJECTED DOSE PER GRAM  $\times 10^{-4}$

	Patient Number					
	I	II	III	IV	V	VI
Bone Biopsy Results						
0-24 hr	8.7	11.2	12.9	10.8	8.0	8.8
	7.9	6.7	3.3		6.3	9.3
	23.4	4.4	2.0		5.9	
	16.2	15.9				
	8.2					
	13.4					
	17.9					
24-48 hr	7.0				2.2	
	15.1					
Autopsy Data						
Expiration Time (days)	2 $\frac{1}{2}$	74			139	18
Organ						
Adrenal gland	11.1	1.6			0.6	6.0
Aorta	7.1				0.01	7.1
Bladder	2.2	0.1			0.09	
Brain					0.05	13.8
Brain (frontal lobe)	270.8	0.2				
Brain (parietal lobe)	28.2					
Brain (temporal lobe)		0.1				
Cartilage					0.1	
Cartilage (rib)		0.9				
Cartilage (tracheal)						3.5
Fat (subcutaneous)	0.6					0.6
Fat (from skin)						8.7
Femur (II & V bone from shaft)		0.5			0.6	
(I & VI bone from distal end)	5.8					4.4
Gall bladder	4.8				0.2	13.7
Heart	2.0	0.1			0.2	0.7
Intestine (small)	2.1	0.3			0.1	1.8
Kidney	554.0	22.1			39.3	239.9
Liver	10.4	1.4			0.9	6.5
Lung	4.7	0.3			0.2	3.6
Lung (necrotic)	23.9					
Marrow (bone)		0.1			0.2	
Muscle	0.4	0.3			0.09	1.0
Muscle (psoas)						0.3
Pancreas	96.0	1.2			0.08	1.1
Prostate		0.2			0.2	1.6

TABLE 2 (continued)

Organ	Patient Number					
	I	II	III	IV	V	VI
Rib	19.7	2.6			0.9	42.1
Skin	3.0	0.2			0.1	1.7
Skull	7.9	11.9			1.9	
Spleen	18.8	3.6			0.5	7.7
Sternum					0.5	
Stomach	3.2	0.1			0.05	0.8
Testis		2.1			0.05	2.9
Thyroid		0.1			0.07	1.5
Tumor (tissue from edge)	24.8	0.6			0.4	
Tumor (viable)		0.6				
Vertebrae (lumbar)		1.8				
Vertebrae (thoracic)	53.8					

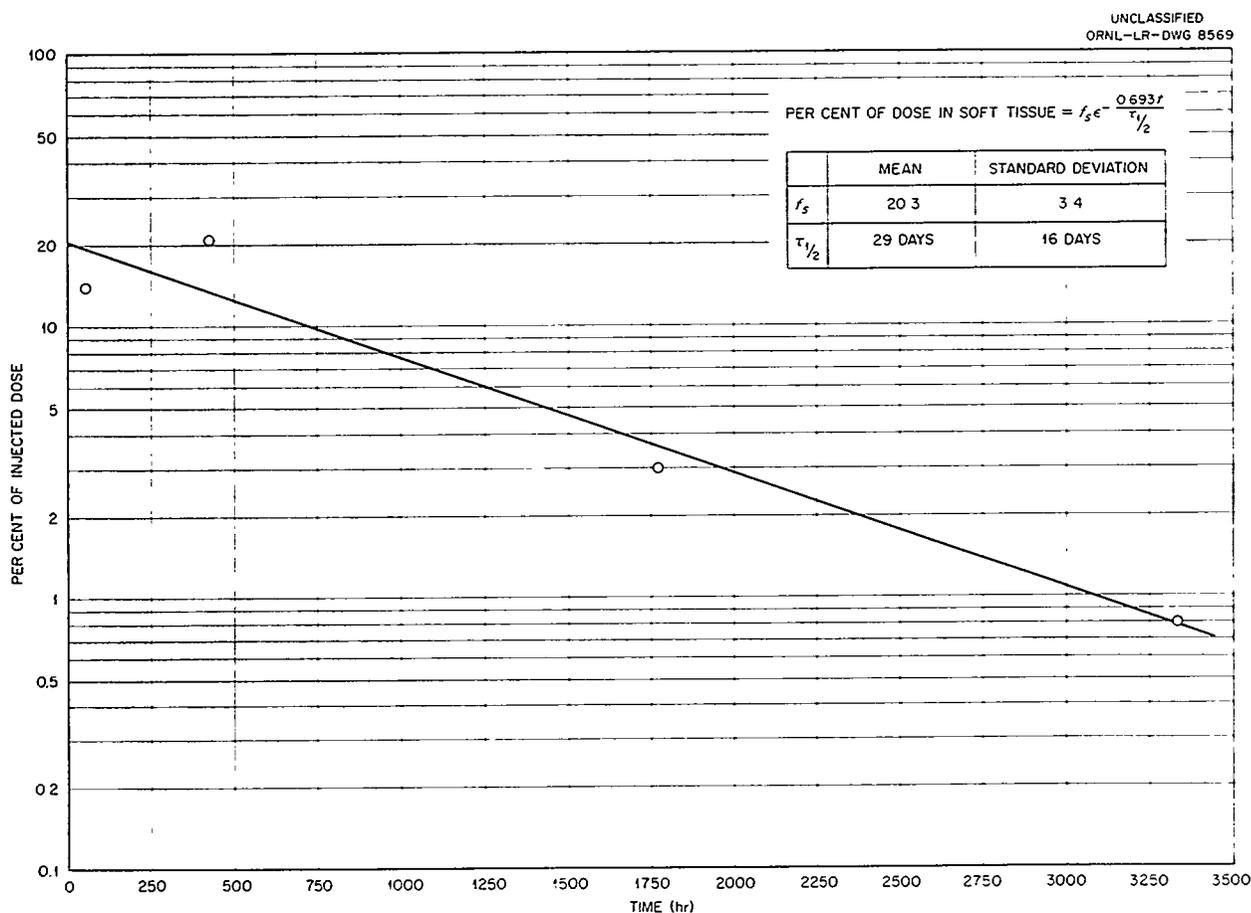


Fig. 3. Per Cent of Injected Dose in Soft Tissues (Other Than Kidney) at Autopsy.

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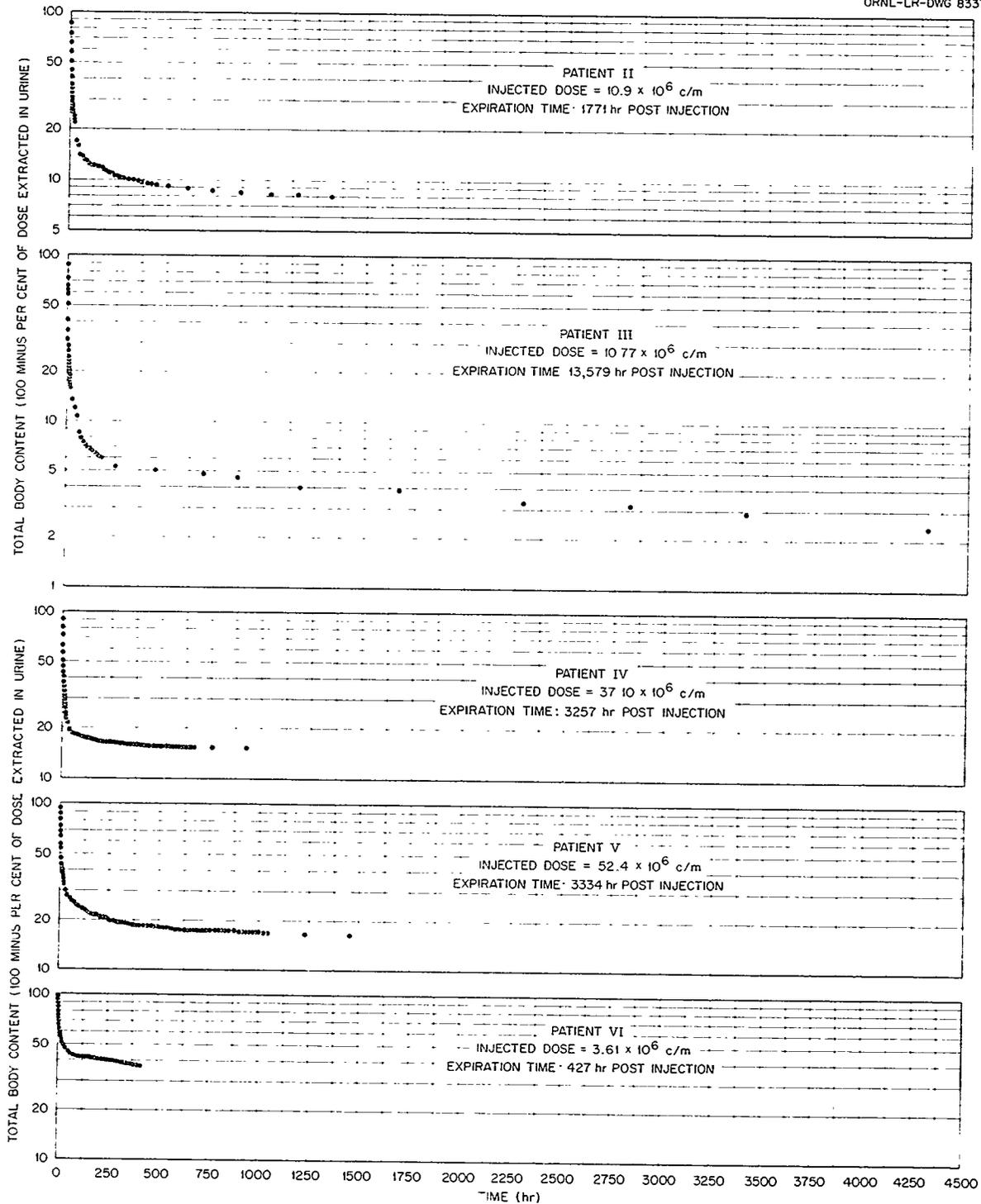


Fig. 4. Per Cent of Injected Dose Retained in the Body as a Function of Time After Injection.

## ECOLOGY

S. I. Auerbach

H. F. Howden<sup>5</sup>            M. D. Engelmann<sup>6</sup>  
 V. L. Sheldon<sup>5</sup>            R. J. Davis<sup>6</sup>

**Studies of the Uptake of Fission Products  
 by Earthworms**

**Uptake of Sr<sup>89</sup> by *Eisenia foetida* (Savigny).** — Earthworms are a group of organisms that play an important role in the maintenance of soil fertility. Their value in this regard was first extensively discussed by Darwin in 1882.<sup>7</sup> More recently, in 1948, their ecology in relation to agriculture has been reviewed by Hopp.<sup>8</sup> These organisms are also important food items in the diets of many higher animals and as such are links in natural food chains.

In view of the ecological significance of earthworms, it was considered advisable to begin a study of the effects on earthworms of the fission products which might, at some future time, be released into the soil environment. The primary objective of the first experiment was to test the ability of certain species of earthworms to take up from local soils and to concentrate the radio-nuclide Sr<sup>89</sup>. The studies were initiated with Sr<sup>89</sup>, not only because it is an important fission product, but also because it has certain technical advantages in an initial series of experiments. These advantages include a relatively short half life and an ease of analysis. The earthworms used in these experiments were the common red worm, *Eisenia foetida* (Savigny),<sup>9</sup> and were obtained from commercial bait stores.

Red-yellow podsolc soil was brought in from the laboratory area, air-dried, and sieved through 10- and 40-mesh screens to yield a soil mass of uniform particle size. Organic matter was provided in the form of pulverized peat. The chemical analysis of this soil was as follows: organic matter, 5%; P<sub>2</sub>O<sub>5</sub>, 31 ppm; K, 11 ppm; Mg, 13 ppm; Ca, 110 ppm; pH, 4.1; total hydrogen, 10 milli-

equivalents per 100 g; cation exchange capacity, 16.82 milliequivalents per 100 g; per cent base saturation, 40.5.

One kilogram (corrected for moisture content) of soil was placed in each of 25 red-clay flower pots. These were divided into 20 experimentals and 5 controls. The experimental pots were subdivided into five series of four pots; each series contained a different activity level of Sr<sup>89</sup>. The isotope was added to the soil by taking aliquots at the required activity level, diluting them to 100 ml with water, and thoroughly slurring this solution with 100-g aliquots of soil from each of the experimental pots. The initial amounts of strontium used were sufficient to produce the following activities (in counts per minute per gram) in each series of pots: 350, 700, 1050, 1400, and 1750 — all at 10% geometry.

After the isotope was mixed with the aliquots of soil, the solutions were dried, pulverized in mortars, and homogeneously blended into the remaining 900 g of soil from each experimental pot, by putting both dry mixtures into a stainless steel cylinder, sealing it, and then rotating it for 15 min on a lathe. The soil was then returned to the pots, and sufficient water was added to bring the soil to optimum moisture. Controls were treated in similar fashion except that the isotope was not added. One day later ten adult worms were added to each of the pots. Moisture was added as needed. After 30 days the pots were examined for the surviving worms. A total of 168 out of an initial inoculation of 250 worms were found after 30 days. Forty-one of the survivors were taken from the experimental and the control pots and were immediately killed and prepared for counting. The remainder were placed in moist sphagnum moss for three days to "scour" their intestinal tracts of any soil that might be within them. This was done because the activity of Sr<sup>89</sup> in the worms was so low that the isotope-containing soil held in the gut might produce misleading results. This was proved to be the case, as is shown by Table 3. After removal from the moss, the worms were sacrificed.

All worms were prepared for counting by digestion in concentrated HNO<sub>3</sub> with H<sub>2</sub>O<sub>2</sub> added. After all the organic material was destroyed, the residue was dissolved with 15 to 20 drops of 1 N HNO<sub>3</sub> and transferred to a stainless steel counting dish of 3.2 mm depth and 25 mm diameter. All samples were counted on the second shelf of a

<sup>5</sup>Research participant.

<sup>6</sup>Temporary summer employees.

<sup>7</sup>C. R. Darwin, *The Formation of Vegetable Mould, Through the Action of Worms, with Observations of Their Habits*, Appleton, New York, 1882.

<sup>8</sup>H. Hopp, *Soil Sci. Soc. Amer., Proc.* 12, 503-507 (1948).

<sup>9</sup>The authors are indebted to Dr. William Murchie, Thiel College, Greenville, Penn., for the identification of the earthworms.

TABLE 3. ANALYSIS OF Sr<sup>89</sup> ACTIVITY IN EARTHWORM, *EISENIA FOETIDA* (SAVIGNY), AFTER 30 DAYS

Series No.	Initial Activity of Soil at 10% Geometry (counts/min/g)	With Soil Present in Gastrointestinal Tract			Without Soil in Gastrointestinal Tract		
		Number of Individuals	Average Activity (counts/min)	Per Cent Activity of Total in Soil	Number of Individuals	Average Activity (counts/min)	Per Cent Activity of Total in Soil
I	350	7	10.9 ± 2.7	3.1 × 10 <sup>-3</sup>	21	1.3 ± 2.4	3.7 × 10 <sup>-4</sup>
II	700	7	22.4 ± 2.9	3.2 × 10 <sup>-3</sup>	20	5.9 ± 2.5	8.4 × 10 <sup>-4</sup>
III	1050	6	34.3 ± 3.1	3.3 × 10 <sup>-3</sup>	24	6.7 ± 2.7	6.6 × 10 <sup>-4</sup>
IV	1400	7	42.3 ± 3.5	3.0 × 10 <sup>-3</sup>	21	9.5 ± 2.9	6.7 × 10 <sup>-4</sup>
V	1750	8	51.6 ± 3.2	2.9 × 10 <sup>-3</sup>	11	11.7 ± 2.6	6.7 × 10 <sup>-4</sup>
Controls		6	0.6 ± 2.3		30	0.4 ± 2.3	
		41			127		

thin-window G-M counter. Samples were counted for 40 min and backgrounds for 20 min. Statistical error at the 95% confidence level was calculated for each sample. The results are summarized in Table 3.

These results indicate that there was some uptake of Sr<sup>89</sup>. Under the particular experimental conditions there was some correlation between the amount of radioactivity in the earthworms and the environment in which they were kept. In all cases the order of magnitude of uptake was very small in comparison to the uptake of Sr<sup>89</sup> by vertebrate animals.

If the average radioactivity in each series of experimental worms is expressed as the percentage of the total activity available to them in the soil mass for the 30-day period, it is apparent that under the conditions of this experiment there was no concentration of Sr<sup>89</sup>.

#### Studies of the Effectiveness of Various Types of Containers in Maintaining Tree-Hole Arthropod Populations in the Laboratory

A necessary prerequisite for experimentation on the delayed effects of ionizing radiation on tree-hole arthropod populations is a suitable container which will maintain the populations in their natural substrate for extended periods of time. Four types of containers were tested over a three-month period for their ability to fulfill this need; they were (1) two artificial tree holes bored in a 3-ft *Lirioden-*

*dron tulipifera* log kept in the laboratory, (2) two artificial tree holes bored in two separate trees of the same species as the log, (3) two wooden boxes constructed of the same wood as the logs, and (4) two 6-in. red-clay flower pots.

In January, 400 g of *L. tulipifera* tree-hole mold was placed in each of the containers. To prevent excessive moisture loss, the boxes and flower pots had glass covers and the artificial holes had wooden lids with a screen opening. One of the boxes and one of the flower pots were placed in an airtight chamber into which air of 85% relative humidity was piped. The other box and flower pot were kept in the laboratory, where the relative humidity was about 30%. All the containers were examined weekly for moisture content, and water was added when needed. At intervals of 30, 60, and 90 days samples of mold were taken from each of the containers and from the original tree holes, the latter serving as controls. These samples were weighed and were processed in Berlese funnels to separate the arthropod populations, and the arthropods were counted and then separated into major taxonomic categories.

The pertinent data are summarized in Table 4. These data include the fresh weight of the sample from each container, the moisture content of the mold sample at the time of "berlesing," the number of arthropods per gram of dry weight of mold, and the frequency of the taxonomic categories in each sample.

TABLE 4. SUMMARY OF TESTS OF CONTAINERS OF TREE-HOLE MOLD (FOR THE PERIOD FROM JANUARY TO JUNE 1955)

Type of Container	30-day Berlese				60-day Berlese				90-day Berlese			
	Wet Weight of Sample (g)	H <sub>2</sub> O (%)	Arthropods per Gram of Dry Weight	Frequency of Categories	Wet Weight of Sample (g)	H <sub>2</sub> O (%)	Arthropods per Gram of Dry Weight	Frequency of Categories	Wet Weight of Sample (g)	H <sub>2</sub> O (%)	Arthropods per Gram of Dry Weight	Frequency of Categories
I. Wood box (in airtight container)	64	21.2	2.8	5	56	26.1	1.52	6	87	46.2	7.3	8
II. Wood box	62	17.8	0.94	3	57	7.4	0.72	1	77	15.4	6.7	6
III. Flower pot (in airtight container)	75	34.9	24.1	8	66	25.9	22.4	5	99	52.1	12.8	7
IV. Flower pot	86	38.2	19.0	7	77	38.9	16.8	4	98	56.6	18.3	5
V. Log hole (laboratory)	73	30.1	33.2	7	63	27.4	27.9	3	77	41.0	38.8	7
VI. Log hole (laboratory)	72	26.6	20.9	6	73	31.4	59.5	6	81	34.9	23.6	6
VII. Log hole (field)	75	41.8	18.2	5	174	74.7	8.9	5	137	74.5	12.6	6
VIII. Log hole (field)	94	35.7	14.1	7	86	39.7	19.4	7	101	52.0	46.0	6
Control	82	33.8	23.9	8	64	28.7	13.3	6	62	22.0	17.5	11
Control					54	11.8	6.5	6				6

The results indicate that the flower pots and the artificial tree holes in the laboratory are the most satisfactory of the containers. The arthropod populations were maintained at levels equal to, or in excess of, the populations of the artificial holes in the field and of the controls. There were fluctuations in the frequencies of taxonomic categories, but the data are too few for any conclusions to be drawn. In general, in all the containers the numbers of individuals, and in some cases the frequency of taxonomic categories, increased during the experiment. This was due to new individuals being hatched from eggs either already present or oviposited during the course of the experiment.

It was also found that the amount of moisture lost was least – and that optimum moisture levels could best be maintained – in the flower pot in the airtight chamber. In addition, in this type of container there is less possibility of contamination by extraneous organisms, not originally present at the start of the experiment, moving into the pot.

#### URINALYSIS RESEARCH

L. B. Farabee

The development of a procedure for the determination of radioactive strontium in urine specimens has been completed, and a detailed report has been prepared for publication.<sup>10</sup> Although this procedure was designed primarily for analysis of urine for strontium, it recovers radioactive barium equally as well. This is to be expected, because the stability constants of the versene chelates of barium and strontium are similar. Since this urinalysis procedure does not provide a chemical separation of strontium from barium, identification of the radioactive isotope can be made by half-life studies.

The inorganic constituents of the final sample from a 24-hr urine specimen consist of tracer amounts of calcium, magnesium, and sodium and essentially all the inert strontium and barium in one day's excretion. Preliminary tests show that about 0.3 to 0.4 mg of inert strontium is excreted per day. This strontium can be precipitated from all the other elements except barium by two  $\text{Sr}(\text{NO}_3)_2$  precipitations from an 84% nitric acid solution. This precipitation can be used as an

adjunct to the procedure. Since the sample can be counted a short time after the separation of the rare-earth daughter products of  $\text{Sr}^{90}$  and  $\text{Ba}^{140}$  by this precipitation, growth and/or decay studies can be made to identify the radioactive isotope.

#### DISTRIBUTION OF RADIOISOTOPES IN ANIMAL TISSUE

M. J. Cook      F. G. Karioris<sup>11</sup>  
K. Z. Morgan

A previously reported study on continuous and single internal exposures of mice to  $\text{Co}^{60}$  has shown that single-exposure data may be used to obtain approximate maximum permissible values for continuous exposure.<sup>12</sup> An experiment similar to the  $\text{Co}^{60}$  study is in progress in which  $\text{Sr}^{90}\text{-Y}^{90}$  is administered orally to DBA-strain mice. In the first group of approximately 200 mice each mouse is given a single 10- $\mu\text{c}$  dose, and for the second group of approximately 200 mice the drinking water contains the radioisotope in a concentration of 1  $\mu\text{c}/\text{ml}$ .

It is believed that when a hanging-drop bottle is used much water is wasted by dripping, evaporating, and the mice playing in it. A capillary drinking-water fountain was designed which prevented dripping, kept evaporation to a minimum, and prevented the mice from playing in the water, and this fountain is under test at the present time.

#### ISOTOPIC DISTRIBUTION IN MAN

I. H. Tipton      M. J. Cook  
D. K. Bowman      J. C. Gallimore

#### Spectrographic Analysis of Human Tissue

The tissue-collection program has been established in Denver, Dallas, Miami, Atlanta, and Baltimore. All the samples have been received from Denver, but tissue is continuing to be received from the other four cities.

Medical examiners or coroners in St. Louis, Cleveland, New Orleans, Seattle, Tacoma, and Richmond have sent letters offering assistance.

<sup>11</sup>Summer research participant from the Physics Department, Marquette University, Milwaukee, Wis.

<sup>12</sup>M. J. Cook, K. Z. Morgan, and A. G. Barkow, "An Experiment Designed to Test the Validity of the Current Practice of Using Single-Exposure Data to Calculate Maximum Permissible Concentration in Water for Continuous Exposure to Radioisotopes," to be published in *Am. J. Roentgenol., Radium Therapy Nuclear Med.*

<sup>10</sup>L. B. Farabee, *Procedure for the Radiochemical Analysis of Strontium and Barium in Human Urine*, ORNL-1932 (Sept. 6, 1955).

The wet-ashing procedure has been replaced by the dry-ashing procedure, which is a more rapid process. By the dry-ashing procedure approximately 50 samples per week may be prepared for spectrographic analysis.

The spectrographic laboratory for the analysis of human tissue at the University of Tennessee has refined the quantitative methods for 29 elements

in soft tissue and 21 elements in bone. Analyses are being made at the rate of 40 samples per week.

The results of analyses of 61 bone samples are given in Table 5. These samples included those received from Boston, New York, Birmingham, Columbus (Ohio), and Knoxville from April 1951 through September 1954.

TABLE 5. SPECTROGRAPHIC ANALYSIS OF BONE ASH

Number of Samples: 62

Mean Per Cent of Ash from Bone: 17

Element	Limit of Sensitivity (ppm)	Coefficient of Variation (%)	Total Number of Samples Containing Element	Number of Samples Containing Trace Amounts	Mean Concentration (ppm)	Range (ppm)	Remarks
Al	25		62	31		260-<25	
Cr	4		28	13		27-<4	
Mn	1		45	31		8-<1	
Fe*	100	±15	46		1428	3000-100	
Ni	25		6	5		29-<25	
Cu	1	±15	62		8**	>300-3	Two samples contained >300 ppm
Sr	10	±15	62		100***	1000-10	One sample contained >>1000 ppm
Ag	2		55	5		11-<2	
Sn	15	±20	62		49	88-30	
Ba	1	±15	62		13	215-4	
Pb	10	±15	62		56	200-10	
No other elements detected							

\*Only 46 samples analyzed for Fe.

\*\*Two high values not included in mean.

\*\*\*One high value not included in mean.

## SANITARY-ENGINEERING RESEARCH

E. G. Struxness

FIELD INVESTIGATIONS AND EXPLORATIONS  
(LIQUID-WASTE DISPOSAL)

R. J. Morton                      H. J. Wyrick  
K. E. Cowser                      W. deLaguna (USGS)  
E. R. Eastwood

## Water Decontamination Study

Activated carbon is usually a good agent for removing traces of color, tastes, or other undesirable substances from water. However, activated carbon alone is ineffective for the adsorption of ionically dispersed metallic compounds. Ion-exchange methods can be used effectively for this purpose. Trace metals can be removed from solutions if an adsorbable radical is first attached to the metal ion and then the activated carbon is employed to remove the resulting metallic organic complex. This observation indicated that the removal of radioactive cations from water by this method should be investigated.

To 2.5 liters of Oak Ridge tap water (pH 7.8, hardness 114 ppm as  $\text{CaCO}_3$ ) a sufficient amount of the particular radioisotope under investigation was added to give a reasonable counting rate (about 3000 counts/min/ml). Analytical-grade dimethylglyoxime, in weights of 0.5, 1.0, 2.5, and 5.0 g, was added to 800-ml glass beakers. A fifth beaker, containing no organic material, was used as a control. In order to wet the powdered dimethylglyoxime, 1 ml of 0.5% aerosol solution was added to each beaker. Samples of the contaminated tap-water solution were taken for chemical and radiochemical analysis. Five hundred milliliters of the solution was then added to each of the 800-ml beakers, and the beakers were stirred for 30 min at about 250 rpm. Fifty-milliliter samples were withdrawn from each beaker at regular 10-min intervals and filtered through a 6-in. depth of technical-grade granular bone charcoal. Three 1-ml samples of this filtered liquid were placed in aluminum counting dishes, dried under infrared heat lamps, and counted by using a G-M mica-end-window tube and 64 scaler.

After 30 min of stirring, the fourth set of samples was removed, and 50 ml from each beaker was added to five 50-ml Lusteroid tubes and centrifuged. The supernatant liquid from each tube was prepared and counted in the described manner, and its

pH was determined by using a Beckman model G glass-electrode pH meter.

All glassware used in the experiment was pre-coated with Desicote.<sup>1</sup> Desicote is an organo-silicon compound which removes even the slightest trace of water from silicate surfaces and leaves a water-repellent coating of molecular thickness. This coating protects the glassware from cross-contamination by the various radioactive materials used and prevents abnormally high removals of certain radioisotopes due to plating-out on the surfaces of the glassware.

The data are given in Table 6. Larger amounts of organic material resulted in increased removals of the radioisotopes. When no organic material was added, the process was simple surface adsorption by the activated charcoal.

For 6 of the 11 cationic radioisotopes studied, the removals obtained were greater than 99% when 10 g of dimethylglyoxime per liter had been used. Three of the remaining radioisotopes were removed in excess of 98%, and only  $\text{Na}^{24}$  showed low removals (63% maximum obtained).

The detailed results indicated that increased contact time does not result in significantly higher removals; for example,  $\text{Ce}^{144}$ - $\text{Pr}^{144}$  and  $\text{Na}^{24}$  were removed almost as efficiently after 10 min as after 30 min of stirring.

The principle involved is the complexing of the radioactive cation and then, by using carbon, the adsorbing of both the isotopic complex and any excess organic reagent. Because the radioactive contaminants represent a concentration too low to obey the law of mass action, it was necessary to use larger-than-stoichiometric proportions of the organic material.

Other complexing organic reagents may also be used for this particular type of treatment; a Darco<sup>2</sup> article suggests mercaptobenzothiazole and xanthates. The article also states that chelating agents do not seem to be effective, probably because they are strongly soluble and thus are not readily adsorbable.

<sup>1</sup>Desicote is a product of the Beckman Instruments, Inc., of S. Pasadena, Calif.

<sup>2</sup>"Darco Digest," *Chem. Eng. News* 33(12), 1187 (1955).

TABLE 6. REMOVAL OF RADIOACTIVITY FROM CONTAMINATED WATER BY ADSORPTION OF ORGANIC COMPLEXES ON CARBON

Radioisotope	Initial Activity (counts/min/ml)*	Removal of Contaminant** (%)					Microcuries per Milliliter in 10-g Sample
		Amount of Organic Material (g/liter)					
		0	1	2	5	10	
Sr <sup>89</sup>	928	68.2	94.0	94.3	95.3	98.1	$8 \times 10^{-5}$
Ba <sup>140</sup> -La <sup>140</sup>	8,330	59.3	67.1	69.7	90.0	98.6	$5 \times 10^{-4}$
Na <sup>24</sup>	3,840	38.3	44.2	52.2	52.8	63.9	$6 \times 10^{-3}$
Sb <sup>124</sup>	13,980	57.4	58.8	67.7	70.0	87.5	$8 \times 10^{-3}$
Zr <sup>95</sup> -Nb <sup>95</sup>	6,580	64.4	85.5	86.9	89.2	98.4	$5 \times 10^{-4}$
Ca <sup>45</sup>	3,600	84.4	90.4	91.2	93.8	99.6	$7 \times 10^{-5}$
Y <sup>91</sup>	3,180	81.0	91.2	93.9	95.2	99.0	$1 \times 10^{-4}$
Ag <sup>110</sup>	2,690	89.2	93.7	95.8	97.0	99.3	$9 \times 10^{-5}$
Ce <sup>144</sup> -Pr <sup>144</sup>	3,980	88.8	98.2	98.7	99.0	99.2	$1 \times 10^{-4}$
Co <sup>60</sup>	4,010	22.6	98.3	98.8	99.2	99.3	$1 \times 10^{-4}$
Ru <sup>106</sup> -Rh <sup>106</sup>	3,870	34.5	81.2	90.9	95.3	99.0	$2 \times 10^{-4}$

\*The data for activity in counts per minute per milliliter were not corrected for geometry (~10%).

\*\*After 30 min of contact time.

Whether the treated material meets the maximum permissible concentration values depends upon the initial concentration of the particular radioisotope.

#### Field Explorations

The 4-acre site<sup>3</sup> in Melton Valley is located on the contact of the bottom red noncalcareous member of the Conasauga shale and the next higher member composed of gray calcareous shale containing a few thin beds of limestone. Study of the drill cores, outcrops, and exposures made by trenching shows that under the site these beds are folded, forming a somewhat complex anticline. This may be an unfavorable feature, as a more uniform attitude of the beds might promote a more uniform movement through the ground of any seeping radioactive liquid.

<sup>3</sup>HP Semiann. Prog. Rep. July 31, 1954, ORNL-1763, p 16.

The several diamond-drill test holes and the 6-in. well were pressure-tested with water to locate depths at which water could move into or out of them. The top 20 or 30 ft of the holes were cased. The most permeable zone was found between the bottom of the casing and a depth of about 100 ft. Below that level the rock was less fractured, and the holes lost little water. The shale itself, where it is unfractured, has a very low permeability. Most of the ground-water movement is along a few individual fractures and not through the mass of the rock.

Water-stage recorders were installed on the wells, and the pattern of natural variation of water levels was studied. There was an easily observable difference between the wells; some showed a marked and rapid rise of water level following a rain, and some did not. Some of the wells showed small variations in water level due to earth tides or fluctuations in barometric pressure, and some

did not. This lack of hydrologic uniformity, and in particular the apparent concentration of fluid movement in certain channels rather than through the whole body of the well, is in itself unfavorable for waste disposal, for a pit depends for its effectiveness on the adsorptive capacity of the solid matrix of the aquifer. Several pumping tests were made, and the data from this study also showed a concentration of water movement along certain channels and at least a detectable difference in the response of the water levels in the several observation wells. As yet it is not possible to say how seriously the departure from hydrologic homogeneity might affect the movement underground of liquid waste; no large volume of shale can be expected to be uniform.

#### Waste-Storage Pits

**Liquid Budget for Waste-Disposal Pits.** – Liquid-waste-storage pit No. 3 was put into service early in the year. By June 30 the pit had been filled with waste and rainwater and had just begun to cascade into pit No. 2, which had received no pumped waste in five months and had dropped very materially in stage. Comparison of the rates of change of pit stage of the two pits shows that pit No. 2 is leaking more rapidly than pit No. 3 and that evaporation is an important factor, particularly in pit 3. The difficulty of accurately determining evaporation loss has shown the need for a more comprehensive study of this part of the budgeting. Two methods of approach appear to be possible, and both will probably be used. One method is to calculate the rate of evaporation from meteorological parameters; the other is to determine the rate of fall of stage during times of negligible evaporation – at such times the fall of stage must be largely due to seepage. Once seepage is determined, evaporation losses are obvious.

The more rapid seepage from pit 2 may be due to more permeable rock near it, or it may be that steeper water-table gradients have been developed out from it. Only part of the slope of the water table can be determined from the few observation wells available, and much remains to be done to explain the operation of the pits.

**Evaluation of Proposed Site for Pit No. 4.** – At the present rate of waste discharge there is need for at least one more disposal pit, and a site was chosen just south of pit No. 2. Pit 3 is just to the north of pit 2. It is proposed to pump all waste

directly into pit 3, let any overflow cascade into pit 2, and allow overflow from pit 2 to cascade into the new pit, No. 4. The new location is at the end of the low, flat ridge on which the pits are located, and the land surface will slope away steeply from the edge of the pit, particularly to the east. The depth to ground water from the pit bottom will be of the order of 20 to 25 ft, somewhat more than in the two previous units. These factors alone would suggest a more rapid rate of seepage from the new pit, which would be desirable as far as the prime purpose of the pit is concerned, and, as far as is now known, quite safe. In order to analyze better the operation of the pit after it is in service, it is planned to make hydrologic tests, including pumping tests, of the area. The construction of the observation wells is already under way.

#### Vertical Definition of Radiochemical Waste Movement from Disposal Pits

To define the location of radioactive wastes that seep from a disposal pit, a method for determining the vertical configuration of the resulting contamination stream is necessary. The contamination profile is being evaluated by means of observation wells around the pit site, radiologging equipment,<sup>4</sup> selected-depth sampling, mixing of the well contents, and flushing out the well contents.

The gamma-ray log obtained would be influenced by (1) activity in the well water, (2) variations in the diameter of the observation hole, (3) sorption of activity on the side wall of the hole, and (4) sorption of activity in the rock or in solution, in the strata through which wastes are traveling. Radiologging followed by sampling is not sufficient to differentiate these effects. In Fig. 5a radiologging without disturbing the liquid contents of the well is referred to as a normal run.

Mixing the well contents to eliminate stratification of wastes was accomplished by pumping from the well bottom and discharging to the liquid surface. Radiologging following this mixing procedure is indicated as a recycle run (Fig. 5b) and is followed by sample collection. Fluctuations in probe response due to variations in hole size were eliminated by flushing out the well contents. The contaminated liquid was pumped from the bottom,

<sup>4</sup>HP Semiann. Prog. Rep. Jan. 31, 1954, ORNL-1684, p 25.

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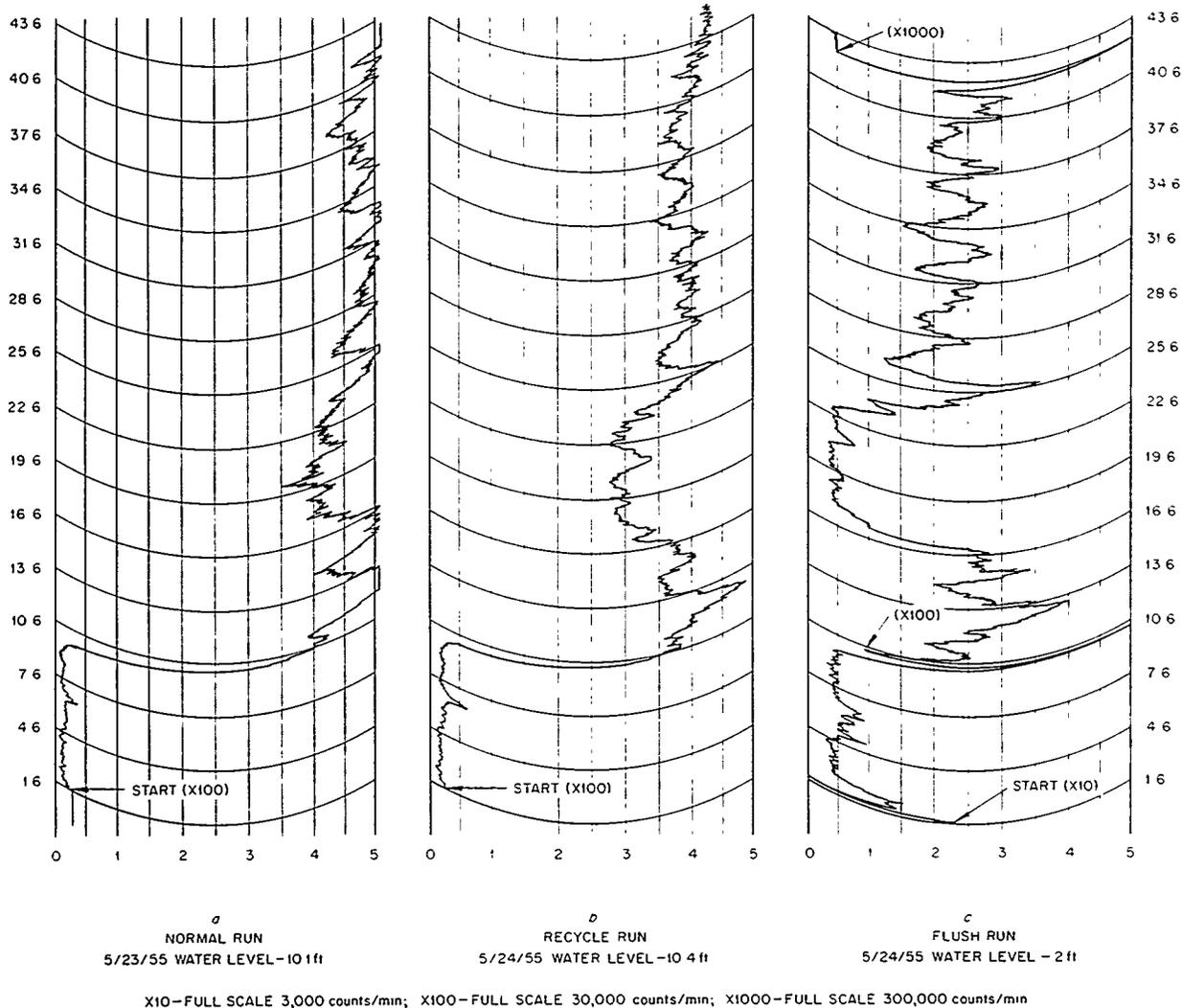


Fig. 5. Radiolog Charts; Well NX8. Line voltage, 115; tube voltage, 900; time constant, *Ml*.

while a positive head of fresh water was maintained in the well. After flushing, a radiolog is obtained (Fig. 5c, flush run), the positive head of fresh water still being maintained. Samples were collected after each radiologging.

Reliability of the radiologging and sampling procedure has been shown with consecutive logs and duplicate samples. Analysis indicates that greater than 90% of the activity in the water is due to  $Ru^{106}$ - $Rh^{106}$ .

The mixing procedure was effective in providing

a uniform activity in the water. The location of maximum responses observed by radiologging remained unchanged after recycling. There was a lack of correlation between probe response and activity in samples collected. From the observations it appeared that the peaks in the radiolog charts were not a result of activity in the water. Flushing reduced the water activity to a negligible amount. Radiologging after flushing shows that peak responses remain at the same depths and substantiates the inference that the peaks are due to activity in the rock strata.

### Hydrology and Geology of the Oak Ridge Area

Work on the report of the hydrology and geology of the Oak Ridge Area has consisted largely in transferring to maps of scale 1:24,000 the pattern of geologic formations shown on the recently compiled geologic maps of eastern Tennessee. Some information on land use has been compiled, and some diagraming of surface drainage patterns, as they might affect the movement of waste reaching the streams, has been completed. From what can be seen, it is clear that the areas now being used or being investigated are the best suited to waste disposal, and the report, when finished, will have value principally by confirming conclusions already reached.

A new topographic map of the area will be published at the end of July, and it is planned to use these quadrangles to prepare a new and better topographic base map of the government-owned area.

### CHEMISTRY AND SOILS ENGINEERING

C. P. Straub (USPHS)	M. I. Goldman (USPHS)
B. Kahn (USPHS)	H. L. Krieger (USPHS)
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Pfc. L. M. Lawless (ERDL)	M/Sgt. R. R. Rollins (ERDL)
D. K. Smith	

### Chemical Laboratory Studies

Procedures for the recovery from soil and identification of the major long-lived fission products have been evaluated. The efficiencies of the various leach solutions selected are indicated in Table 7.

These procedures were tested on 20 samples of river mud collected at various points below the Oak Ridge National Laboratory. The samples show that (1) only naturally occurring radioactivity was found in the mud from the Tennessee River, (2) the concentration in the mud of the Clinch River was approximately five times background, and (3) the concentration in the mud of White Oak Lake was about 1000 times that of the Clinch River mud. The predominant radioisotopes found were cesium, cobalt, and cerium. The methods of analysis will be published.

A technique was tested for analyzing the cobalt leached from soil to determine contamination by the major fission products; the procedure includes leaching with 1 M HNO<sub>3</sub> or HCl, precipitating with

TABLE 7. RESULTS OF LEACHING EXPERIMENTS FOR THE RECOVERY OF ADSORBED RADIOISOTOPES FROM NO. 1 ORNL CLAY-TYPE SOIL

Radioisotope	Leach Solution	Recovery (%)
Cs <sup>137</sup>	9 M H <sub>2</sub> SO <sub>4</sub>	98.8
Sr <sup>90</sup>	0.5 M HNO <sub>3</sub>	99.6
Sr <sup>90</sup>	1.0 M HNO <sub>3</sub>	99.8
Y <sup>90</sup>	0.5 M HNO <sub>3</sub>	98.6
Y <sup>90</sup>	1.0 M HNO <sub>3</sub>	99.6
Ru <sup>106</sup>	1 M HCl + 0.2 g KMnO <sub>4</sub>	98.2*
Zr <sup>95</sup>	9 M H <sub>2</sub> SO <sub>4</sub> + 0.5 M H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	99.7
Nb <sup>95</sup>	1.0 M HCl + 0.5 M H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	99.6
Co <sup>60</sup>	1.0 M HNO <sub>3</sub>	97.7
Co <sup>60</sup>	1.0 M HCl	99.8

\*In distillate.

KOH, dissolving in acetic acid, precipitating with KNO<sub>2</sub>, dissolving in HCl, scavenging with a precipitation of Ce(OH)<sub>3</sub> in basic NH<sub>4</sub>Cl, precipitating with  $\alpha$ -nitroso- $\beta$ -naphthol from HCl solution, and igniting to Co<sub>3</sub>O<sub>4</sub>. The recovery of tracers, corrected for final yield of carrier, is reported in Table 8.

To obtain inexpensive simultaneous removals of the major long-lived fission products from an acid Al(NO<sub>3</sub>)<sub>3</sub> solution by precipitation, the following procedure has been devised:

1. Boil 100 ml of solution. Add 200 mg of Fe(CN)<sub>6</sub><sup>4-</sup>, 60 mg of Ca<sup>++</sup>, 32 mg of Zr<sub>4</sub><sup>+</sup>, and 0.8 ml of 1:10 H<sub>3</sub>PO<sub>4</sub>. Boil and stir 5 min; filter.

2. Boil filtrate, add 1 g of Ba<sup>++</sup>, and pour slowly into 100 ml of boiling water containing 8 g of Na<sub>2</sub>SO<sub>4</sub>. Boil and stir for 1/2 hr, and let settle.

3. Cool to approximately 24°F, dilute with 100 ml of H<sub>2</sub>O, and add 15 mg of Ce<sup>+++</sup>, 150 mg of Fe(CN)<sub>6</sub><sup>4-</sup>, 50 mg of Cu<sup>++</sup>, and 1 g of (NH<sub>4</sub>)<sub>2</sub>C<sub>2</sub>O<sub>4</sub>. Stir in ice bath for 1 min, centrifuge, and decant.

The removals obtained are indicated in Table 9.

The removal efficiencies of the same radioactive tracers from 100 ml of acid Al(NO<sub>3</sub>)<sub>3</sub> waste solution made basic with 80 ml of 18 M NaOH, with 100 mg of Ca<sup>++</sup> and 100 mg of Na<sub>2</sub>CO<sub>3</sub> added to carry the strontium tracer, are also listed, in the column headed "Caustic Solution."

TABLE 8. RECOVERY OF RADIOACTIVE TRACERS IN COBALT-ANALYZING PROCEDURE

Radioisotope	Activity on Soil (counts/min)	Activity in Leach Solution (counts/min)	Activity on $\text{Co}_3\text{O}_4$ Precipitate (Corrected for Carrier Yield) (counts/min)
$\text{Cs}^{137}$	$546 \times 10^4$	$116 \times 10^4$	0
$\text{Sr}^{90}$	$42.3 \times 10^4$	$40.3 \times 10^4$	0
$\text{Y}^{90}$	$42.6 \times 10^4$	$39.2 \times 10^4$	11
$\text{Ce}^{144}$	$152 \times 10^4$	$146 \times 10^4$	11
$\text{Ru}^{106}$	$233 \times 10^4$	$164 \times 10^4$	124
$\text{Zr}^{95}\text{-Nb}^{95}$	$753 \times 10^4$	$39.7 \times 10^4$	461
$\text{Co}^{60}$	$384 \times 10^4$	$349 \times 10^4$	$341 \times 10^4$

TABLE 9. PER CENT REMOVAL OF FISSION PRODUCTS FROM AN ACID  $\text{Al}(\text{NO}_3)_3$  SOLUTION

Radioisotope	Acid Solution (%)	Caustic Solution (%)
$\text{Cs}^{137}$	99.3	44.9
$\text{Sr}^{90}$	97.2	97.0
$\text{Y}^{90}$	86.3	99.0
$\text{Ce}^{144}$	99.3	98.3
$\text{Zr}^{95}\text{-Nb}^{95}$	99.5	91.5
$\text{Zr}^{95}$	100.0	88.0
$\text{Ru}^{106}$ (2-month-old solution)	90.2	52.1

In both procedures, to determine the effect on removals of aging of the solution, the ruthenium carrier was added at least one month before the precipitation. It was found that the fraction of the ruthenium removed decreased with the age of the solution because of chemical instability of the ruthenium in the waste solution.

The cost of chemicals for treating the acid  $\text{Al}(\text{NO}_3)_3$  solution was found to be 1.5 cents per liter and for treating the caustic waste (including the cost of  $\text{NaOH}$ ), 5.0 cents per liter.

In studies on the effect of the concentration of cesium on its adsorption on local clays, it was found that the exchange capacity was a function of the concentration; a lowering of the cesium concentration resulted in a lower exchange capacity

of the clays for cesium. To compare the adsorption of potassium on soil with that of the cesium reported above, known weights of irradiated and processed  $\text{K}^{42}\text{Cl}$  were passed through columns containing 1 to 5 g of soil until the soil was saturated. Samples of the initial and final solutions and of the soil were counted to determine the amount of  $\text{K}^{42}$  adsorbed. Reducing the concentration of potassium from 52.3 to 0.0523 mg/ml reduced the amount of potassium adsorbed on the soil from 14.3 to 6.85 mg per 100 mg of soil.

Twenty AEC-Vanderbilt Fellowship students in training at the Laboratory are extending these studies to determine the effect of concentration on the adsorption of fission products on Conasauga shale.

#### Soils and Engineering Studies

Samples of semiweathered rock material from the 4-acre site have been obtained and their cation-exchange capacity and exchange complex determined. The cation-exchange capacity varies with the textural fraction, about 20 meq (milliequivalents) per 100 g for fractions between 10 and 80 mesh and dropping to 16 meq per 100 g for 6 to 8 mesh and for the finer-than-120-mesh fractions. The estimated total bases in the exchange complex comprise 4 to 6 meq per 100 g, and the  $\text{H}^+$  ion 11 to 14 meq per 100 g by difference.

Permeability studies of natural rock materials from the 4-acre site were conducted. Cores were collected in such a manner that vertical, normal, and parallel-to-stratification permeabilities could be obtained. A vertical permeability ( $k_{20}$ ) of

$3 \times 10^{-3}$  cm/sec and normal and parallel permeabilities of  $1 \times 10^{-3}$  and  $4 \times 10^{-3}$  cm/sec, respectively, were found.

Test sections of Tennessee ball clay and an asphalt membrane (along with test apparatus) were installed in waste pit No. 3 to determine the permeability and stability of the clay and asphalt liners under actual field conditions. There has been no detectable leakage through the  $\frac{1}{2}$ -in. asphalt membrane; the clay liner is leaking to the extent of  $10^{-7}$  cm/sec. The alkaline (pH = 10)  $\text{NaNO}_3$  waste in the pit contains about 50%  $\text{Cs}^{137}$ , 40%  $\text{Ru}^{103,106}$ , and 1%  $\text{Sr}^{90}$ , with no significant variation of composition with depth. The material which leaches through the clay indicates approximately the same composition and level of activity.

The possibility of increasing the stability of the clay to weathering by diluting with sand has been tested on a laboratory model. Although the permeabilities of the clay-sand mixtures are comparable to the permeability of the undiluted clay (about  $10^{-8}$  cm/sec), the most stable liner with respect to erosion was 100% clay.

Studies of strontium uptake by undisturbed core samples show a capacity of about 9 meq per 100 g of soil, as compared with values of about 23 meq per 100 g for 10- to 20-mesh screened samples of the same material. These values, which agree with the cation-exchange capacity of these fractions as determined by the ammonium acetate method, show the inefficiency of the undisturbed rock material for adsorption of cations as compared with the potential capacity. Of the textural fractions examined, the 6- to 8-mesh portion most closely approximates the ability of natural cores to exchange strontium. Cores saturated with tagged strontium were broken open, and activity was found to have concentrated along the bedding planes and crevices, indicating that at the flow rates studied ( $k_{20}$  approximately  $5 \times 10^{-4}$  cm/sec) exchange capacity of the entire rock fragments was not utilized.

Tests of the ability of semiweathered shale rock to neutralize acid aluminum nitrate solution show that 150 kg of shale is required to raise the pH of 1 liter of solution from less than 1 to 1.5; above the latter point, increased soil contact appears to have little if any effect.

By using tap water and acid aluminum nitrate solutions, the permeabilities of soil were determined. No consistent relationship between

water flow rates and acid-waste flow rates through the same cores was observed in the five cores tested. This may be due to the chemical nature and the density and viscosity of the waste solution.

Studies of uptake by shale of critical radioisotopes from a solution of distilled water and mixed fission products have been partially completed. The solution contains carriers in concentrations predicted for an acid aluminum nitrate waste. A series of tests, conducted at pH 3.5, has been completed, and data indicate that the order of removal through shale columns from this solution is  $\text{Nb} > \text{Y} > \text{Zr} > \text{Cs} > \text{Ru} > \text{Sr}$ . A soil-to-solution ratio of about 0.5 g to 1 ml is sufficient to retain essentially 100% of the fission products in the solution. A second series at pH 5.0 shows the same order of removal as obtained in the first series, but a soil-to-solution ratio of only 0.3 g to 1 ml is required to remove all the fission products from solution at this pH. Further studies are under way at pH 1.5, and preliminary results indicate that the soil-to-solution ratio required for complete retention on the soil at this pH may be larger by an order of magnitude than the ratio required at the higher pH values tested.

#### Soil Fertility and the Uptake of Strontium by Bean Plants

In order to establish (1) the relationship between strontium and the other elements of soil fertility, especially calcium, on the nutrient-supplying power of the soil, (2) the relative uptake of  $\text{Sr}^{90}$  when the amount of carrier strontium is varied, (3) the distribution of these elements within the various portions of the plant, and (4) the uptake of the elements throughout the growth period, a pot-culture experiment was initiated in which the Conasauga shale was used as the medium and the garden bush bean as the indicator plant. This soil, being relatively infertile, was brought to 100% of its cation-holding capacity as follows: 5% potassium, 15% magnesium, and 80% calcium. The calcium was successively replaced with strontium to give seven levels or ratios of calcium to strontium. In addition, the soil was treated with 240 lb of nitrogen, 270 lb of phosphorus, and 120 lb of sulphur per acre.

Each culture contains 3 kg of dry soil into which five bush beans were seeded. Sufficient cultures were established to allow for five harvesting dates at approximately 12-day intervals and to allow

statistical analysis of the data. To date, two harvests have been completed, and analyses of the soils and plant parts have been initiated.

AIRBORNE-RADIOACTIVITY STUDIES

J. W. Thomas R. E. Yoder  
F. M. Empson

A detailed study of the efficiency of one type of sand as an entrainment separator (aerosol filter) has been made. The sand was divided into five fractions: 8 to 12, 12 to 16, 16 to 20, 20 to 30, and over 30 mesh. Each fraction was tested with each of five dioctyl phthalate aerosols having radii of 0.20, 0.26, 0.41, 0.64, and 0.84  $\mu$  at linear flow rates varying from 0.05 to 2.0 cm/sec. In general, the data for upflow through the four larger sizes of sand were fitted to within  $\pm 25\%$  by the following equation:

$$1000kD_g = (1 - \alpha) \frac{1 + 0.087/r}{r} (1.5V^{-0.50} + 12r^3V^{-0.90}) ,$$

where

$$k = - \frac{\ln F}{b} ,$$

$F$  = fractional aerosol penetration, dimensionless,

$b$  = height of sand column, cm,

$D_g$  = average diameter of sand granule, cm,

$\alpha$  = void fraction of sand, dimensionless,

$r$  = radius of aerosol particle,  $\mu$ ,

$V$  = linear velocity through bed =  $Q/A$ , cm/sec,

$Q$  = volumetric flow through bed, cm<sup>3</sup>/sec,

$A$  = cross-sectional area of the empty sand holder, cm<sup>2</sup>.

The form of this semiempirical equation was derived by S. H. Jury of the University of Tennessee. Over the range for which the equation was fitted, the size for maximum penetration is independent of sand granule size and varies monotonically from a 0.3- $\mu$  radius of aerosol particle at  $V = 0.0545$  cm/sec to a 0.45- $\mu$  radius at  $V = 2.18$  cm/sec. The calculated performance of a column of sand 1 ft (30 cm) thick, at the aerosol size for maximum penetration, is given in Table 10 as a function of the linear velocity through the sand ( $V$ ) and the size fraction of sand.

TABLE 10. SAND-COLUMN EFFICIENCY AT AEROSOL SIZE FOR MAXIMUM PENETRATION

Air Velocity, $V$ (cm/sec)	Fractional Aerosol Penetration, $F$			
	8- to 12-mesh Sand	12- to 16-mesh Sand	16- to 20-mesh Sand	20- to 30-mesh Sand
0.0545	0.017	0.0032	0.0003	0.00001
0.109	0.076	0.026	0.0057	0.0007
0.218	0.196	0.101	0.038	0.0096
0.545	0.415	0.287	0.169	0.079
1.09	0.565	0.449	0.320	0.198
2.18	0.697	0.600	0.487	0.357

## RADIATION DOSIMETRY

G. S. Hurst

R. H. Ritchie

## EXPERIMENTAL PHYSICS OF DOSIMETRY

R. D. Birkhoff	H. H. Hubbell
T. E. Bortner	C. C. Sartain
J. S. Cheka	B. G. Saunders
W. G. Stone	

## Beta Spectrometer

Further data have been obtained on the distribution of energy losses in a beam of 328-keV electrons after passage through thin foils. Under high resolution (0.2%) slight discrepancies appear when the theories of Landau and of Bluch-Leisegang are applied. These discrepancies are probably due to approximations made in the theories. In an effort to obtain better data, a smaller counter having a much lower background than the present counter has been developed. When reliable operation is secured, a more precise investigation of the disagreements will be made.

## Accelerator

The data on the excitation of the conduction electron plasma in metals by the passage of a high-energy electron have been evaluated and compared with the theory of Pines and Bohm. For aluminum, agreement with the theory is found, with respect to both the excitation energy and the mean free path for the interaction. The excitation energy in magnesium is also found to check with theoretical expectations although the experimental mean free path disagrees with theory, possibly due to uncertainties in the thicknesses of the readily oxidized magnesium foils. Data on copper and silver fail to show the characteristic sharp absorption peaks indicative of plasma behavior, and it is believed that if the plasma effect exists in these metals it must be strongly modified by the interaction with inner-shell electrons. A report has been submitted to *The Physical Review* embodying the results of this research, and the project will be temporarily discontinued in expectation of further theoretical developments.

Measurements on the distribution of dose as a function of depth for 100-keV electrons striking a slab of aluminum have been completed. Attempts are being made to correlate results with a new electron-diffusion theory advanced by

Spencer.<sup>1</sup> The pumping system and the electron gun on the accelerator have been modified to facilitate more rapid taking of data by using a new ion chamber.

Construction of an ion source for the accelerator has been started as an initial step in a program of study of the ionization of gases by heavy ions. Ion energies will be of the order of those found from neutron recoils, and the principal purpose of the experiment will be to measure the average energy required to create an ion pair, a quantity of importance in neutron dose studies.

## X-Ray Exposure Facility

Several exposures of various test film badges were made for the Applied Health Physics Section. Exposures were also made to test the energy dependence of a scintillation counter to be used for the river surveys. Several quartz oscillator crystals and samples of pure and impure fused silica were given a series of long exposures at high dose rates for projects in this division and the Solid State Division.

## THEORETICAL PHYSICS OF DOSIMETRY

J. Neufeld	R. H. Ritchie
W. S. Snyder	

## Disordering of Solids by Neutron Radiation

By using the scattering theory of Bohr, the number of interstitials produced in a monoatomic solid by neutrons has been calculated. It was found that for neutron energies such that ionization could be neglected, half the energy was expended in producing interstitials. For higher energies the fraction of energy spent in this way was found to be much smaller.

The paper has appeared in *Phys. Rev.* 97, 1636-1646 (1955).

**A Note on the Half Life of Fission Products  
Produced by Uniform Irradiation  
in a Reactor**

According to Way and Wigner,<sup>2</sup> the energy released in unit time by fission products produced

<sup>1</sup>L. V. Spencer, *Phys. Rev.* 98, 1597 (1955).

<sup>2</sup>K. Way and E. P. Wigner, *Phys. Rev.* 73, 1318 (1948).

at time  $t = 0$  varies roughly as  $t^{-1.2}$ , where  $t$  is the time since the fission occurred. While this formula does not represent the rate of energy release very precisely, it does give an order-of-magnitude estimate which is valid for times from a few seconds after the fission has occurred to times of the order of several years. Actually the exponent varies and seems generally to increase as the period of time lengthens. If a reactor is operating at a constant power level, the mixture of fission products which has accumulated at the end of a certain period of time will decay at a different rate than will the products formed from a single fission. The problem is to estimate the half life of such a mixture at any time subsequent to the period of irradiation.

Assume that fissions are occurring at a constant rate in a material during the time interval  $0 \leq t \leq t_1$ . Then the energy released by these fission products per unit of time at time  $t_1 + t_2$  is given by

$$(1) \int_0^{t_1} A(t_1 + t_2 - t)^{-1.2} dt \\ = \frac{A}{0.2} \left[ \frac{1}{t_2^{0.2}} - \frac{1}{(t_1 + t_2)^{0.2}} \right],$$

where  $A$  is a constant depending on the units chosen, as well as upon the conditions of the irradiation.

If the rate of energy release at time  $t = t_1 + t_3$  is to be a fraction  $p$  of the rate of energy release at time  $t = t_1 + t_2$ , then  $t_3$  satisfies the equation

$$(2) p \left[ \frac{1}{t_2^{0.2}} - \frac{1}{(t_1 + t_2)^{0.2}} \right] \\ = \frac{1}{t_3^{0.2}} - \frac{1}{(t_3 + t_1)^{0.2}}.$$

Taking  $t_1$  as the unit of time, this becomes

$$(3) p \left[ \frac{1}{x^{0.2}} - \frac{1}{(x + 1)^{0.2}} \right] = \frac{1}{y^{0.2}} - \frac{1}{(y + 1)^{0.2}},$$

where  $x$  and  $y$  represent the lapses of time after the end of the period of irradiation in units of the

period of irradiation, that is,  $x = t_2/t_1$  and  $y = t_3/t_1$ .

By graphing the function

$$\frac{1}{x^{0.2}} - \frac{1}{(x + 1)^{0.2}},$$

the solution of Eq. 3 can be read from the graph (Fig. 6). This has been done for  $p = 1/2$ , and the value of  $y - x$  has been plotted as a function of  $x$ . Here  $y - x$  represents the additional period of waiting required for the activity at time  $x$  to be decreased by half.

It is found that

$$y - x \approx 0.78x + 0.4\sqrt{x},$$

the fit being well within the limits of accuracy of the underlying assumptions for  $0.01 \leq x \leq 1000$  but being about 40% too high at  $x = 0.001$ .

When the data as given by Wheeler<sup>3</sup> are used, Table 11 will give some idea of the accuracy to be expected from the treatment.

This paper has been issued as ORNL CF-55-4-104 (April 28, 1955).

#### Passage of Charged Particles Through Plasma

The electronic plasma has been treated as a dispersive medium characterized by a dielectric constant which is a function of both the frequency and the wave number of the disturbance. The passage of charged particles through the plasma was investigated by means of this approach, and formulas for the stopping power for low- and high-velocity particles have been derived.

This report has been published in *Phys. Rev.* 98, 1632-1642 (1955).

#### On the Density Effect

A rigorous justification was given for the statement by A. Bohr that for an incident particle of relativistic velocity the electrostatic effect of the surrounding electrons is negligible and the main factor in screening is due to electromagnetic interaction.

This paper is to be published in *Phys. Rev.* with the title "Density Effect in Ionization Energy Loss of Charged Particles."

<sup>3</sup>C. D. Coryell and N. Sugarman (eds.), *Radiochemical Studies: The Fission Products*, NNE-IV, vol 9, Book 1, p 349 (1951).

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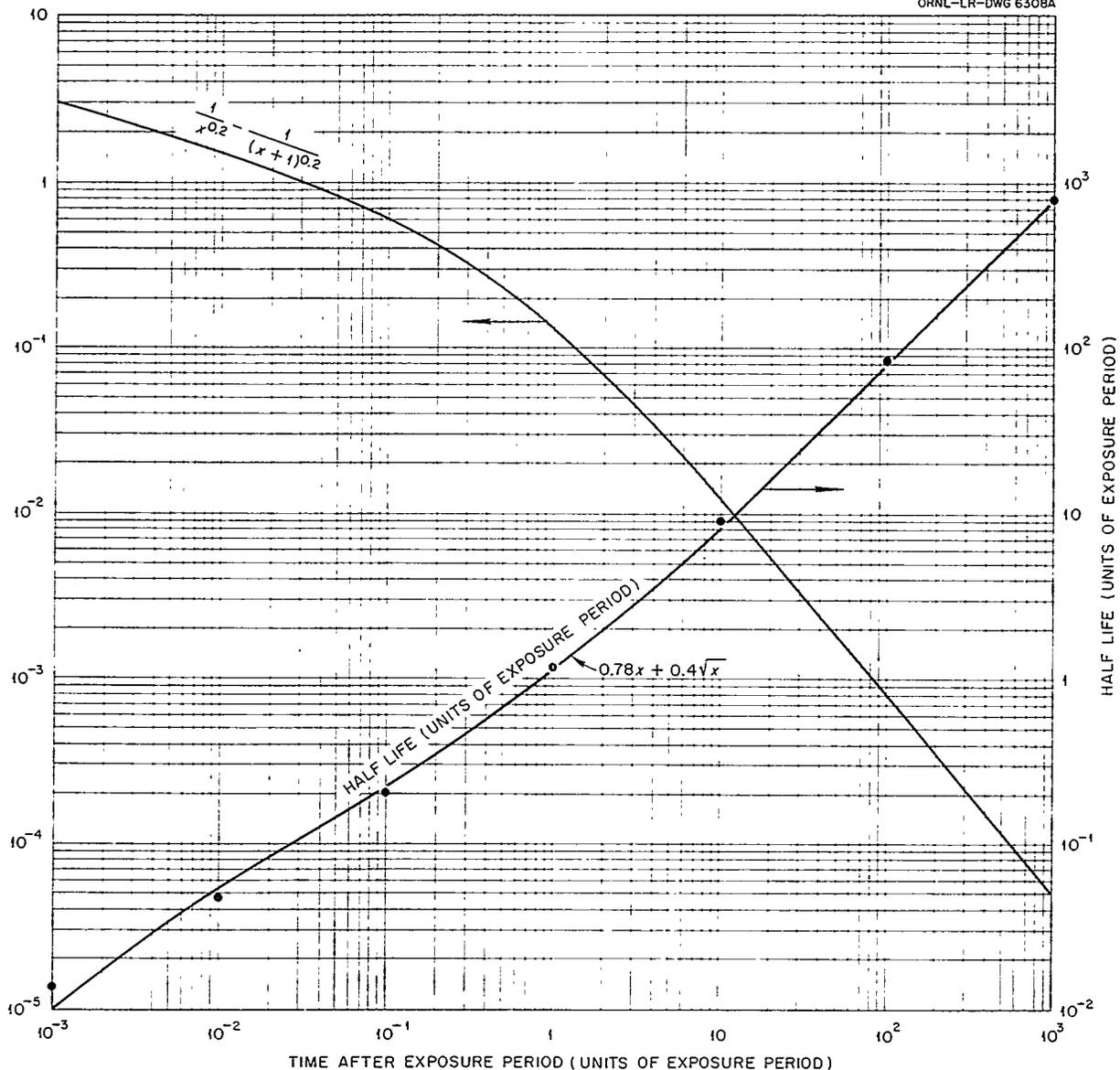


Fig. 6. Half Life of Fission Products Produced by Uniform Irradiation in a Reactor.

**On the Number of Vacancies Created by Heavy Corpuscular Radiation**

Kinchin and Pease<sup>4</sup> have suggested that a moving atom which collides with and displaces another atom may, in certain cases, take its place. Thus the number of displaced atoms is not the same

as the number of vacancies, even when diffusion of interstitial atoms is neglected.

Let  $E$  be the energy of the striking atom before a collision and  $E - y$  its energy after the collision. Altering the assumptions of Kinchin and Pease, it is assumed that if the struck atom receives energy  $y$  the probability of displacement is  $p(y)$  and that if displacement occurs and if the energy of the striking atom after the collision

<sup>4</sup>G. H. Kinchin and R. S. Pease, *J. Nuclear Energy* 1, 200-202 (1955).

TABLE 11. HALF LIFE OF FISSION PRODUCTS AT SUBSEQUENT TIMES AFTER IRRADIATION FOR VARIOUS PERIODS OF REACTOR IRRADIATION

Period of Irradiation, $t_1$ (days)	Cooling Period, $t_2$	Additional Time to Reach Half Value, $t_3 - t_2$	$(0.78x + 0.4\sqrt{x}) \cdot t_1$ Period of Irradiation, $x = t_2/t_1$
180	1 day	17 days	6.1 days
180	10 days	30 days	24.8 days
10	1 hr	5 hr	7.0 hr
10	10 days	17 days	11.8 days
1	1 hr	2.2 hr	2.7 hr
1	10 days	16 days	9.1 days
1	100 days	60 days	82 days

is  $E - y$  then the probability of the atom replacing the struck atom is  $q(E - y)$ . In general,  $p(y)$  would be expected to be zero for small  $y$  and to increase to 1 at some higher energy, while  $q(E - y)$  should decrease and become zero when  $E - y$  is large.

Let  $g(E)$  equal the mean number of vacancies created by the ejection of an atom of the medium whose energy after ejection is  $E$ . If  $p(y) = 0$  for  $y < \alpha$ , then  $g(E) = 1$  for  $E < \alpha$ . For  $E > \alpha$ ,  $g(E)$  satisfies the equation

$$(1) \quad g(E) = \int_0^E dy K(E,y) [p(y)g(y - \alpha) + g(y) - p(E - y)q(y)g(y)] ,$$

where  $K(E,y) dy$  is the probability that a striking atom with energy  $E$  will lose energy  $y$  in  $dy$  in its next collision. The derivation of this equation follows closely the similar discussion of Eq. 7 in a previous paper of the authors<sup>5</sup> and assumes that ionization can be neglected. In accordance with the theory given<sup>5</sup> it should apply only for  $E < Me^4/2\hbar^2$ .

For low energies "hard sphere" scattering is assumed and  $K(E,y)$  is taken as  $1/E$ . If  $p(y) = 0$  for  $y < \alpha$  and  $p(y) = 1$  for  $y > \alpha$  and if  $q(y) = 1 - p(y)$ , then by the methods developed<sup>5</sup> it is shown that

$$(2) \quad \frac{E + \alpha}{3\alpha} < g(E) < 1.056 \frac{E + \alpha}{3\alpha}$$

<sup>5</sup>J. Neufeld and R. H. Ritchie, *Phys. Rev.* 97, 1637-1646 (1955).

for all monoatomic substances and for  $2\alpha < E < \beta$ . The value  $\beta$  indicates the energy above which Rutherford scattering is assumed to apply and is given by  $\beta = 2Z^2e^2/a$ , with  $a$  the Bohrradius of the atom (ref. 5, p 1638). For Rutherford scattering,  $K(E,y) = \beta^2/4Ey^2$  for  $E\beta^2/(4E^2 + \beta^2) < y < E$ , and  $K(E,y) = 0$  otherwise. It is established that the inequality (Eq. 2) is valid for all  $Z > 10$  for the region of Rutherford scattering and, with minor modifications, for lower  $Z$ .

The results for  $E > Me^4/2\hbar^2$  are not complete but indicate a less rapid rate of increase for  $g(E)$  due to ionization.

Thus the number of vacancies seems to be about two-thirds the number of displacements as calculated in the previous paper.<sup>5</sup>

Harrison and Seitz<sup>6</sup> have calculated the change in resistivity of copper irradiated by 17-Mev deuterons. By assuming that the number of displaced atoms was equal to the number of vacancies, they found that the calculated value was 5 times the observed value. The calculation of vacancies indicated above reduces this to 3.3 times the observed value.

The equation is being studied for cases when  $p$  and  $q$  change continuously from 0 to 1, and preliminary results indicate that the number of vacancies is much less than that given by Eq. 2.

<sup>6</sup>W. A. Harrison and F. Seitz, *Bull. Am. Phys. Soc.* 30(2), 7 (1955).

### Depth Dose Curves for Neutrons of Intermediate Energy

Depth dose curves for beams of neutrons normally incident on a 30-cm slab of tissue have been obtained by the Monte Carlo method. The neutron energies chosen were 100, 20, 5, and 0.1 kev. The energy absorbed from protons, heavier recoils, and gamma rays was tabulated separately. A dose curve was obtained by taking the RBE of protons and of heavy recoils as being 10 and 20, respectively, and gives a rem dose well in line with values obtained by interpolating in an earlier study.<sup>7</sup> The crude data will be smoothed and an error estimate will be calculated before the final release of the study.

### Variation of Neutron Damage with Energy and Geometry

In connection with work on heavy particles for Subcommittee 4 of the National Committee on Radiation Protection, a preliminary study has been made of the variation of neutron dose with energy and with geometry of source and absorber. The discussion here attempts to give an indication of the trend and an order-of-magnitude estimate of the variation of damage.

It will be convenient to analyze the damage at any given site into (1) the "first-collision damage," which is the damage occasioned by the energy absorbed from the atoms with which the neutrons have their first collisions, (2) the "buildup damage," which is produced by recoils struck by the neutron in later collisions, and (3) the "absorption damage," due to energy released when a neutron is absorbed. The advantage of this way of analyzing the damage is that the first-collision damage is relatively easy to calculate when the energy of the incident neutrons is known, and it is possible to give some indication of the variability of the buildup damage and absorption damage in certain practical situations.

For a homogeneous phantom the first-collision dose is given in rem for a monoenergetic beam source by

$$(1) \quad I E e^{-\sigma T} \left[ \sum_i \sigma_i R_i \frac{2M_i}{(M_i + 1)^2} \right],$$

where  $I$  is the intensity of the source (neutrons/cm<sup>2</sup>),  $E$  is the initial energy of the neutrons,  $\sigma_i$  is

the macroscopic cross section of the  $i$ th type of atom in the phantom,  $M_i$  is its mass number,  $R_i$  is the RBE for such a collision,  $\sigma = \sum_i \sigma_i$  with all summations over the constituent elements of the phantom, and  $T$  is the thickness of phantom material a neutron must penetrate to reach the site in question. For an isotropic point source, it is necessary only to multiply by the factor  $\frac{1}{4} \pi R^2$ , where  $R$  is the distance from the source to the site of damage, and to take  $I$  as the number of neutrons emitted by the source. The values of the  $R_i$  can be obtained from other sources.<sup>8,9</sup>

At the irradiated surface of the phantom the buildup damage never exceeds the first-collision damage for any of the beams which have been calculated by Snyder and Neufeld.<sup>10</sup> Table 12 gives these values.

It should be emphasized that these figures are for damage at the irradiated surface, as the buildup dose is of much greater importance at sites farther below the surface. For the energy range indicated in Table 12, it is true, however, that the maximum damage can be taken as occurring at the surface, and the absorption damage can be neglected without serious error. Thus the rule for fast neutrons, that is, energy 0.1 to 10 Mev, can be stated: *The maximum damage may safely be taken as not more than twice the maximum first-collision damage. Moreover, the damage does not vary by more than a factor of 2 over the irradiated surface of the phantom.* When the size and shape of the phantom are varied, the first-collision damage remains unchanged at a point on the irradiated surface, and the buildup damage may be expected to decrease as the size of the phantom decreases. It therefore seems to be a safe rule that *the maximum damage from fast neutrons will not vary by more than a factor of 2 as the size of the phantom varies.* For example, the maximum damage received by a man and by a mouse subjected to the same beam of fast neutrons should

<sup>7</sup>W. S. Snyder and J. Neufeld, *Calculated Depth Dose Curves in Tissue for Broad Beams of Fast Neutrons*, ORNL-1872 (May 5, 1955).

<sup>8</sup>W. S. Snyder and J. Neufeld, *Proposed Program for Computing the Rem Dose Due to Irradiation by Fast Neutrons* (to be published; available from the authors).

<sup>9</sup>*Permissible Dose from External Sources of Ionizing Radiation*, p 48, NBS Handbook 59 (Sept. 24, 1954).

<sup>10</sup>W. S. Snyder and J. Neufeld, *Calculated Depth Dose Curves in Tissue for Broad Beams of Fast Neutrons*, ORNL-1872 (May 5, 1955).

TABLE 12. DAMAGE AT IRRADIATED SURFACE OF PHANTOM BY NEUTRONS OF VARIOUS ENERGIES

Initial neutron energy, Mev	10	5	2.5	0.5	0.1
First-collision damage at surface, rem/neutron $\times 10^{-8}$	5.8	5.0	4.0	1.9	0.68
Total damage at surface, rem/neutron	7.7	7.7	5.2	2.4	0.80

TABLE 13. ABSORPTION DAMAGE BY INCIDENT NEUTRONS OF VARIOUS ENERGIES

Energy of incident neutrons, Mev	10	5	2.5	0.5	0.1	0.005	$10^{-4}$	$2.5 \times 10^{-8}$
Maximum absorption damage, rem/neutron $\times 10^{-9}$	0.7	0.8	1	1	1.2	1.3	1.4	1
Depth below surface where maximum occurs, cm	12	11	9	6	6	5	3	0.3

not differ by more than a factor of 2, and the variation of damage over the irradiated surface of either should not vary by more than a factor of 2. This rule is intuitively plausible if it is recalled that in a medium where collisions with hydrogen predominate, the first collisions account for, roughly, half the energy carried by the neutrons.

For thermal or epithermal neutrons the absorption dose is preponderant, and little information is available concerning the variation of this damage with the geometry of the phantom. For the practical case of a large phantom, for example, the trunk or even the head of a human body, it is possible to state a simple rule: *The maximum absorption damage in a large phantom is essentially constant at about  $1 \times 10^{-9}$  rem/neutron. The site at which the damage occurs varies in depth, as Table 13, compiled from other data,<sup>10</sup> indicates.*

The above data apply strictly only to broad-beam sources, but similar rough limits on the variability apply to the damage from an isotropic point source if allowance is made for the effect of the inverse-square law. For example, the maximum damage caused by an isotropic point source of neutrons will not differ by more than a factor of about 2, regardless of the size of the animal exposed to the damage, provided that the distance from the source is kept constant. The variation of damage over the irradiated surface when adjusted to eliminate the dependence on the inverse-square law should not vary by more than a factor of about 2.

#### Depth Dose Curves for Neutrons with RBE as a Function of LET

The National Committee on Radiation Protection has recommended<sup>11</sup> that the relative biological effectiveness (RBE) be based on linear energy transfer (LET). As a member of Subcommittee 4, W. S. Snyder has been requested to compute depth dose curves for neutrons by using the RBE as specified in *Handbook 59*. The linear energy transfer of protons and heavy recoils has been obtained by the use of the curves computed by the authors in a previous report.<sup>12</sup> To simplify the program, tissue is considered to consist of hydrogen and a fictitious element with the composite cross section required for the carbon, nitrogen, and oxygen atoms of tissue and with the weight of oxygen. The rem dose delivered by a proton will be taken as a fourth-degree polynomial in the energy of the recoil, for example,

$$\sum_{i=1}^4 p_i E^i,$$

and similarly for the rem dose of a heavy recoil. Only the first four moments of the energy of the proton will be tabulated for each depth region, and similarly for heavy recoils. Thus any future changes of RBE values may be substituted without recalculation, provided that the rem dose can

<sup>11</sup> *Permissible Dose from External Sources of Ionizing Radiation*, p 48, NBS Handbook 59 (Sept. 24, 1954).

<sup>12</sup> W. S. Snyder and J. Neufeld, *On the Energy Dissipation of Moving Ions in Tissue*, ORNL-1083 (Nov. 29, 1951).

be taken as a fourth-degree polynomial in the energy. It is planned to include a slab of bone (one additional heavier element) of arbitrary location in the slab and of any desired thickness up to 5 cm. The amount of energy absorbed from non-ionizing heavy particles will also be estimated. The code for the Oracle is substantially complete. It is hoped that computation can begin within a few weeks.

A memorandum with further details on the program was prepared for the use of Subcommittee 4 and is available.<sup>13</sup>

#### Nondirectional Count-Rate Neutron Dosimeter

An analytic expression has been derived for the number of protons ejected with energies greater than  $B$  from the walls into the interior of a spherical cavity lined with paraffin by incident neutrons of energy  $E$ . This expression has been employed in the design of a nondirectional neutron counter whose counting response simulates the dose-energy variation for soft tissue. Calculations will be made by evaluating the uncertainties introduced by heavy atom recoils and wall losses in the high-energy region.

#### Effect of the Polarization Field on Capture by Moving Ions in Dense Media

A method has been formulated by using the impact parameter approach, for evaluation of the effect of polarization of a dense medium by the distant field of a charged particle on the capture of electrons by the incident particles. With the use of this method, calculations of the cross section for capture of protons moving in liquid helium are being carried out.

#### DOSIMETRY APPLICATIONS

F. J. Davis	J. A. Harter
P. W. Reinhardt	J. M. Garner
J. A. Auxier	

#### Background Survey with Aircraft<sup>14</sup>

Flights over a series of cross-country traverse lines were made in order to study the variations in normal background gamma radiation. The equipment used was the scintillation detector developed

by this Laboratory for the use of the U. S. Geological Survey in uranium prospecting. This equipment consists primarily of six NaI(Tl) crystals, each 4 in. in diameter and 2 in. thick. The counting rate of the crystals was recorded by two Esterline-Angus recorders, one recording the actual count rate and the other recording the count rate corrected by the function  $e^{-\mu b}$ , where  $b$  is the height above ground and  $\mu$  is the absorption coefficient for radium gamma rays in air. This function has been shown to fit the variation of gamma-ray intensity with height in a previous report.<sup>15</sup> The correction is effected by a servo-mechanism which follows the height above ground as given by a recording radioaltimeter and controls the sensitivity of the rate meter to compensate for the altitude variations.

Flights were made over traverse lines during the last week in January and the first week in February 1955. The first line was north from Lafayette, Louisiana, to Moline, Illinois. The second line was south from Wichita, Kansas, to San Antonio, Texas. The third line was north from El Paso, Texas, through Albuquerque, New Mexico, and Farmington and Grand Junction, Colorado.

A portion (from St. Louis, Missouri, to Moline, Illinois) of the record of the first traverse line flown is shown in Fig. 7. The records run from right to left. The top record is the altitude in feet above ground, the second is the radiation without altitude corrections, and the third is the radiation corrected for altitude variation. The third record also has the soft-cosmic-radiation component subtracted so that the record shows only the reading proportional to the radiation from the ground. It is to be noted that, while the radiation from the ground is quite uniform, the second record shows variation due to altitude, and these variations are the mirror image of the altitude, that is, when the plane is low the radiation goes up and when the plane is high the radiation goes down. At point  $a$  is shown the record of the crossing of the Mississippi River near St. Louis. The radiation from the water is negligible compared to that from the land, and so the third record drops to zero. The second record drops only to 200 counts/sec (10 counts/sec/division). This represents the count due to soft cosmic radiation.

<sup>13</sup>W. S. Snyder and J. Neufeld, *Proposed Program for Computing the Rem Dose Due to Irradiation by Fast Neutrons* (to be published; available from the authors).

<sup>14</sup>In cooperation with the U. S. Geological Survey.

<sup>15</sup>F. J. Davis, P. W. Reinhardt, and J. A. Harter, *HP Semiann. Prog. Rep. Jan. 31, 1954*, p 11.

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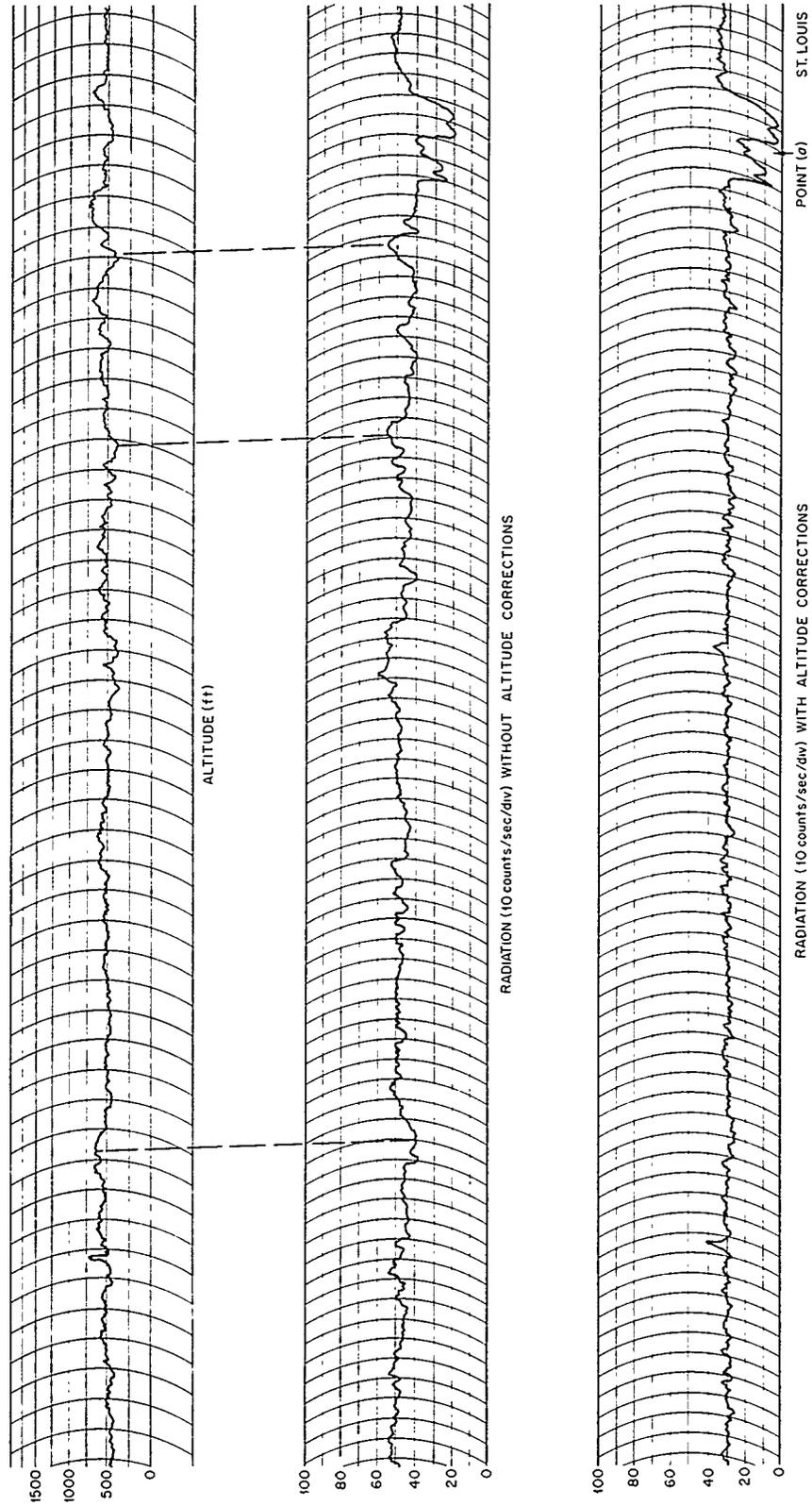


Fig. 7. Record of Radiation Measurement from St. Louis, Mo., to Moline, Ill.

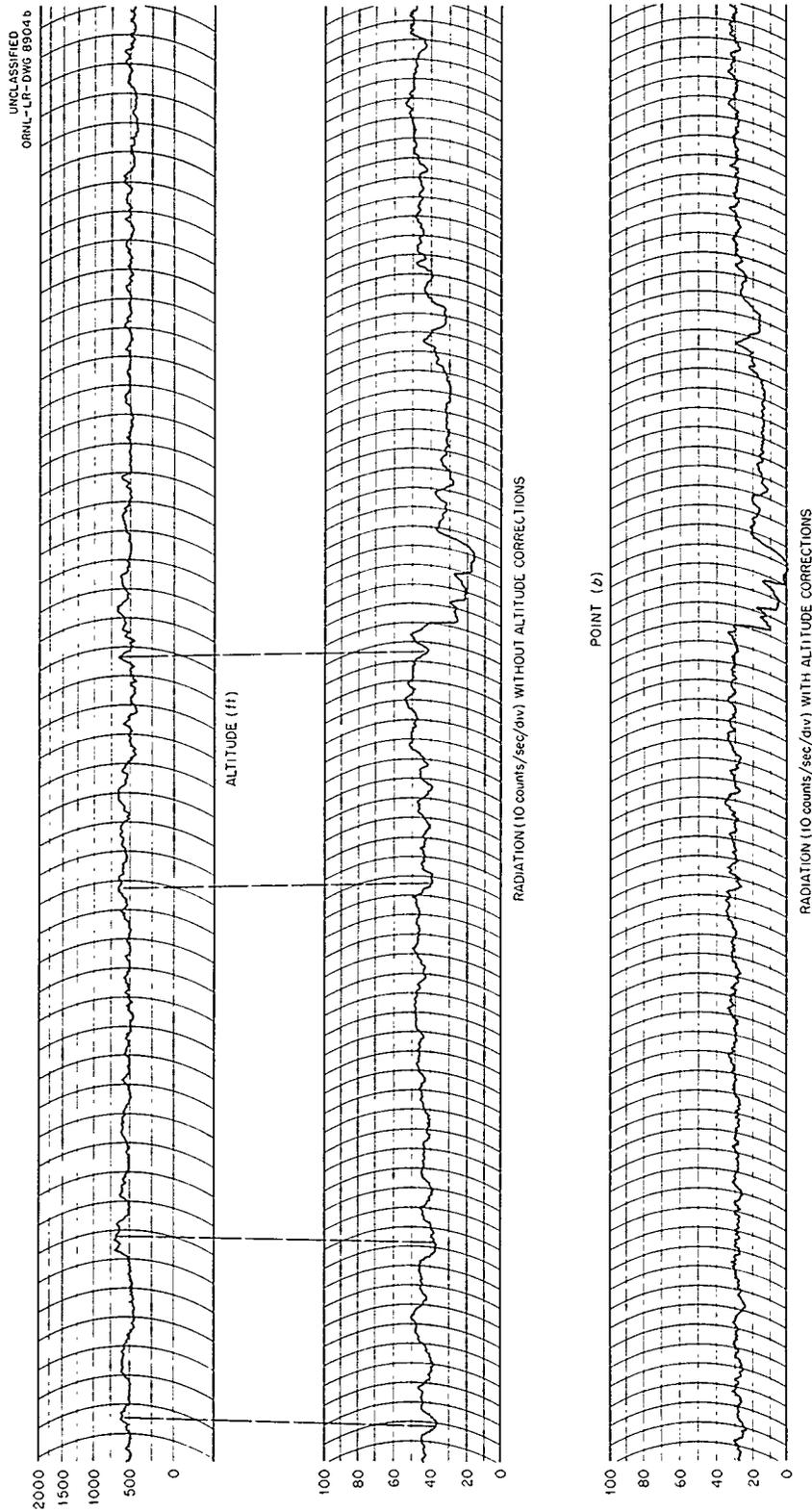


Fig. 7 (continued)

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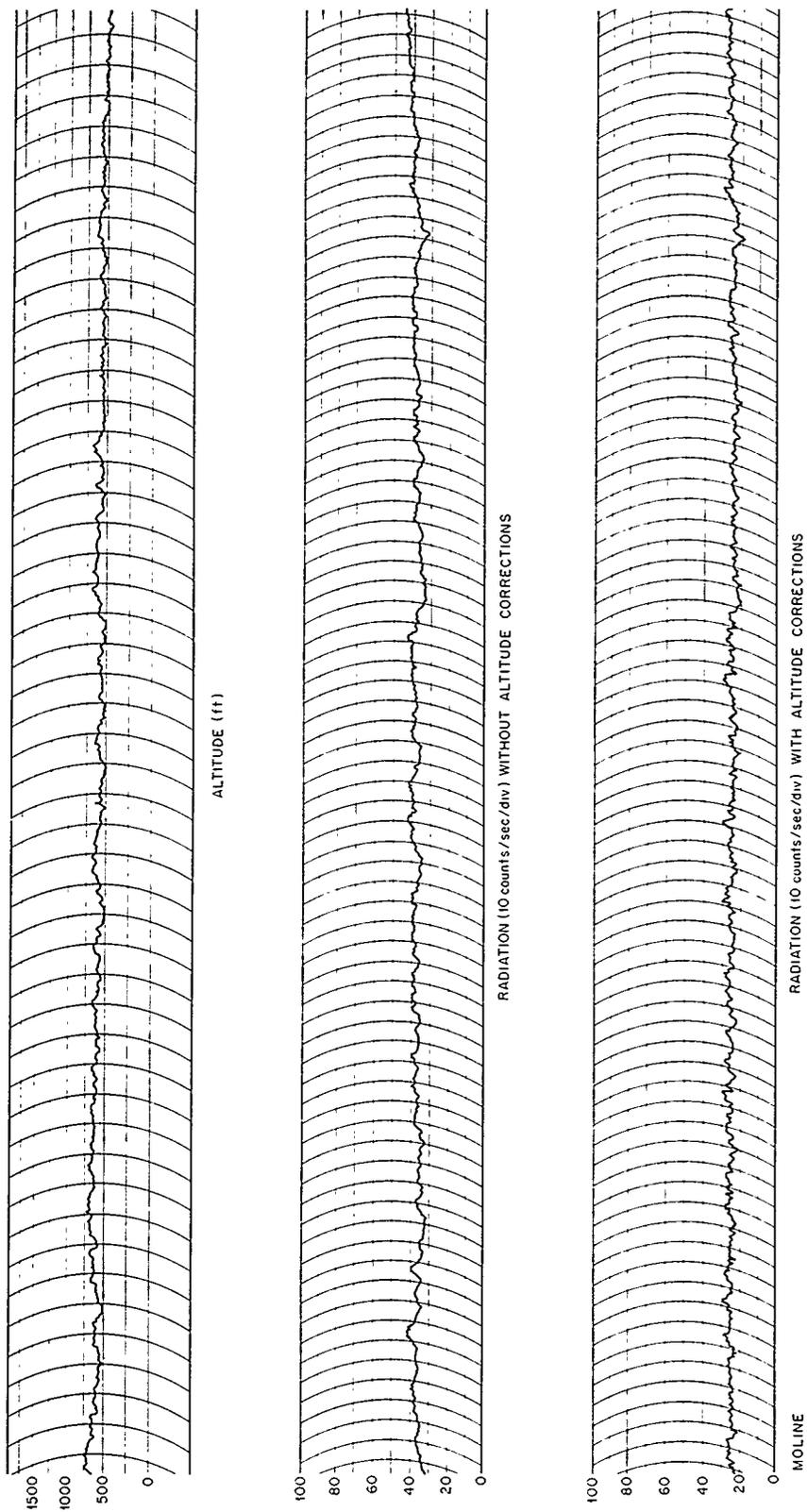


Fig. 7 (continued)

Over land the count is 300 counts/sec as shown in the bottom record. Point *b* in Fig. 7 is the crossing of the Illinois River. The radiation is seen to drop off as Moline, Illinois, is approached. This was probably due to the shielding of snow which was 4 to 6 in. deep. These records were selected because of their uniformity in radiation so that the altitude effect could be shown. This is by no means normal - records obtained on the Texas-New Mexico-Colorado flight showed variations from 10 to 100 divisions, corresponding to 100 to 1000 counts/sec. The line from St. Louis to Moline showed considerably more variation when flown in June 1955, probably because of areas of cultivation and effects of meteorology. It has been noted that after a rain the background radiation is lower.

#### The Use of Threshold Detectors in Operation Teapot

The technique of using threshold detectors to measure neutron spectra was further refined since the original report.<sup>16</sup> Before their use in Nevada in Operation Teapot, the techniques were applied

to the measurements at the ORNL 86-in. cyclotron and at the Los Alamos Lady Godiva. In each case the spectrum was measured and dose was computed by means of the first-collision tissue dose curve; good agreement was found between this method of dosimetry and the direct proportional-counter method.<sup>17</sup>

In Operation Teapot, gold, plutonium with B<sup>10</sup>, neptunium, and sulfur were used as threshold detectors, and the spectrum was measured in air and in lead hemispheres as a function of distance from the source for the five shots investigated in the Biomedical Program. From the measured spectrum the dose (rep) received by the mice being studied by the Los Alamos group was computed. The most important conclusion is that the neutron spectrum does not change with distance; hence a re-examination of data to obtain better dose estimates at previous test series is possible.

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<sup>16</sup>G. S. Hurst *et al.*, *Neutron Flux and Tissue Dose Studies with Fission Threshold Detectors*, ORNL-1671 (March 30, 1954).

<sup>17</sup>G. S. Hurst, *Brit. J. Radiol.* XXVII, 353 (1954).

## EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson

## AEC FELLOWSHIP PROGRAM

E. E. Anderson      M. F. Fair

The 15-week graduate course in Radiological Physics was completed at Vanderbilt University for the 20 AEC Fellows. The ORNL Field Training Program for these Fellows was organized and is now in progress. Ten of the Fellows coming to the Laboratory from Vanderbilt in June have been granted extensions of their fellowships and will work on research problems either at ORNL or at Vanderbilt University which will complete their theses in partial fulfillment of the requirements for a master's degree.

The AEC Fellows for the 1955-1956 program have been selected and will enroll at Vanderbilt University in September.

## OTHER ACTIVITIES

E. E. Anderson      M. F. Fair  
M. R. Ford

A course in mathematics of electricity was conducted for the instrument mechanics in the Laboratory Apprentice Training Program.

A two-week advanced and concentrated course in health physics was given to one Japanese and three Egyptian scientists. Masami Izawa, the Japanese, is a member of the National Institute of Health, Tokyo, Japan, and he will have the responsibility for monitoring air, food, and water when he returns to Japan. The three Egyptians belonged to the group of four Egyptian personnel sent to this country for training in medical and biological uses of radioisotopes and will be the key scientists responsible for the establishment and operation of a radioisotope laboratory in Cairo, the first such laboratory to be established in Egypt.

A six-week advanced course in health physics was conducted for seven medical officers from the Advanced Radiobiology Course of the Armed Forces Special Weapons Project, and one officer from the Radiological Training Department, Ft. McClellan, Alabama.

The section assisted the USNRDL in the establishment of a training program and in the preparation of training material for Operation Wigwam, and also assisted Ohio State University in the planning and conducting of the first unclassified health physics conference ever to be held. The conference was held on the Ohio State University campus at Columbus, Ohio.

The section conducted special lectures and discussion periods for: (1) armed forces visitors, (2) Carbide and Carbon Chemicals Company visitors, (3) MIT Practice School, (4) ORNL Safety Department, and (5) ORNL Orientation Program.

The program of consultation with all outside agencies has continued.

One member of the section participated in calculating maximum permissible single-exposure values for the radioisotopes considered in the ICRP Handbook. Tables of values were set up and were based on five different criteria, as follows:

1. the inhalation of soluble radioactive material,
2. the injection of soluble radioactive material into the body by way of a puncture wound,
3. the injection of insoluble radioactive material by way of a puncture wound,
4. the inhalation of insoluble radioactive material with the lung as the critical organ,
5. the inhalation of radioactive material where some portion of the gastrointestinal tract is the critical body tissue.

For case 5 the dose for the various radioisotopes was calculated at the end of each of the 31 hr that the radioisotopes spent in the gastrointestinal tract. The ORNL digital computer was used for these calculations.

This material will be presented at the Geneva Conference.

Tables of values were compiled from the literature for range and specific ionization of alpha and beta particles in air and tissue. These values will appear in the *Nuclear Engineering Handbook* to be published by McGraw-Hill.

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E. E. Anderson, *Fallout*, Lenoir City Rotary Club, May 1955, Lenoir City, Tennessee.

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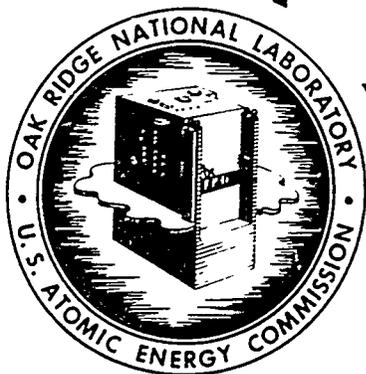
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ERRATUM

HEALTH PHYSICS DIVISION SEMIANNUAL PROGRESS REPORT  
FOR PERIOD ENDING JANUARY 31, 1956

Page No.

Erratum

40

Last equation should read: 
$$K = \frac{10^{-3}}{Dg} (1 - \alpha) \frac{1}{r} \left( 1 + \frac{0.087}{r} \right) \times$$
$$(2.09 V^{-0.57} + 22 V^{-0.78} r^3) ,$$

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## CONTENTS

APPLIED RADIOBIOLOGY .....	1
Distribution and Excretion of Uranium in Man .....	1
Ecology .....	5
Urinalysis Research.....	17
Distribution of Radioisotopes in Animal Tissue .....	17
Isotopic Distribution in Man .....	18
SANITARY ENGINEERING RESEARCH .....	27
Field Investigations.....	27
Chemistry and Soils Engineering .....	36
Airborne-Radioactivity Studies.....	38
RADIATION DOSIMETRY .....	43
Experimental Physics of Dosimetry.....	43
Theoretical Physics of Dosimetry .....	53
Dosimetry Applications .....	54
EDUCATION, TRAINING, AND CONSULTATION.....	60
PUBLICATIONS .....	60
PAPERS .....	62
LECTURES .....	62

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## HEALTH PHYSICS DIVISION SEMIANNUAL PROGRESS REPORT

### APPLIED RADIOBIOLOGY

E. G. Struxness

#### DISTRIBUTION AND EXCRETION OF URANIUM IN MAN

S. R. Bernard	N. L. Gillum
D. K. Bowman	W. E. Lotz
G. J. Dodson	K. K. McDaniel
M. B. Edwards	J. R. Muir
B. R. Fish	G. W. Royster, Jr.

In a continuation of the study<sup>1</sup> of the distribution and excretion of uranium in man, all the urine, blood, and feces samples from patients VII and VIII, who were injected with uranium tetrachloride (UCl<sub>4</sub>), have been analyzed. In addition, the analyses of autopsy samples taken from patients III and VIII have been completed.

Detailed statistical analyses of the distribution and excretion data on the patients (I through VI) injected with U(VI) were started during this period in order to obtain the best set of parameters to represent the data. One of the statistical methods used is the regression test of linearity<sup>2</sup> applicable to data such as decay curves when several measurements are taken at a given time. The test is simple; the variance within measurements is compared to the variance between the data and the best fitting regression curve by the *F* ratio test, and, if this variance is significantly different, the data are said to depart significantly from a re-

gression curve. When this procedure was applied to excretion data of patients I, II, III, IV, V, and VI where the linear version of the power function  $Ae^{bt}$  ( $b < 0$ ) was assumed, it was concluded that the data were not best described by this function. It is interesting to know that when the same test was applied to plutonium urinary excretion data<sup>3</sup> there was no significant departure from linear regression.

The per cent of injection dose per 10<sup>4</sup> g of bone (autopsy samples) for patients I, II, III, V, and VI is plotted in Fig. 1. The graph, which includes all the individual analyses, shows a wide range of concentrations. If a single exponential is assumed to be representative of these data and if the linearity test (*vide supra*) is applied, the data depart significantly from this function. The value of the intercept is  $3.8 \times 10^{-4}$ % of injected dose per gram and the half life is 241 days. Functions other than the single exponential term, for example,  $(a + bt)^{-2}$ , were similarly tested without success.

It is suggested that these data can be represented by letting  $\lambda$  in the function  $e^{-\lambda t}$  vary with time. The following procedure shows that this is true: (1) assume a single exponential term; (2) calculate the half life from bone biopsy and autopsy values for each patient; and (3) plot this calculated half life vs the time of expiration. The calculated half lives of step 2 are listed in Table 1. Note the significant difference between

<sup>1</sup>S. R. Bernard *et al.*, *HP Semiann. Prog. Rep.* July 31, 1955, ORNL-1942, p 1.

<sup>2</sup>W. J. Dixon and F. J. Massey, *Introduction to Statistical Analysis*, p 160-161, McGraw-Hill, New York, 1951.

<sup>3</sup>W. H. Langham *et al.*, *Distribution and Excretion of Plutonium Administered Intravenously to Man*, LA-1151 (Sept. 20, 1950), p 24-25.

TABLE 1. BIOLOGICAL HALF LIVES OF U(VI) IN BONE - BIOPSY AND AUTOPSY SPECIMENS

	Patient Number				
	I	VI	II	V	III
	Expiration Time (days)				
	2.5	18	74	139	566
Biological half life and standard deviation (days)	$2.3 \pm 0.56$	$15.1 \pm 6.24$	$17.1 \pm 6.89$	$44.4 \pm 6.83$	$222.1 \pm 68.3$

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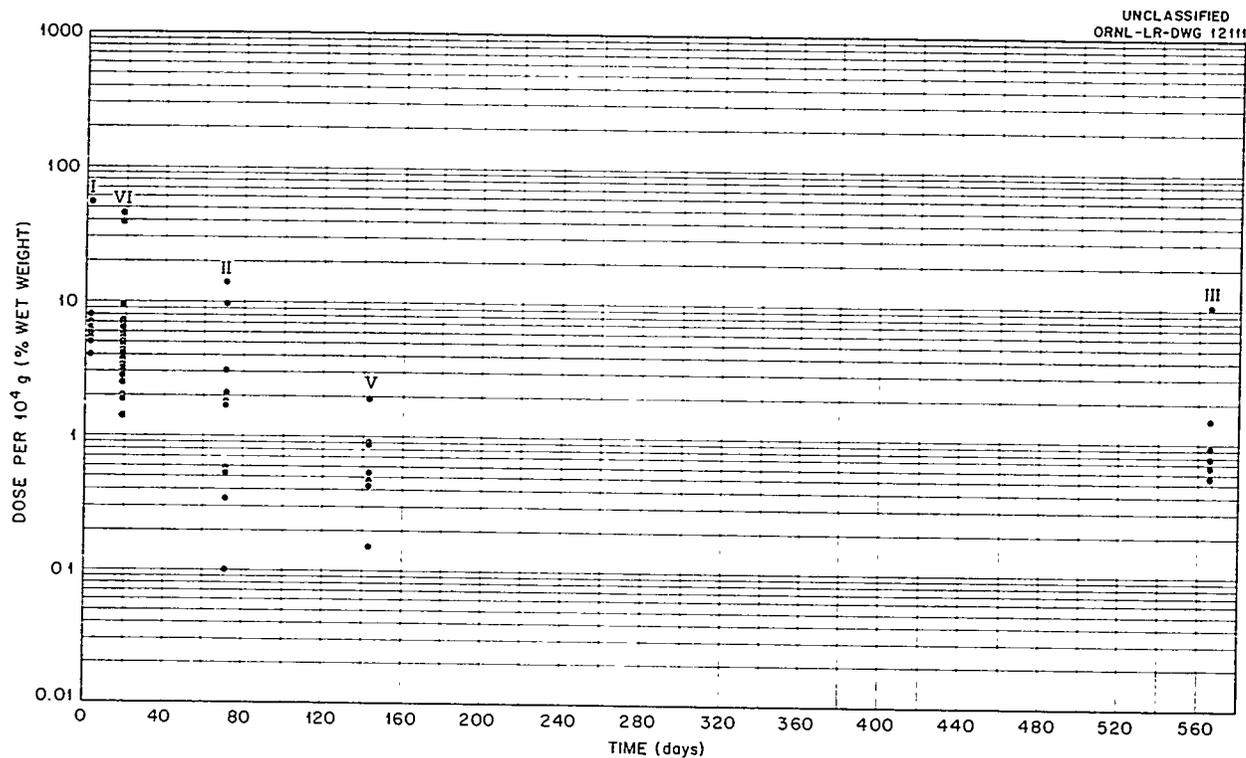


Fig. 1. Plot of Individual Bone Autopsy Results for Five Patients Injected with U(VI).

the patients. The graph of step 3 is shown in Fig. 2, where the half life is seen to increase in proportion to  $t^{4/5}$ .

Other data which have important application to the calculations of maximum permissible concentrations (MPC) for uranium are those contained in Tables 2 and 3 and Fig. 3. Table 2 shows that (1) the different samples of bone reflect different mean concentrations; (2) the U(IV) autopsy bone concentrations are very similar to U(VI); and (3) the samples of the femur are the lowest in concentration, while the vascular bone, rib, is highest in the early stages after injection and the skull concentration is highest at later stages. Figure 3 is a diagram of the uranium concentrations in a longitudinal plane sectioned from the distal end of the femur. The section, approximately  $\frac{1}{4}$  in. thick, was cut into smaller sections and each section was analyzed for uranium. The numbers in each section are the concentrations in counts per minute per gram of bone. In general, it may be said that the concentrations decrease in the direction of the shaft.

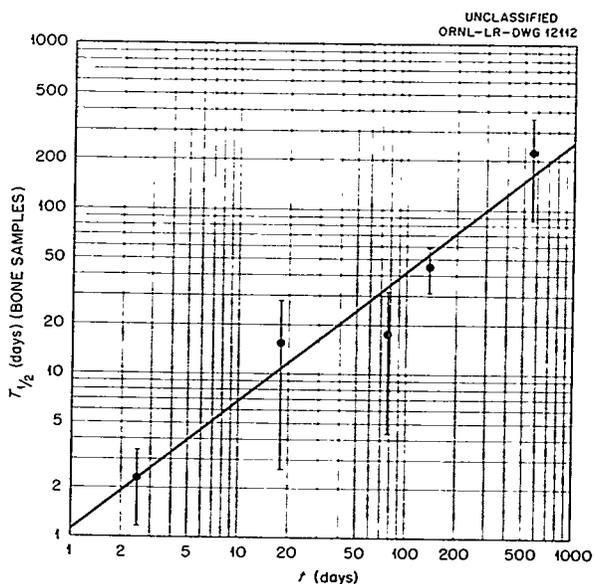


Fig. 2. Plot of Biological Half Life of U(VI) in Bone Determined from Femur Autopsy and Biopsy Samples vs Time of Autopsy.

TABLE 2. BONE AUTOPSY DATA - PER CENT OF INJECTED DOSE PER 7000 g

Patient No.*	Postinjection Time (days)	Sample					Mean
		Femur	Rib	Skull	Sternum	Vertebra	
Injection: $UO_2(NO_3)_2 \cdot 6H_2O$							
I	2½	4.1	13.8	5.5		37.7	14.0
VI	18	3.3	29.5				16.3
II	74	0.4	1.8	8.3	0.4	1.3	2.4
V	139	0.4	0.6	1.3			0.8
III	566	0.6	0.6	7.4	1.1	0.4	2.0
Injection: $UCl_4$							
VIII	21	0.6	27.5			15.1	14.4

\*No autopsy data obtained for patients IV and VII.

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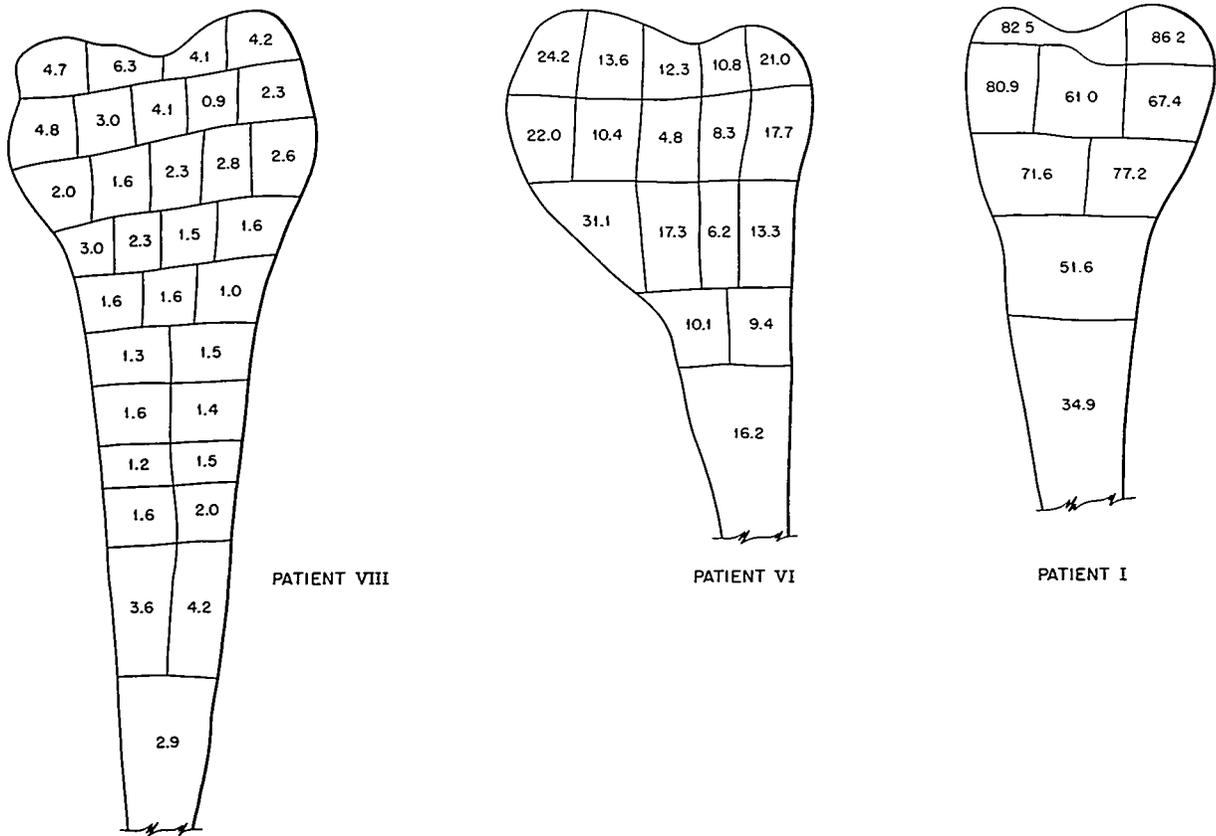


Fig. 3. Diagram of Concentration of Uranium in Longitudinal Section of Distal End of the Femur. Numbers in each section represent counts/min/g.

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TABLE 3. PER CENT OF INJECTED DOSE PER STANDARD MEAN ORGAN OR TISSUE FOR SIX TERMINAL BRAIN TUMOR PATIENTS

Patients I, VI, II, V, and III injected with  $UO_2(NO_3)_2 \cdot 6H_2O$   
 Patient VIII injected with  $UCl_4$

Organ or Tissue	Sample Amount (g)	Patient Number					
		I	VI	II	V	III	VIII
		Expiration Time (days)					
		2.5	18	74	139	566	21
Kidney	300	16.6	7.2	0.7	1.2	0.4	1.1
Muscle	30,000	1.2	2.1	0.9	0.3	0.06	0.4
Skin and subcutaneous tissues	6,100	1.8	1.0	0.1	0.06		
Fat	10,000	0.6	0.6			0.04	
Red marrow	1,500			0.02	0.03	0.1	
Yellow marrow	1,500						
Blood	5,400	1.0	0.2	0.005	0.002	0.004	0.08
Lower large intestine	150						
Stomach	250	0.08	0.02	0.003	0.001	0.001	
Small intestine	1,100	0.2	0.2	0.03	0.01	0.006	0.1
Upper large intestine	135						
Liver	1,700	1.8	1.1	0.2	0.2	0.05	9.2
Brain	1,500						
Lungs	1,000	0.5	0.4	0.03	0.02	0.008	0.3
Lymphoid tissue	700						
Heart	300	0.06	0.02	0.003	0.006	0.002	0.004
Spleen	300	0.6	0.2	0.1	0.02	0.006	5.6
Urinary bladder	150	0.03		0.002	0.001	0.0003	0.06
Pancreas	70	0.7	0.008	0.008	0.0006	0.0004	
Salivary glands	50						
Testes	40		0.01	0.008	0.002	0.002	0.008
Spinal cord	30						
Eyes	30						
Thyroid gland	20		0.003	0.0002	0.0001	0.0002	0.0009
Teeth	20						
Prostate gland	20		0.003	0.0004	0.0004	0.0001	0.003
Adrenal gland	20	0.02	0.01	0.003	0.001	0.0004	0.02
Thymus	10						
Miscellaneous tissues (blood vessels, cartilage, nerves, etc.)	390	0.3	0.2	0.04	0.002	0.002	0.04

Some interesting observations can be made of the distribution and excretion of tetravalent uranium. Table 3 shows that U(IV) favors deposition in the reticulo-endothelial tissues of the liver and spleen in direct contrast to U(VI), which concentrates in the kidney. Figures 4, 5, and 6 show the disappearance of U(IV) from blood, feces, and urine, respectively. There appears to be little difference between the urinary excretion of U(VI) and U(IV); however, in excretion via the gastrointestinal tract, the data in Fig. 5 for U(IV) show some time relationship not seen in the data for the fecal excretion of U(VI). Only 0.1% of the injected dose had accumulated in feces of patient VII at 430 hr. The rate of disappearance of U(IV) from the blood is only slightly different from that of U(VI).

#### ECOLOGY

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#### Soil Fertility and the Uptake of Strontium by Plants

Strontium and calcium have been related chemically in both soils and plants. Variations in the uptake of these elements have been attributed to the amount and kind of clay minerals occurring in soils and to the rate of plant growth.

Since soils may serve for the disposal of nuclear wastes containing strontium, an evaluation is required to determine the degree to which this element may replace calcium on soil colloids.

In the studies reported here the nonradioactive isotope of strontium and the normal plant nutrients have been adsorbed on Conasauga shale, and the amounts of the isotope and the nutrients taken up by bean plants at various stages of maturity have been determined. In addition, each series of soils received equal amounts of radioactive Sr<sup>90</sup>.

Occurring naturally as the subsoil of Armuchee silt loam, the Conasauga shale was taken from the Four-Acre Site at ORNL. Preliminary studies indicate this material to be 87% silt (0.006 to 0.002 mm) and 12% clay (0.002 mm and less). It has a total exchange capacity of 20 milliequivalents (meq) with 4.26 meq Ca<sup>++</sup>, 1.08 meq Mg<sup>++</sup>, 0.19 meq Na<sup>+</sup>, and 0.47 meq K<sup>+</sup> per 100 g of soil. It contains 0.009% nitrogen, 0.0055% sulfur, 0.064%

carbon, and 0.53% strontium. About 0.82 ppm of phosphorus is extractable with 0.1 N HCl. Results from the x-ray powder photographs, electromicrographs, and differential-thermal-analyses patterns of the colloidal fraction indicate that the exchange surface is composed of a mica-type mineral with some quartz and a little halloysite present. Little or no kaolin was detectable. The soil was brought to the laboratory, air-dried, and ground to pass through an 8-mesh screen.

Seven ratios of calcium to strontium were established so that the soils of each series had a cation composition of 5% potassium, 15% magnesium, and 80% calcium and strontium. The latter two elements were varied so that their sum remained constant. For each Ca-Sr ratio, triplicate cultures, consisting of 3 kg of oven-dried soil, were prepared for each of the four stages of bean plant maturity at which the plant will be analyzed for Sr. Each culture received 360 mg of nitrogen, 300 mg of phosphorus, and 240 mg of sulfur.

An aliquot of soil material of particle size less than 175  $\mu$  in diameter and representing approximately 5% by weight of the total soil to be contaminated was obtained by mechanical dry sieving. To the aliquot, Sr<sup>90</sup>CO<sub>3</sub> was added to give a 1:1 ratio by weight of soil to water suspension which was maintained by agitation for 30 min and then dried at 70°C. These dried fine fractions and the nutrients to be added were pulverized and incorporated into the soil for each plant series by mechanical batch- or barrel-type mixing. The specific activity was adjusted to about 2.7  $\mu$ c per 100 g of soil.

The cultures were kept moist for at least five days to allow each soil nutrient complex to reach a possible equilibrium. Five seeds of the garden bush bean *Phaseolus vulgaris*, variety Top Crop, were seeded in each pot and covered with  $\frac{1}{2}$  in. of white quartz sand. Plants from each calcium-strontium series were harvested at 12-day intervals.

The upper portions of the plants were removed by cutting the stem 1 in. above the soil. The individual plant parts were separated and weighed and then dried at 70°C for 24 hr. The entire material was digested by the nitric-perchloric acid method of Piper. Aliquots were removed for counting and for making chemical determinations of calcium, strontium, magnesium, and potassium.

One object of this experiment was to determine the effect of high concentrations of calcium and

<sup>4</sup>Research participant.

<sup>5</sup>Temporary summer employee.

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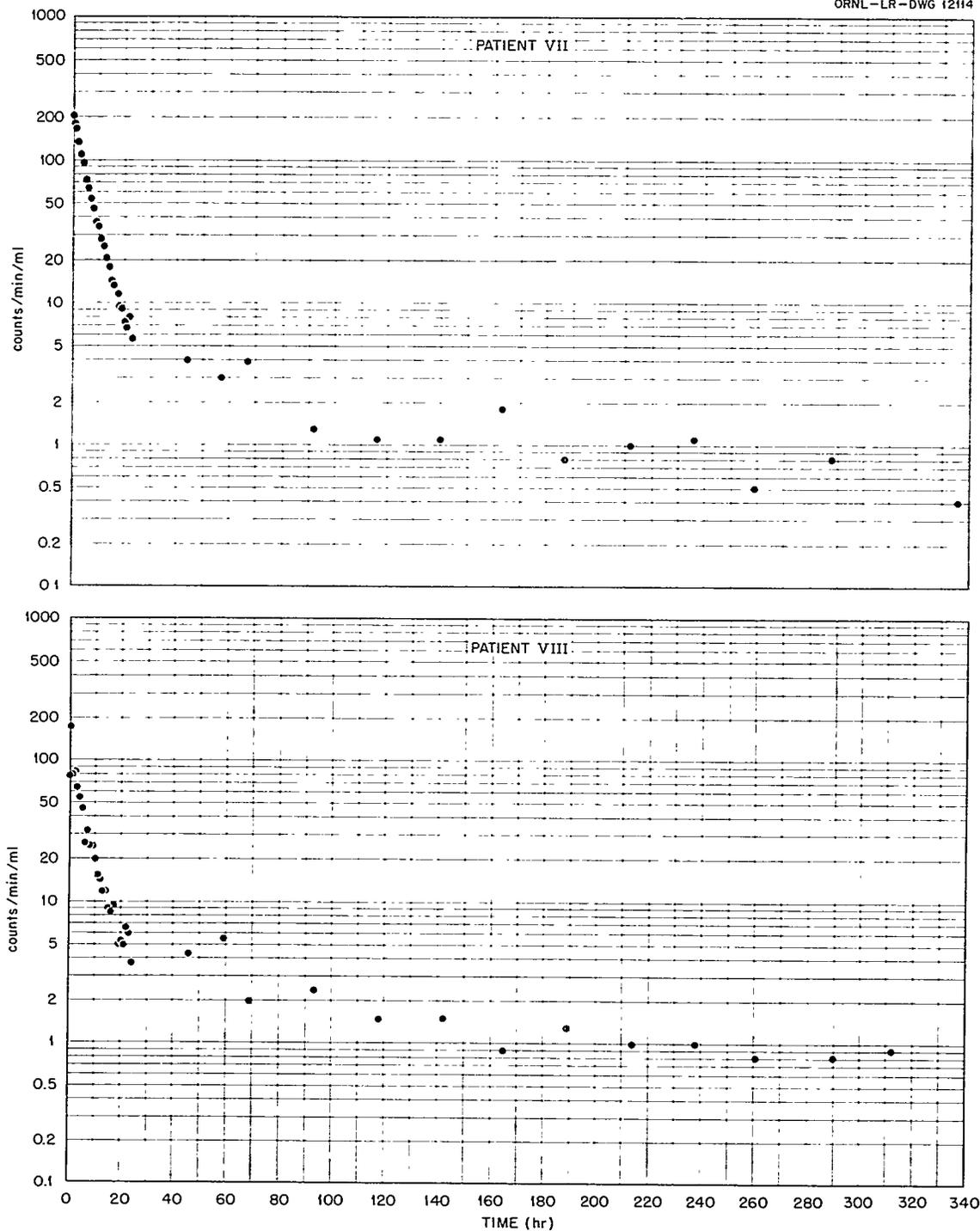


Fig. 4. Disappearance of U(IV) from Blood of Patients Injected Intravenously with  $UCl_4$ .

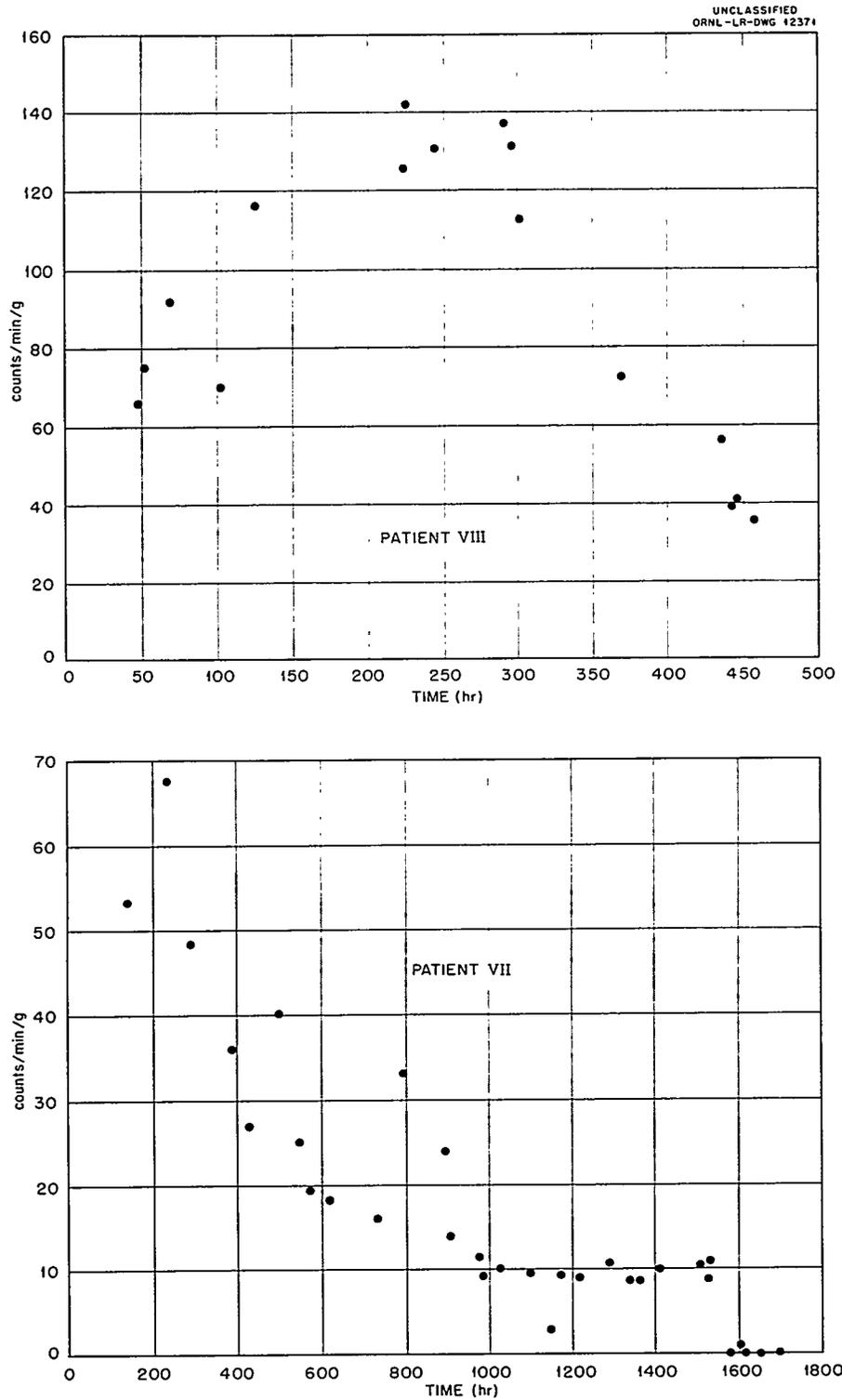


Fig. 5. Excretion of Uranium Via Feces Following Intravenous Administration of  $UCl_4$ .

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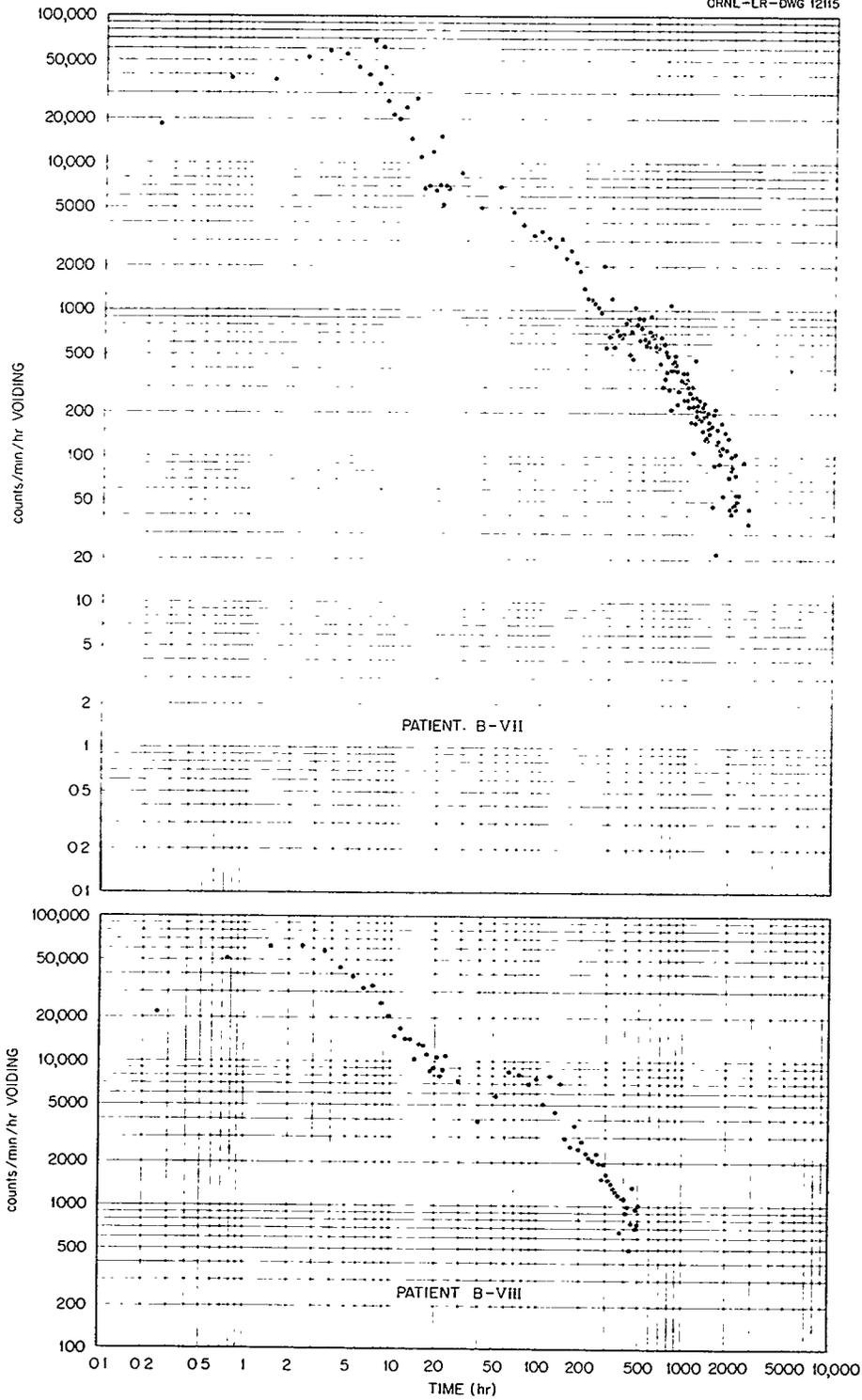


Fig. 6. Urinary Excretion of Uranium Following Intravenous Administration of  $UCl_4$ .

strontium in the soil on the uptake of Sr<sup>90</sup> by the bean plants. There appears to be a gradual decrease in the concentration factor

$$\frac{\text{counts/min per gram of leaf}}{\text{counts/min per gram of soil}}$$

as the per cent of strontium in the cation composition of the soil increases, as indicated by the data in Table 4.

The distribution of the Sr<sup>90</sup> activity in the various parts of the plant with respect to soil treatment is well illustrated by the data in Table 5. A general decline of activity in the stems, leaves, and pods with increasing amounts of carrier

strontium available was noted. The seeds seem to accumulate more of the activity as more carrier strontium and less calcium are available in the soil. In each series the leaves contained more activity than the corresponding stems, pods, or seeds.

Tables 6 and 7 indicate the magnitude of the decline of the Sr<sup>90</sup> activity of the leaves and stems. It is notable that the decline occurs at all stages of growth. This is in agreement with the theory of isotope dilution.

By increasing the degree of saturation of the soil with carrier strontium, the uptake of this element by all plant parts was enhanced, although the concurrent decrease of calcium in the soil was not always accompanied by a proportionate decrease of the calcium concentration in the plants. The data in Table 8 indicate that only after 36 days of growth do the plants begin to show a definite dependence on the soil calcium. Determination of the magnesium and potassium concentration in the plant parts indicated that these elements had been supplied in adequate amounts and that they were freely available from the soil colloids used in this study.

The growth of the plants did not show evidence of injury from either the activity or high concentration of strontium in the soil. Definite decreases in seed yield became evident as less calcium and more strontium were available in the soils.

It appears reasonable to conclude from the experiments conducted that (1) the uptake of Sr<sup>90</sup> from natural soils will be concentrated to a higher degree in the leaves than in the other parts of the bean plant, and (2) the concentration factor will be approximately sixfold and that this factor may depend on the total amounts of strontium available in the soil. The amount per unit weight of active strontium absorbed and translocated to leaves declines as more carrier strontium is available in the soil. Uptake of calcium from the soil appears to be almost independent of soil saturation with calcium, at least in the earlier stages of plant growth.

Strontium can replace calcium on the soil colloid to make adequate amounts of potassium and magnesium available for plant growth.

#### Effects of Gamma Radiation on *Onthophagus texanus* Schaeffer (Coleoptera, Scarabaeidae)

A species of soil-inhabiting beetle, *Onthophagus texanus*, was subjected to gamma radiation from a

TABLE 4. CONCENTRATION OF Sr<sup>90</sup> IN 12-DAY-OLD BEAN LEAVES ACCORDING TO SATURATION OF SOIL WITH CALCIUM AND STRONTIUM CARRIER

Degree of Soil Saturation (%)		Concentration Factor
Sr	Ca	
10	70	8.19
20	60	6.71
30	50	6.48
40	40	5.38
50	30	3.99
60	20	3.91

TABLE 5. Sr<sup>90</sup> ACTIVITY IN BEAN PLANT PARTS ACCORDING TO CALCIUM AND STRONTIUM IN THE SOIL

Degree of Saturation of Soil Colloids (%)		Activity (counts/min/mg)			
Sr	Ca	Stems	Leaves	Pods	Seeds
10	70	48.7	60.9	30.4	4.8
20	60	38.3	54.0		5.1
30	50	39.9	53.5	30.5	5.7
40	40	37.6	50.7	25.6	8.1
50	30	33.8	38.0	25.7	9.6
60	20	27.6	35.4	19.2	11.4

HEALTH PHYSICS PROGRESS REPORT

Co<sup>60</sup> source. *Onthophagus* beetles were used because they have a short, continuous life cycle, can be easily handled and sexed, and are readily reared in earth-filled flower pots.

Female beetles, when supplied with day-old cow dung, construct 3 to 7 in. burrows, each with a wad of dung at its terminus. A single egg is

placed in each wad; the larva develop within the wad. Since the larvae could not complete development without this food supply furnished by the adult beetles, not only doses which produce sterility but any radiation effect on adult activity must be considered. The dry wads containing the larvae were easily removed from the pots, irradiated,

TABLE 6. CONCENTRATION OF CARRIER\* AND RADIOACTIVE STRONTIUM\*\* IN BEAN LEAVES OF DIFFERENT STAGES OF GROWTH

Degree of Saturation of Soil Colloids (%)		Growth Stage							
Stable Sr	Ca	12 Days		24 Days		36 Days		48 Days	
		Sr <sup>90</sup>	Total Sr						
0	80	0.8	0.025	0.7	0.014	0.7	0.023	0.7	0.034
10	70	79.3	0.179	112.2	0.635	53.7	0.439	60.9	0.375
20	60	76.4	0.597	105.7	1.288	65.2	0.927	54.0	0.637
30	50	62.6	1.031	98.4	1.986	64.4	1.394	53.5	1.127
40	40	56.3	1.143	79.2	2.848	48.6	1.796	50.7	1.260
50	30	56.2	1.203	64.6	2.534	53.0	2.160	38.0	1.613
60	20	47.5	1.304	59.1	2.634	52.7	2.405	35.4	1.910

\*Total Sr given as per cent dry weight.

\*\*Sr<sup>90</sup> given as counts/min per mg of dry leaf corrected to 10% geometry. Each value is the average of three determinations on independently grown cultures of five plants each.

TABLE 7. CONCENTRATION OF CARRIER\* AND RADIOACTIVE STRONTIUM\*\* IN BEAN STEMS HARVESTED AT DIFFERENT STAGES

Degree of Saturation of Soil Colloids (%)		Growth Stage							
Stable Sr	Ca	12 Days		24 Days		36 Days		48 Days	
		Sr <sup>90</sup>	Total Sr						
0	80	0.6	0.062	1.0	0.011	0.4	0.027	0.9	0.019
10	70	122.9	0.500	69.3	0.354	56.5	0.415	48.7	0.314
20	60	72.3	0.609	69.1	0.935		0.788	38.3	0.547
30	50	71.2	1.018	70.1	1.495	45.7	0.971	38.0	0.884
40	40	57.5	0.953	59.6	1.752	41.1	1.385	37.6	1.064
50	30	53.3	1.113	55.0	1.629	41.6	1.653	33.8	1.251
60	20	51.9	4.89	44.9	1.825	41.5	1.733	27.6	1.324

\*Total Sr given as per cent dry weight.

\*\*Sr<sup>90</sup> given as counts/min per mg of dry stem corrected to 10% geometry. Each value is the average of three determinations on independently grown cultures of five plants each.

TABLE 8. Sr-Ca COMPOSITION OF BEAN PLANTS AT VARIOUS STAGES OF GROWTH ACCORDING TO TREATMENT OF THE SOIL WITH CALCIUM AND STRONTIUM

Degree of Saturation of Soil Colloids (%)		Leaves		Stems		Roots			
Sr	Ca	Total Sr	Ca	Total Sr	Ca	Total Sr	Ca		
12-Day-Old <sup>a</sup>									
0	80	0.035	0.981	0.062	0.916	0.079	0.328		
10	70	0.179	0.540	0.500	1.132	0.147	0.325		
20	60	0.597	1.160	0.609	1.169	0.230	0.264		
30	50	1.031	1.102	1.018	0.941	0.309	0.262		
40	40	1.143	0.728	0.953	0.546	0.294	0.229		
50	30	1.203	0.577	1.113	0.446	0.416	0.239		
60	20	1.304	0.536	4.89	0.284	0.448	0.232		
24-Day-Old <sup>b</sup>									
0	80	0.014	1.447	0.011	0.9842	0.217	0.6259		
10	70	0.635	1.583	0.354	0.6531	0.365	0.6118		
20	60	1.288	1.692	0.935	0.8981	0.604	0.6117		
30	50	1.986	1.342	1.495	0.9850	0.862	0.6619		
40	40	2.848	1.587	1.752	0.9184	0.756	0.6066		
50	30	2.534	1.514	1.629	1.0023	0.423	0.4310		
60	20	2.634	1.352	1.825	0.8192	0.787	0.5224		
36-Day-Old <sup>a</sup>									
0	80	0.023	2.635	0.027	1.618	0.020	0.971		
10	70	0.439	2.203	0.415	1.604	0.095	0.910		
20	60	0.927	2.385	0.788	1.699	0.176	0.644		
30	50	1.394	2.012	0.971	1.008	0.228	0.628		
40	40	1.796	1.755	1.385	1.231	0.326	0.723		
50	30	2.160	1.720	1.653	1.146	0.416	0.719		
60	20	2.405	1.220	1.733	0.962				
Degree of Saturation of Soil Colloids (%)		Leaves		Stems		Pods		Seeds	
Sr	Ca	Total Sr	Ca	Total Sr	Ca	Total Sr	Ca	Total Sr	Ca
48-Day-Old <sup>a</sup>									
0	80	0.034	2.405	0.019	1.6030	0.004	0.681	0.002	0.084
10	70	0.375	1.783	0.314	1.2054	0.144	0.583	0.014	0.084
20	60	0.637	1.605	0.547	1.2007	0.334	0.551	0.023	0.097
30	50	1.127	1.765	0.884	0.9009	0.354	0.562	0.030	0.115
40	40	1.260	1.495	1.064	0.9001	0.408	0.444	0.056	0.115
50	30	1.613	1.300	1.251	0.8063		0.406	0.066	0.139
60	20	1.910		1.324	0.7037	0.465	0.376	0.073	

<sup>a</sup>Each value is an average of three cultures representing a total of 15 plants. Values given in per cent of dry weight.

<sup>b</sup>In the determination of strontium in the roots, there was some contamination from soil.

HEALTH PHYSICS PROGRESS REPORT

and then kept in metal salve boxes, where their development could be observed.

Adult beetles were given a dose of 5000 r at a dose rate of 26 r/sec. Second-stage larvae in the dung wads were given total doses of 2000 and 4000 r at the same dose rate.

The number of dung wads placed at the ends of the burrows by the adults was considered as one criterion of activity, while the lack of eggs within the wads was considered as an indicator of sterility. With doses of 3000 to 5000 r the adult beetles formed fewer egg cells than the controls, and in no case did the treated adults produce fertile eggs. Table 9 summarizes this portion of the work.

The second-stage larvae were divided into three lots of 30 cells each, which were in turn divided into sublots of 10 cells. One lot of 30 cells was left untreated, one lot received a dose of 2000 r, and one lot of 30 received 4000 r. Table 10 summarizes the results. No developmental differences could be noted between the controls and

those cells given the 2000-r dose. With 4000 r there was a high mortality and the few beetles reaching the adult stage were badly deformed. The crumpled elytra, shortened antennae with the antennal clubs fused, tarsal segments fused or missing, and the deformed clypeus were a few of the more obvious deformities produced. While radiation-induced deformities have been noted in *Drosophila* and *Habrobracon*, they have not been previously recorded for beetles.

The adults resulting from the treated larvae were placed in rearing pots. The deformed adults from the larvae given the 4000-r dose were too abnormal to burrow and were therefore incapable of reproduction even if they had been fertile. The adults from the 2000-r larval treatments, while normal in appearance, produced few cells and no fertile eggs, as is indicated in Table 11. Whiting and Bostian<sup>6</sup> found that some *Habrobracon* adults

<sup>6</sup>A. R. Whiting and C. H. Bostian, *Genetics* 16, 659-680 (1931).

TABLE 9. REPRODUCTION OF ONTHOPHAGUS CONTROLS AND IRRADIATED ADULTS

Number of Pairs	Dose (r)	♂ Life Span (days)	♀ Life Span (days)	Number of Egg Cells Formed	Number of Egg Cells Viable
Irradiated					
1	5000	19	8	4	0
1	5000	14	16	4	0
3	5000	7, 8, 15	7, 17, 13	0	0
3	5000	9, 14, 14	14, 14, 16	1	0
1	3000	17	21	0	0
3 ♂	♂ - 5000	9, 9, 14			
Controls					
1 ♀	♀ - 0		14	1	0
1	0	15	25	5	3
2	0	15	18	8	8
2	0	av for males	av for females	7	6
2	0			8	7
2	0	15	18	13	12
2	0	15	18	23	22
2	0	15	18	8	8
2	0	15	18	4	4

TABLE 10. DEVELOPMENT OF ADULT ONTHOPHAGUS FROM CONTROL AND IRRADIATED SECOND INSTARS

	Number of Cells	♂	♀	Number Unsuccessful	Average Development Time (days)
Control					
	10	4	2	4	35-51, 39 median
	10	5	2	3	
	10	3	4	3	
Total	30	12	8	10	
Irradiated					
2000 r					
	10	1	6	3	35-44, 38 median
	10	4	2	4	
	10	7	0	3	
Total	30	12	8	10	
4000 r					
	10	1	0	9	42-49, 42 median; all adults deformed
	10	0	2	8	
	10	0	0	10	
Total	30	1	2	27	*

\*1 ♂, 3 ♀ dead in cells.

emerging from larvae which had been subjected to doses as low as 730 r failed to reproduce. The number of failures increased as the dose was increased. These investigators suggested that this was not entirely due to sterilization but to lessened vigor, which resulted in early death. In the *Onthophagus* from the 2000-r treatment there was no evidence of shortened life span, but, since they produced considerably fewer cells, it is possible that their vigor was affected as well as (or instead of) their fertility.

**Delayed Effects of Gamma Radiation on Tree-Hole Arthropods**

A single beech tree hole from the Laboratory environs was completely excavated, and part of the removed substrate was subdivided into 100-g samples. These samples were grouped into three series, each series consisting of eight samples divided into the following doses of gamma radiation from a Co<sup>60</sup> source: 3 × 10<sup>3</sup>, 8 × 10<sup>3</sup>, 1.5 × 10<sup>4</sup>, 2.5 × 10<sup>4</sup>, 5 × 10<sup>4</sup>, 7.5 × 10<sup>4</sup>, 1 × 10<sup>5</sup>, and

1.25 × 10<sup>5</sup> r, at a dose rate of 26 r/sec. Five control samples were set up as a part of each series. After irradiation each sample was transferred to a sterile red-clay flower pot covered with cellophane. The pots were stored in chambers where the temperature was kept at 75 ± 3°F and the relative humidity ranged from 65 to 85%. At the end of 30 days a series, consisting of eight experimental and five control samples, was removed and processed through Berlese-type funnels to extract the surviving arthropods. Of the remaining two series, one was processed after 60 days and the other after 90 days. All samples were counted in a gridded evaporating dish under a dissecting microscope. Total counts were made in all cases.

Preliminary analysis of the data indicates differences in response to irradiation under these conditions for Acarina, Collembola, Isopoda, and Chilopoda. In the case of the Acarina and Collembola there is evidence of difference even between species which are morphologically closely

TABLE 11. REPRODUCTION OF *ONTHOPHAGUS* FROM CONTROLS AND ADULTS IRRADIATED AT SECOND INSTAR

Number of Pairs	Dose (r)	♂ Life Span (days)	♀ Life Span (days)	Number of Cells Formed	Number of Cells Viable
Irradiated					
2	2000	18, 20	14, 14	0	0
2	2000	12, 13	16, 38	3	0
2	2000 (+3000 as adults)	13, 14	16, 18	1	0
1	4000	6	6	0*	
Control					
1	0	15	25	5	3
2	0	15	18	8	8
2	0	av for	av for	7	6
2	0	males	females	8	7
2	0	15	18	13	12
2	0	15	18	23	22
2	0	15	18	8	8
2	0	15	18	4	4

\*Adults unable to burrow.

related. At the higher taxonomic category levels, differences appear to be even more pronounced. Most of the Acarina showed relatively high resistance to radioactivity for the entire period of the experiment, but the Isopoda and Chilopoda were adversely affected (as measured by survival) by much lower doses of radiation. The Collembola, both at the species and family level, showed greater resistance to the irradiation under these conditions than did either the isopods and chilopods but less resistance than did the mites. A more detailed statistical analysis of the data is currently in progress.

#### Studies of the Uptake of Fission Products by Earthworms

**Uptake of Sr<sup>89</sup> by *Allolobophora caliginosa* (Savigny).** — To investigate further the ability of earthworms to concentrate Sr<sup>89</sup> present in the soil, an experiment was conducted which was similar to

the one used for *Eisenia foetida* (Savigny)<sup>7</sup> except that *Allolobophora caliginosa* (Savigny)<sup>8</sup> was used in place of *Eisenia foetida*. *Allolobophora caliginosa* is believed to be the most abundantly represented and most widely distributed of the North American earthworms.<sup>9</sup>

The design of this experiment differed somewhat from the previous experiment.<sup>7</sup> Two soil series were used. In one series the same type of soil as in the previous experiment was used without modification. In the second series the soil was enriched with certain inorganic constituents considered to be of importance in soil fertility. The

<sup>7</sup>S. I. Auerbach *et al.*, *HP Semiann. Prog. Rep.* July 31, 1955, ORNL-1942, p 7.

<sup>8</sup>The authors are indebted to Dr. W. Murchie, Thiel College, Greenville, Penn., for supplying the worms.

<sup>9</sup>F. Smith, *Proc. U. S. Nat. Museum* 52, 157-182 (1917).

analyses of these two soils<sup>10</sup> are given below:

	Soil	
	I	II
Organic matter, %	4.1	4.4
P <sub>2</sub> O <sub>5</sub> , ppm	29	45
K, ppm	12	28
Mg, ppm	13	13
Ca, ppm	100	160
pH	5.3	6.2
Total hydrogen, meq/100 g	6.0	2.5
Cation exchange capacity, meq/100 g	12	12
Base saturation, %	50	79

Six red-clay flower pots were used for each series. Each series was divided into five experimental pots and one control pot. Each of the five pots was brought up to a different activity level of Sr<sup>89</sup>. The activities (in microcuries per gram of soil) were as follows:  $1.88 \times 10^{-3}$ ,  $3.77 \times 10^{-3}$ ,  $5.65 \times 10^{-3}$ ,  $7.54 \times 10^{-3}$ ,  $9.43 \times 10^{-3}$ . These activities were the same in both series. The isotope was added to the soils in the same manner as before.<sup>7</sup> Six adult worms were added to each pot. The pots were weighed twice a week to determine the water loss, and water was added as needed.

After 30 days the pots were examined for the surviving worms; 69 of an initial 72 specimens were found to have survived. All the specimens were placed between sheets of moistened filter

paper for three days while they emptied their intestinal tracts of soil.

Fifty per cent of the individuals from each pot were cut in half. The two halves were analyzed separately to determine any gross difference in the distribution of the radionuclide in the body of the worm. All the remaining worms were then weighed individually and sacrificed. Preparation of the worms for counting and the counting procedures were the same as before.<sup>7</sup>

The radionuclide uptake, as determined from the whole worms in each series, is presented in Table 12, together with the activity of the soil at the time that the worms were removed. The ratio of worm to soil (in  $\mu\text{C/g}$ ) is given. The results indicate that although there is some uptake of the fission product Sr by this species of worm there is no concentration under the conditions of this experiment. Furthermore, as shown in the enriched soil series, it is evident that the addition of calcium to the soil served to depress the uptake of Sr<sup>89</sup>.

In Table 13 these ratios for *A. caliginosa* are compared with those for *E. foetida*. The data indicate that *A. caliginosa*, even when the diluting effect of calcium is present, has a greater affinity for the radionuclide than does *E. foetida*. The reason for this is probably related to the fact that *A. caliginosa* is a true soil-feeding species whereas *E. foetida* prefers humus and other decomposing organic matter both as food and as a niche.

In Table 14 the uptake ratios and the specific activity for the anterior and posterior sections of *A. caliginosa* under both soil conditions are

<sup>10</sup>Soil analyses were made by the Department of Soils, College of Agriculture, University of Missouri, Columbia.

TABLE 12. ANALYSIS OF Sr<sup>89</sup> ACTIVITY IN EARTHWORM, ALLOLOBOPHORA CALIGINOSA (SAVIGNY)

Pot No.	Activity of Soil at End of Experiment ( $\mu\text{C/g}$ )	Number of Individuals	Untreated Soil Series		Number of Individuals	Enriched Soil Series	
			Activity ( $\mu\text{C/g}$ of worm)	Ratio ( $\frac{\mu\text{C/g of worm}}{\mu\text{C/g of soil}}$ )		Activity ( $\mu\text{C/g}$ of worm)	Ratio ( $\frac{\mu\text{C/g of worm}}{\mu\text{C/g of soil}}$ )
I	$1.25 \times 10^{-3}$	3	$2.39 \times 10^{-4}$	0.191	3	$0.963 \times 10^{-4}$	0.077
II	$2.51 \times 10^{-3}$	2	$3.23 \times 10^{-4}$	0.128	3	$1.64 \times 10^{-4}$	0.065
III	$3.76 \times 10^{-3}$	3	$5.22 \times 10^{-4}$	0.138	3	$3.37 \times 10^{-4}$	0.089
IV	$5.02 \times 10^{-3}$	3	$5.58 \times 10^{-4}$	0.111	3	$4.63 \times 10^{-4}$	0.092
V	$6.27 \times 10^{-3}$	3	$7.16 \times 10^{-4}$	0.114	3	$4.17 \times 10^{-4}$	0.066
Control	0	3	0		3	0	

TABLE 13. COMPARISON OF WORM UPTAKE-SOIL ACTIVITY RATIOS OF  $\text{Sr}^{89}$  IN THE CASE OF *EISENIA FOETIDA* AND *ALLOLOBOPHORA CALIGINOSA*

Pot No.	<i>Eisenia foetida</i>		<i>Allolobophora caliginosa</i>		
	Activity of Soil at End of Experiment ( $\mu\text{c/g}$ )	Ratio $\left(\frac{\mu\text{c/g of worm}}{\mu\text{c/g of soil}}\right)$	Activity of Soil at End of Experiment ( $\mu\text{c/g}$ )	Untreated Soil Ratio $\left(\frac{\mu\text{c/g of worm}}{\mu\text{c/g of soil}}\right)$	Enriched Soil Ratio $\left(\frac{\mu\text{c/g of worm}}{\mu\text{c/g of soil}}\right)$
I	$0.937 \times 10^{-3}$	0.030	$1.25 \times 10^{-3}$	0.191	0.077
II	$1.87 \times 10^{-3}$	0.057	$2.51 \times 10^{-3}$	0.128	0.065
III	$2.81 \times 10^{-3}$	0.043	$3.76 \times 10^{-3}$	0.138	0.089
IV	$3.75 \times 10^{-3}$	0.046	$5.02 \times 10^{-3}$	0.111	0.092
V	$4.69 \times 10^{-3}$	0.049	$6.27 \times 10^{-3}$	0.114	0.066
Control	0	0	0	0	0

TABLE 14. ANALYSIS OF ACTIVITY IN ANTERIOR AND POSTERIOR PORTIONS OF *ALLOLOBOPHORA CALIGINOSA*

Pot No.	Number of Individuals	Anterior Portions ( $\mu\text{c/g}$ of tissue)	Ratio	Posterior Portions ( $\mu\text{c/g}$ of tissue)	Ratio
			$\left(\frac{\mu\text{c/g of tissue}}{\mu\text{c/g of soil}}\right)$		$\left(\frac{\mu\text{c/g of tissue}}{\mu\text{c/g of soil}}\right)$
Untreated Soil					
I	3	$1.90 \times 10^{-4}$	0.152	$0.89 \times 10^{-4}$	0.071
II	3	$4.77 \times 10^{-4}$	0.190	$2.27 \times 10^{-4}$	0.090
III	3	$8.10 \times 10^{-4}$	0.215	$3.27 \times 10^{-4}$	0.086
IV	3	$8.33 \times 10^{-4}$	0.166	$3.89 \times 10^{-4}$	0.077
V	3	$10.30 \times 10^{-4}$	0.164	$2.49 \times 10^{-4}$	0.040
Control	3	0	0	0	0
Enriched Soil					
I	3	$1.82 \times 10^{-4}$	0.145	$0.95 \times 10^{-4}$	0.076
II	2	$2.35 \times 10^{-4}$	0.093	$1.16 \times 10^{-4}$	0.046
III	3	$4.17 \times 10^{-4}$	0.111	$3.78 \times 10^{-4}$	0.100
IV	3	$7.07 \times 10^{-4}$	0.141	$2.69 \times 10^{-4}$	0.053
V	3	$6.98 \times 10^{-4}$	0.111	$1.98 \times 10^{-4}$	0.031
Control	3	0	0	0	0

presented. In both series at each level of soil activity the anterior portions contained more radionuclide than did the posterior portion. The explanation for this phenomenon may be due to the presence of the calciferous glands in the anterior segments of the worm. Recent work<sup>11</sup> on some other species of earthworms has demonstrated that these glands are concerned with the extraction and storage of calcium. This would account for their affinity for strontium and for the higher activity in the nontreated soil series.

#### URINALYSIS RESEARCH

L. B. Farabee

Although there are several complicated techniques in general use for the determination of radioactive cesium in biological materials and in water, none of them are entirely satisfactory. There is a need for a simple, reliable procedure. The recently reported<sup>12</sup> precipitation of potassium as its tetraphenylboron salt provides a simple method for the separation of potassium from a wide range of ions associated with it. Potassium and cesium form very insoluble tetraphenylboron compounds in dilute mineral acids, whereas the sodium salt is very soluble.

Preliminary tests with procedures for separating Cs<sup>137</sup> from biological materials with the use of sodium tetraphenylboron give excellent recovery as well as good separation from the other fission products. However, potassium, which is present in large amounts in such samples, coprecipitates with the cesium and makes the sample rather bulky for counting. Also, K<sup>40</sup> contributes to the radioactivity of the sample.

In the analysis of muscle tissue of fish as well as in urinalysis the radioactive cesium can be concentrated by a precipitation of the potassium in the sample as potassium cobaltinitrite. The cesium can be separated subsequently from potassium by precipitating cesium silicotungstate. The cesium is finally precipitated as cesium tetraphenylboron.

#### DISTRIBUTION OF RADIOISOTOPES IN ANIMAL TISSUE

M. J. Cook            F. G. Kariotis<sup>13</sup>  
K. Z. Morgan

It is extremely important to test experimentally the mathematical relation used (in publications by

the National Committee on Radiation Protection<sup>14</sup> and the International Commission of Radiological Protection<sup>15</sup>) in employing single-exposure data to determine the MPC of radionuclides in air and water for continuous exposure. A pilot experiment on Co<sup>60</sup> was computed,<sup>16</sup> and the indication is that the mathematical relations used in the handbooks on internal dose are correct within a factor of 2 for Co<sup>60</sup>. A study with mice was initiated to check this relationship for other radionuclides.

Each mouse was given a single dose of 10  $\mu$ c of Sr<sup>90</sup> + Y<sup>90</sup> by stomach tube. In groups of 10, the mice were sacrificed at the following intervals: 4 and 24 hr; 3, 5, and 7 days; 2, 3, 4, 5, and 7 weeks. The animals that were sacrificed at the periods of from 4 hr through 2 weeks were dissected into 16 parts. In the 2-week group, only a trace of Sr<sup>90</sup>-Y<sup>90</sup> remained in the soft tissue; therefore, the mice sacrificed after 2 weeks are dissected only into soft tissues, femur, and carcass. Other mice will be sacrificed at 3, 6, 12, and 18 months.

As a second part of the experiment mice will be subjected continuously to a fixed concentration of Sr<sup>90</sup> + Y<sup>90</sup> in the drinking water. In order to know the exact amount of water containing the radioisotope which the mice drink *ad libitum*, a capillary drinking fountain was designed and is pictured in Fig. 7. The critical factor in this device is the height of the liquid in the drinking pool, which must remain within narrow limits to be available to the animals and to prevent spills. Within less than 24 hr, the mice learn to drink from the fountain. Now that this fountain has been

<sup>11</sup>H. V. Kashyap and M. R. Ranade, *Proc. Zool. Soc. Bengal* 5, No. 1, 1-9 (1952).

<sup>12</sup>G. Wittig and P. Raff, *Ann. Chem., Justus Liebig's* 573, 195 (1951).

<sup>13</sup>Summer research participant from the Physics Department of Marquette University, Milwaukee, Wisconsin.

<sup>14</sup>United States National Bureau of Standards, *Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water*, Handbook 52 (1953), Superintendent of Documents, Washington 25, D.C.

<sup>15</sup>International Congress of Radiology, "Recommendations of the International Commission of Radiological Protection," *Brit. J. Radiol. Suppl.* 6 (revised Dec. 1, 1954).

<sup>16</sup>M. J. Cook, K. Z. Morgan, and A. G. Barkow, "An Experiment Designed to Test the Validity of the Current Practice of Using Single-Exposure Data to Calculate Maximum Permissible Concentration in Water for Continuous Exposure to Radioisotopes." Accepted for publication in *Am. J. Roentgenol., Radium Therapy Nuclear Med.*

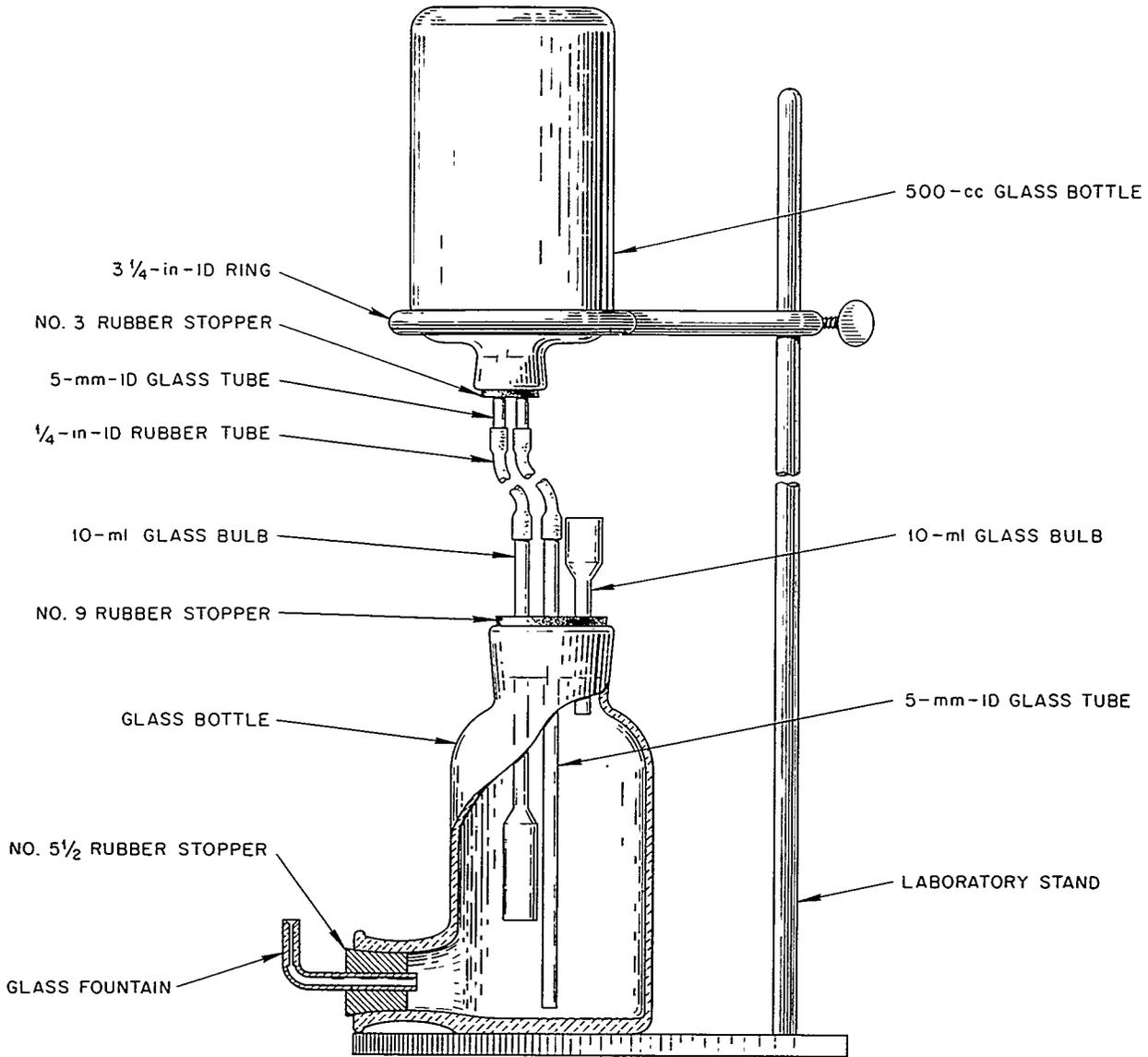


Fig. 7. Measuring Capillary Fountain.

developed and tested, the second part of this experiment is getting under way.

ISOTOPIC DISTRIBUTION IN MAN

Internal Dose

K. Z. Morgan            M. J. Cook  
M. R. Ford

The tables of maximum permissible concentrations for continuous exposure to radioisotopes<sup>14,15</sup> are being revised. The revision will

include new biological data, additional elements, additional isotopes, and additions to the bibliography.

Spectrographic Analysis of Human Tissue

I. H. Tipton            D. K. Bowman  
M. J. Cook            K. K. McDaniel

During the period from July 1, 1955, through December 31, 1955, the collecting of normal human tissue was extended to four more cities in the

United States, making a total of eight cities distributed in seven states. Tissues from 57 adult autopsies, with an average of 26 tissues per autopsy, were received.

In addition to the tissues from adult autopsies the program is being expanded to include analyses of tissues from fetuses, still births, babies, children, and teen-agers. From each city where adult tissues are being received, it is hoped that the following tissues may be received in order to compare the elements found in the tissues of adults with those in the tissues of younger people:

Fetus (6 to 9 months)	2 whole
Birth to 6 months	1 autopsied
3 to 6 years	1 autopsied
14 to 18 years	1 autopsied

Invitations have been extended by pathologists in four additional cities in the United States, and arrangements will be made at a later date to extend the program to these cities.

Perhaps the most difficult tissue to obtain is the eye. Fifteen eyes have been secured from fetuses and still births or from infants whose bodies were left at the hospital for disposal.

The tissues are packed in dry ice and shipped via air express to this laboratory, where they are stored in the deep-freeze unit until time for ashing. From shipment until arrival, the time in all instances has been less than 24 hr.

The tissues are dry-ashed as follows:

1. Tissues are trimmed, weighed, and then washed in ion-exchange water.
2. Tissues are placed in the oven and the temperature is gradually brought to 300°C, where it is held for 20 hr.
3. At the end of 20 hr the tissues are cooled and reweighed in order to obtain the dry weight.
4. Tissues are placed in the oven and the temperature is gradually brought to 450°C, at which temperature the tissues remain for 24 hr or longer if necessary.
5. The tissue ashes are cooled and reweighed.
6. The ash is transferred to a polyethylene bottle and ground for 30 min.

During the past six months 806 tissues have been dry-ashed and sent to the Physics Department of the University of Tennessee, where over 30,000 spectrographic determinations have been made.

The analytical method is essentially the same as that described in earlier reports except that two internal standards are employed: indium for the elements boron, zinc, gallium, silver, cadmium, tin, lead, gold, and bismuth; and palladium for the elements manganese, iron, cobalt, nickel, copper, cesium, strontium, molybdenum, barium, lanthanum, and gold. The upper and lower limits of sensitivity in parts per million in ash and the precision of the method expressed as coefficients of variation in per cent are given in Tables 15 and 16. The coefficients of variation were determined from 16 replicate analyses of a single standard sample.

The improved techniques of collection and ashing make the analyses more meaningful, since there is

TABLE 15. SPECTROGRAPHIC DETERMINATIONS OF DRY-ASHED SOFT TISSUE FOR LIMITS OF SENSITIVITY AND COEFFICIENTS OF VARIATION

Element	Limits of Sensitivity (ppm in ash)		Coefficient of Variation (%)
	Upper	Lower*	
Boron	400	10	
Aluminum	4,000	2	15
Titanium	1,000	10	15
Vanadium	1,000	10	
Chromium	1,000	0.1	10
Manganese	1,000	1	10
Iron	100,000	1,000	
Cobalt	400	5	
Nickel	1,000	10	10
Copper	1,000	25	5
Zinc	10,000	400	5
Gallium	20	1	
Strontium	40	1	15
Molybdenum	1,000	10	10
Silver	400	1	15
Cadmium	5,000	75	4
Tin	1,000	10	20
Cesium	3,000	100	
Barium	400	0.2	20
Lanthanum		100	
Gold	400	20	
Lead	1,000	10	15
Bismuth	400	10	

\*Other elements with lower limits include: beryllium (3), arsenic (300), zirconium (30), niobium (100), ruthenium (10), antimony (100), and thallium (10).

HEALTH PHYSICS PROGRESS REPORT

TABLE 16. SPECTROGRAPHIC DETERMINATIONS OF DRY-ASHED BONE FOR LIMITS OF SENSITIVITY

Element	Limits of Sensitivity (ppm in ash)	
	Upper	Lower*
Boron		30
Aluminum	100	4
Titanium		40
Vanadium		20
Chromium		5
Manganese	100	2
Iron	4000	100
Cobalt		10
Nickel		30
Copper	100	2
Zinc	3000	700
Gallium		5
Strontium	1000	10
Molybdenum		15
Silver	100	1
Cadmium		200
Tin	400	10
Cesium		400
Barium	200	4
Lanthanum		400
Gold		15
Lead	400	10
Bismuth		20

\*Other elements with lower limits include: arsenic (1000), zirconium (400), niobium (150), ruthenium (?), antimony (100), and thallium (20).

considerably less cross-contamination. The elements beryllium, arsenic, zirconium, niobium, ruthenium, antimony, and thallium are sought in every sample. However, except for traces of ruthenium in two spleen samples, none have been detected. Part of the results of the analyses of tissues collected from one city are presented in Table 17, which does not include all the tissues received from the autopsies but only the tissues analyzed spectrographically as of December 31, 1955. All the elements were sought, and a blank space means that nothing was detected within the limits of sensitivity. Table 17 presents data which indicate the specific tissues in which the various elements are found. Gallium was found in three specimens of lung only (average value of 0.03  $\mu\text{g/g}$ ) and is not included in the table. Tables are available on request giving the element distribution in each tissue.

TABLE 17. CONCENTRATIONS OF ELEMENTS IN SPECIFIC WET TISSUES

Tissue	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )
	Analyzed	Containing Element*		Analyzed	Containing Element*	
	Aluminum					
Adrenal	3	3	0.70	3		
Aorta	12	12	0.87	12	3	0.40
Bladder	13	13	1.1	13		
Bone	23	(5) 13	0.53	23		
Brain	21	21	0.40	21	(1)	< 0.15 T
Esophagus	8	8	1.4	8	(1) 1	>> 4
Heart	19	19	0.43	19	(1)	< 0.10 T
Intestine						
Duodenum	7	7	0.76	7	1	>> 4
Jejunum and ileum	20	20	0.80	20	(2) 1	>> 4
Large	22	22	1.0	22	(3) 1	0.07
Kidney	24	24	0.67	24	6	1.1
Liver	24	24	0.70	24	3	0.90
Lung	24	24	23	24	(1)	< 0.11 T
Muscle	18	18	0.50	18		
Pancreas	21	21	0.70	21	(1) 2	0.36
Prostate	8	8	0.75	8	(2)	< 0.13 T
Spleen	22	22	2.2	22	2	0.36
Stomach	20	20	0.53	20	(1) 1	>> 4
Thyroid	8	8	1.40	8	(1)	< 0.11 T
	Barium					
Adrenal	3	3	0.03	3	(1) 2	0.17
Aorta	12	12	0.11	12	1	0.40
Bladder	13	(1) 10	0.03	13	(1) 1	0.30
Bone	23	23	1	23		
Brain	21	9	0.04	21	3	0.18
Esophagus	8	8	0.04	8		
Heart	19	(2) 15	0.02	19		
Intestine						
Duodenum	7	7	0.03	7	2	0.08
Jejunum and ileum	20	20	0.05	20	(2) 2	0.22
Large	22	22	0.06	22	(4) 1	0.12
Kidney	24	(3) 16	0.06	24	(1) 1	0.16
Liver	24	(2) 2	0.04	24	(5) 3	0.30
Lung	24	24	2.6	24	(3) 2	0.14
Muscle	18	(1) 12	0.02	18		
Pancreas	21	(2) 14	0.06	21	(2) 4	0.17
Prostate	8	(1) 6	0.08	8	(1) 1	0.24
Spleen	22	(1) 14	0.04	22	(1) 1	0.20
Stomach	20	19	0.03	20	(2) 4	0.13
Thyroid	8	8	0.34	8		
	Bismuth					
				Boron		

\*The numbers in parentheses indicate the number of samples with a trace.

TABLE 17 (continued)

Tissue	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )
	Analyzed	Containing Element*		Analyzed	Containing Element*	
	Cadmium			Chromium		
Adrenal	3	2	0.41	3	3	0.08
Aorta	12	1	0.87	12	(2) 4	0.07
Bladder	13			13	5	0.06
Bone	23			23	(1)	<0.8 T
Brain	21			21	(2) 2	0.02
Esophagus	8			8	(1) 5	0.03
Heart	19			19	(1) 8	0.03
Intestine						
Duodenum	7	(2)	<0.60 T	7	2	0.03
Jejunum and ileum	20	(5) 5	0.92	20	(4) 6	0.02
Large	22			22	(2) 11	0.04
Kidney	24	24	31	24	(2) 4	0.04
Liver	24	(1) 22	3.3	24	(7) 4	0.03
Lung	24	(4) 7	1.1	24	23	0.14
Muscle	18			18	(1) 3	0.06
Pancreas	21	(7) 9	1.6	21	(2) 2	0.04
Prostate	8	(1)	<1.0 T	8	(1) 2	0.30
Spleen	22	1	1.3	22	(8) 5	0.05
Stomach	20	(2)	<0.64 T	20	(4) 6	0.03
Thyroid	8	(1) 2	1.9	8	(2) 3	0.06
	Cesium			Cobalt		
Adrenal	3			3	2	0.05
Aorta	12			12	2	0.12
Bladder	13	(1) 1	1.7	13		
Bone	23			23		
Brain	21			21		
Esophagus	8			8		
Heart	19			19	1	0.20
Intestine						
Duodenum	7			7		
Jejunum and ileum	20			20		
Large	22			22	1	0.12
Kidney	24	(2)	1.1 T	24	(1)	<0.11 T
Liver	24			24	(2) 4	0.12
Lung	24	12	3.1	24	(1) 3	0.22
Muscle	18			18		
Pancreas	21			21		
Prostate	8			8		
Spleen	22			22		
Stomach	20			20		
Thyroid	8	1	2.8	8	2	0.26

\*The numbers in parentheses indicate the number of samples with a trace.

TABLE 17 (continued)

Tissue	Number of Samples		Average Value for Samples Containing Element ( $\mu\text{g/g}$ )	Number of Samples		Average Value for Samples Containing Element ( $\mu\text{g/g}$ )
	Analyzed	Containing Element*		Analyzed	Containing Element*	
	Copper			Iron		
Adrenal	3	3	1.1	3	3	28
Aorta	12	12	1.1	12	12	30
Bladder	13	13	1.1	13	13	19
Bone	23	23	0.69	23	23	95
Brain	21	21	4.8	21	21	44
Esophagus	8	8	1.3	8	8	32
Heart	19	19	3.1	19	19	46
Intestine						
Duodenum	7	7	1.5	7	7	48
Jejunum and ileum	20	20	3.0	20	20	32
Large	22	22	1.4	22	22	29
Kidney	24	24	2.9	24	24	76
Liver	24	24	5.7	24	24	170
Lung	24	24	1.4	24	24	210
Muscle	18	18	0.90	18	18	31
Pancreas	21	21	1.8	21	21	43
Prostate	8	8	1.9	8	8	25
Spleen	22	22	1.3	22	22	280
Stomach	20	20	1.5	20	20	24
Thyroid	8	8	1.2	8	8	69
	Gold			Lanthanum		
Adrenal	3	(1) 2	0.24	3		
Aorta	12	(2) 1	0.24	12		
Bladder	13	(1)	<0.16 T	13		
Bone	23			23		
Brain	21			21		
Esophagus	8	(2)	<0.19 T	8		
Heart	19	(1) 1	0.33	19		
Intestine						
Duodenum	7			7		
Jejunum and ileum	20	(1)	<0.18 T	20		
Large	22			22		
Kidney	24	(1)	<0.22 T	24		
Liver	24			24	(1)	<1.2 T
Lung	24			24	(3)	<1.1 T
Muscle	18			18		
Pancreas	21			21		
Prostate	8			8		
Spleen	22			22	(6)	<1.3 T
Stomach	20			20		
Thyroid	8			8		

\*The numbers in parentheses indicate the number of samples with a trace.

TABLE 17 (continued)

Tissue	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )
	Analyzed	Containing Element*		Analyzed	Containing Element*	
	Lead			Molybdenum		
Adrenal	3	3	0.08	3	(1) 2	0.17
Aorta	12	(1) 11	0.87	12		
Bladder	13	(1) 8	0.23	13		
Bone	23	23	4.2	23		
Brain	21	(5) 4	0.85	21	1	0.30
Esophagus	8	(2) 5	0.09	8		
Heart	19	(7) 4	0.68	19	1	0.30
Intestine						
Duodenum	7	5	0.10	7		
Jejunum and ileum	20	15	0.38	20		
Large	22	(6) 10	0.12	22	1	0.07
Kidney	24	24	0.94	24	24	0.33
Liver	24	24	1.5	24	21	1.1
Lung	24	24	0.63	24		
Muscle	18	(3) 2	0.09	18		
Pancreas	21	21	0.63	21		
Prostate	8	(5) 1	2.6	8	1	0.13
Spleen	22	21	0.38	22		
Stomach	20	(4) 14	0.14	20		
Thyroid	8	(2) 6	0.14	8		
	Manganese			Nickel		
Adrenal	3	3	0.15	3	3	0.50
Aorta	12	12	0.10	12	3	0.35
Bladder	13	11	0.10	13	(1) 3	0.29
Bone	23	(1)	<0.35 T	23	1	1.8
Brain	21	21	0.26	21	1	0.15
Esophagus	8	8	0.14	8	1	0.09
Heart	19	19	0.18	19	(1) 3	0.17
Intestine						
Duodenum	7	7	0.3	7	(1)	<0.08 T
Jejunum and ileum	20	20	0.43	20	(2) 4	0.34
Large	22	22	0.23	22	(2) 9	0.18
Kidney	24	24	0.56	24		
Liver	24	24	0.76	24	2	0.26
Lung	24	24	0.19	24	8	0.33
Muscle	18	18	0.06	18		
Pancreas	21	21	0.73	21	1	0.36
Prostate	8	8	0.30	8		
Spleen	22	22	0.13	22		
Stomach	20	20	0.25	20		
Thyroid	8	8	0.26	8	1	0.23

\*The numbers in parentheses indicate the number of samples with a trace.

TABLE 17 (continued)

Tissue	Number of Samples		Average Value for Samples Containing Element ( $\mu\text{g/g}$ )	Number of Samples		Average Value for Samples Containing Element ( $\mu\text{g/g}$ )
	Analyzed	Containing Element*		Analyzed	Containing Element*	
	Silver			Tin		
Adrenal	3	3	0.03	3	3	0.24
Aorta	12	(2) 7	0.06	12	(1) 10	0.30
Bladder	13	(5) 3	0.008	13	11	0.20
Bone	23	1	0.4	23	(1) 1	3
Brain	21	(3) 17	0.03	21	(1)	<0.15 T
Esophagus	8	(1) 6	0.01	8	7	0.22
Heart	19	(7) 8	0.01	19	(2) 11	0.18
Intestine						
Duodenum	7	(3) 4	0.01	7	(1) 5	0.56
Jejunum and ileum	20	(6) 13	0.02	20	(1) 16	0.66
Large	22	(7) 10	0.01	22	21	0.78
Kidney	24	(5) 15	0.02	24	(2) 21	0.27
Liver	24	(7) 17	0.03	24	(1) 23	0.56
Lung	24	(11) 8	0.02	24	24	1.1
Muscle	18	(5) 3	0.02	18	(1) 1	0.12
Pancreas	21	(7) 10	0.02	21	(5) 6	0.20
Prostate	8	(2) 4	0.05	8	(2) 6	0.26
Spleen	22	(9) 5	0.06	22	(4) 15	0.27
Stomach	20	(4) 11	0.02	20	15	0.24
Thyroid	8	(2) 5	0.06	8	7	0.35
	Strontium			Titanium		
Adrenal	3	3	0.03	3	2	0.16
Aorta	12	12	0.20	12	(1) 2	0.48
Bladder	13	13	0.12	13	(1) 3	1.1
Bone	23	23	20	23		
Brain	21	21	0.07	21		
Esophagus	8	8	0.13	8	(2) 1	0.17
Heart	19	19	0.07	19		
Intestine						
Duodenum	7	7	0.12	7	1	0.08
Jejunum and ileum	20	20	0.15	20	(1) 2	0.46
Large	22	22	0.13	22	(1) 4	0.34
Kidney	24	24	0.08	24	(2) 5	0.67
Liver	24	24	0.04	24	2	0.50
Lung	24	24	0.13	24	24	2.8
Muscle	18	18	0.04	18		
Pancreas	21	21	0.08	21	(3) 3	0.36
Prostate	8	7	0.14	8	2	0.41
Spleen	22	22	0.06	22	(1) 4	1.0
Stomach	20	20	0.11	20	(2)	<0.08 T
Thyroid	8	7	0.17	8	4	1.20

\*The numbers in parentheses indicate the number of samples with a trace.

## HEALTH PHYSICS PROGRESS REPORT

TABLE 17 (continued)

Tissue	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )	Number of Samples		Average Value for Samples Contain- ing Element ( $\mu\text{g/g}$ )
	Analyzed	Containing Element*		Analyzed	Containing Element*	
	Vanadium			Zinc		
Adrenal	3			3	3	7.8
Aorta	12	(1)	<0.10 T	12	12	16
Bladder	13			13	13	21
Bone	23			23		
Brain	21			21	21	14
Esophagus	8			8	8	23
Heart	19			19	19	29
Intestine Duodenum	7			7	7	16
Jejunum and ileum	20	(1)	<0.09 T	20	20	22
Large	22	1	0.34	22	22	19
Kidney	24	(1)	<0.11 T	24	24	48
Liver	24	(2)	<0.12 T	24	24	48
Lung	24	(4)	0.27	24	24	17
Muscle	18			18	18	53
Pancreas	21			21	21	31
Prostate	8			8	8	80
Spleen	22	(2)	<0.13 T	22	22	21
Stomach	20			20	20	19
Thyroid	8			8	8	28

\*The numbers in parentheses indicate the number of samples with a trace.

## SANITARY ENGINEERING RESEARCH

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## FIELD INVESTIGATIONS

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Unlined Experimental Pit<sup>1</sup>

During the drilling of the auger holes around the unlined experimental pit, it was found that the depths of these holes were limited by a shale material at approximately 19 ft below the surface. In order to determine whether this shale would restrict in any unusual fashion the vertical movement of waste solutions in the pit, water-level recorders were installed on an existing core hole (UC43) cased through the shale and on an adjacent auger hole (UI) that terminated at the top of the shale. A continuous record of the water levels for a two-week period was obtained. The water-level fluctuations in these wells were compared with barometer response and with tide effect in another ORNL well. The fluctuations in levels in UC43 and UI do not appear to be tidal but rather to follow barometer changes. The changes in water levels in wells UC43 and UI were 11.5 and 12%, respectively, of the associated changes in barometric pressure. On the basis of this analysis, it would appear that the shale encountered will not create any unusual restrictive effect on potential vertical movements of chemical wastes in the pit.

## Probe Development

The circuit of the trailer-mounted well-logging equipment was modified to improve the stability and operating characteristics of the assembly. Halogen-type G-M tubes are now in use in these units. To improve cable feed, a spring-loaded pulley which will apply pressure on the cable as it revolves over the existing feed pulley is being installed in one unit.

A portable deep-well scintillation probe has been obtained from the AEC New York Operations Office and will be tested in operations at ORNL.

## Aerosol Entrainment Well

The entrainment-well experiment was originally designed to evaluate the evolution and entrainment

of radioactive aerosols in the Hope-type waste-disposal pit. This objective has been altered to obtain more general data on the filtration of aerosols arising from hot and boiling radioactive liquids. The installation is shown in Fig. 8. A second thermocouple is located at the center of the entrainment well, coinciding in this view with the heater conduit. Each thermocouple well contains seven thermocouples spaced equally through the 20-ft depth of the well. The thermocouple wells and the heater conduit are maintained under a positive nitrogen pressure to prevent leakage of water into the system. The thermocouple wells and heater assembly are of welded construction.

In operation, the entrainment well will be maintained under a slight negative pressure by a vacuum pump. Radioactive aerosols, carried by water vapor and some air from the vent, will flow to the condenser and cold trap. The filter test unit installed ahead of the condenser will allow study of the effectiveness of various filter materials. The filter unit may be bypassed for study of the formation of aerosols.

Preliminary tests have been made of entrainment at temperatures below boiling. A dilute solution of  $K_2^{42}CO_3$  was heated in the well, and the vapor was condensed. The results are tabulated in Table 18. The extremely low decontamination factors shown here led to the laboratory study of the evolution of  $K^{42}$  described in a later section.

Future work will include an evaluation of sand and glass fiber for removal of radioactive aerosols at superficial velocities approaching 0.002 cm/sec and a study of the entrainment of radioactive aerosols from both hot and boiling solutions.

## Pilot Pit No. 1

Pilot pit No. 1 is designed as the first step in the field-scale testing of a method for radioactive waste disposal which involves fixing and fusing of the radioactive material in an insoluble ceramic mass. It is proposed to add shale, limestone, and soda ash to high-level-waste solutions. This will form a mass which will be sintered at a temperature of 500 to 900°C by self-heating. Successful laboratory-scale tests were made by the Ceramics Group of the Metallurgy Division. These were

<sup>1</sup>R. J. Morton *et al.*, *HP Semiann. Prog. Rep. Jan. 31, 1955*, ORNL-1860, p 14.

nonradioactive experiments in which electric heat was used.

Pilot pit No. 1 (Fig. 9) will be a concrete tank, 6 ft in diameter and 10 ft deep and composed of

precast sections, within a larger tank built of concrete silo blocks; the design has been completed and construction has begun. The tank will be insulated by 18 in. of foam-glass blocks on the

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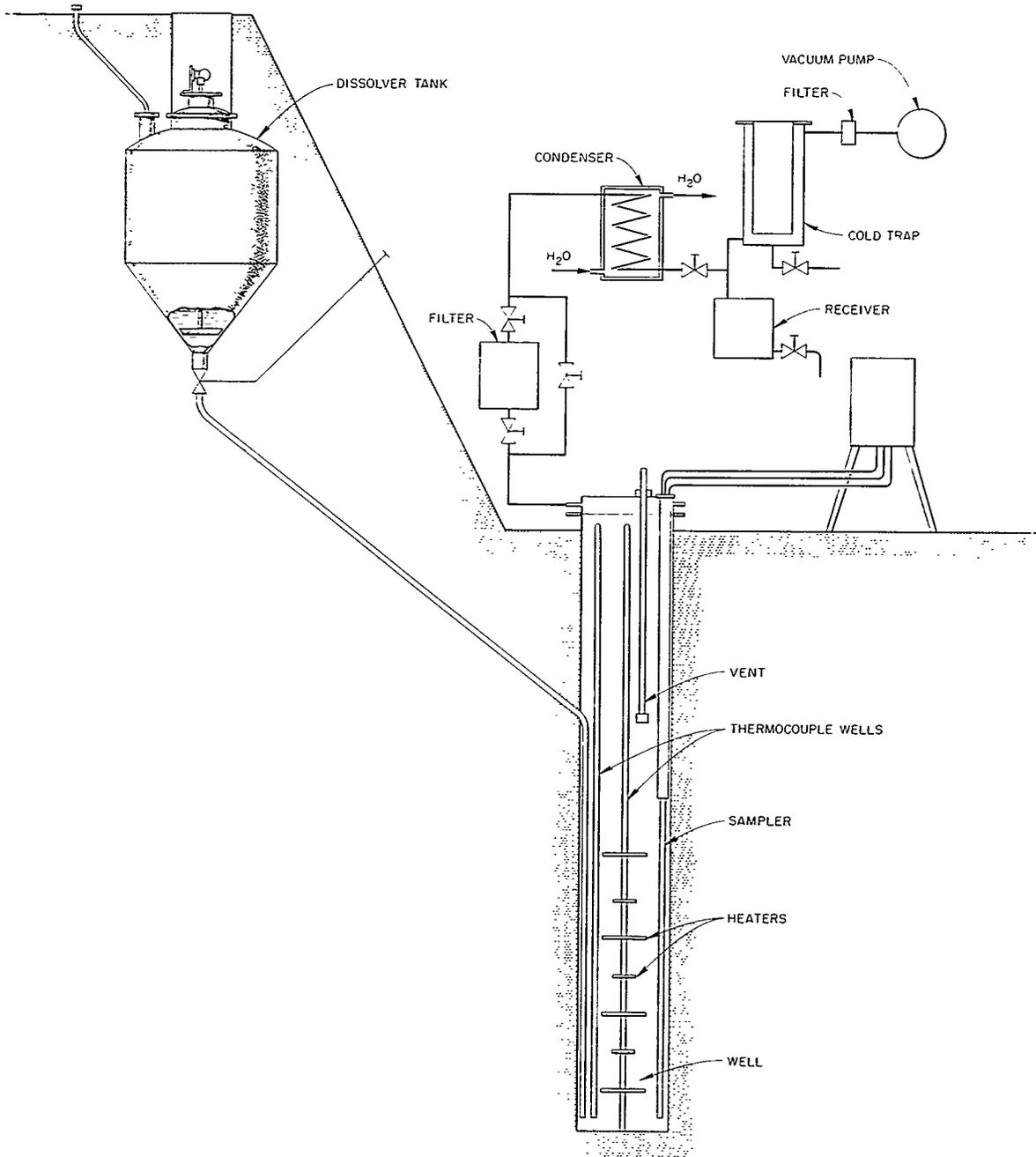


Fig. 8. Schematic Elevation of Dissolver Tank and Entrainment Well.

TABLE 18. ENTRAINMENT BY EVAPORATION-ENTRAINMENT WELL

Well		Condensate Activity (counts/min/ml)	Decontamination Factor
Temperature (°C)	Activity (counts/min/ml)		
90-100	856	1.340	$6.39 \times 10^2$
86	8514	1.35	$6.3 \times 10^3$
91	8514	2.47	$3.44 \times 10^3$
95	8514	63	$1.35 \times 10^2$

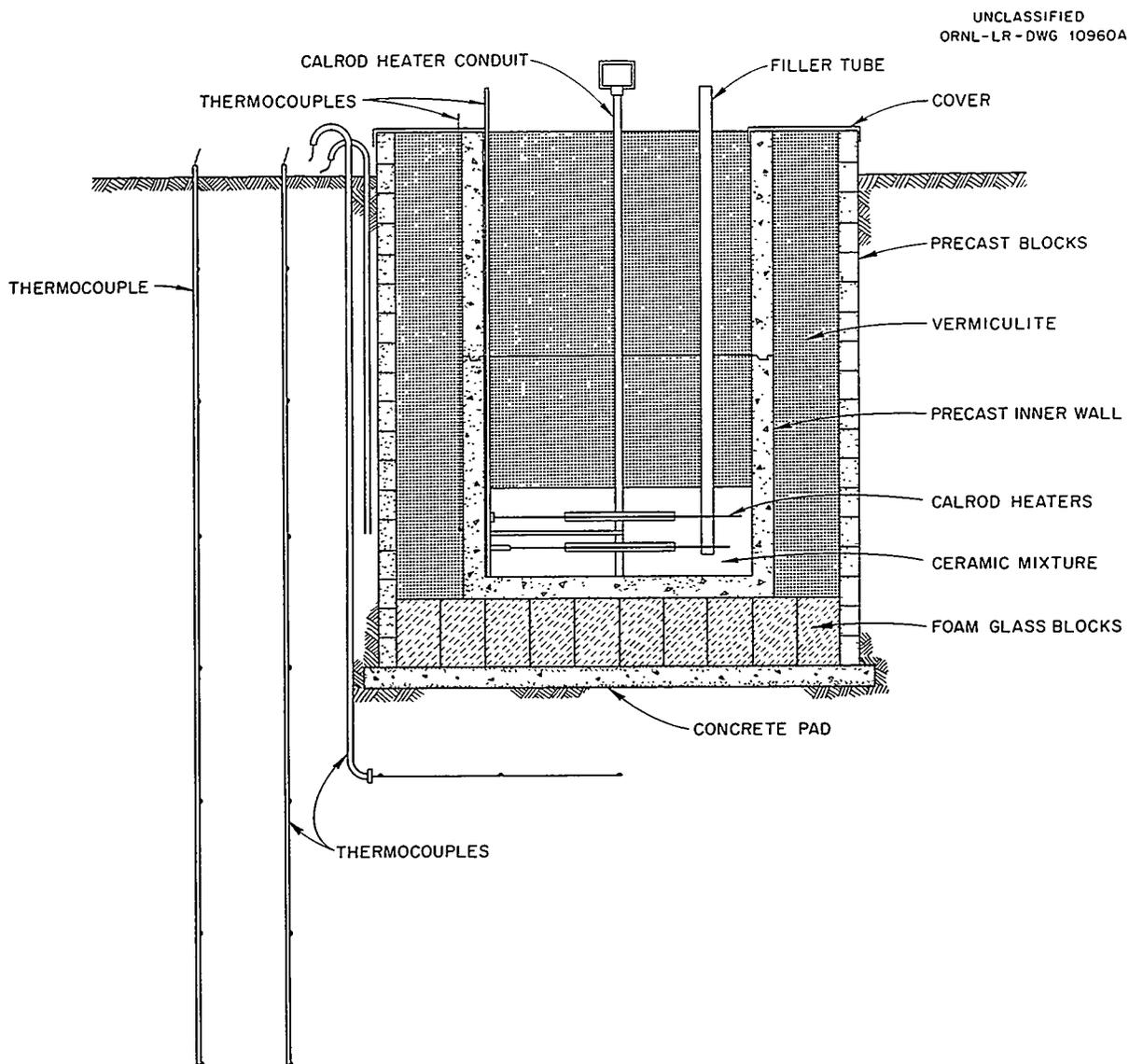


Fig. 9. Pilot Pit No. 1.

bottom and 18 in. of vermiculite on the sides. This insulation is needed for sufficiently high operating temperatures to be obtained. Electric heat, to simulate the self-heating of radioactive waste, will be added through Calrod heaters located near the bottom of the inner tank. Thermocouples will be located on the heaters, in the ceramic mixture, between the tanks, and in the earth outside the outer tank. They will be used to determine temperatures during operation of the pit and to obtain heat transfer data. The entire inner tank assembly can be removed to permit use of the facility for more than one experiment.

In this experiment a mixture of 2405 lb of shale, 720 lb of soda ash, 720 lb of limestone, and 720 gal of simulated acid aluminum nitrate waste solution will be placed in the pit and heated. The water will evaporate first; then nitrogen oxides will be given off. When all the water has evaporated, a bed of vermiculite will be added over the dried ceramic mass to insulate the upper surface for the final sintering of the mass. The first run will not include the use of mixed fission products but will test only the sintering process.

#### Chemical Waste Storage Pits

To facilitate understanding of the operation of the chemical waste pit system, a more detailed material balance was initiated to include chemical, radiochemical, and liquid components of the wastes. The physical arrangement of the system is shown in Fig. 10. The numbered circles show the location of wells which were drilled to provide geologic and hydrologic information and which are used as observation wells to detect underground movement of wastes. The relative locations of the waste pits, of the discharge pipe through which wastes are pumped to the pits, and of the overflow pipes between pits are as indicated. Wastes are pumped directly to pit 3, and after completion of pumping

they are transferred to pit 2 through a valved overflow pipe. Pit 2 may be overflowed to pit 4, which was constructed during November 1955 but has not yet been used.

**Liquid Inventory.** – Seepage from the pits is of primary interest. However, the total liquid budget of the pits includes additions by waste-pumping and rainfall and losses by evaporation as well as by seepage. Through a cooperative project of the U.S. Weather Bureau, U.S. Geological Survey, and ORNL a study of the evaporation component of the loss has been undertaken at the pit sites. The meteorological data necessary for computing evaporation by the mass-transfer method must include measurements of air and liquid temperature gradients, wind speed gradients, and humidity, for which equipment has been procured and is being installed. Two circular, sunken, 5-ft-dia evaporation pans, one unscreened and containing water and the other screened and containing a simulated waste solution, have been installed to empirically determine rate of evaporation.

A comparison of records taken from continuous-stage recorders in pit 3 and in the unscreened evaporation pan suggests that the evaporation rates from the pit and the pan are much the same. An example of the data showing the comparison is given in Table 19. The seepage estimate corresponds to a daily loss of 1200 gal from pit 3. Less detailed records from pit 2 suggest a daily seepage rate of 3200 gal. These figures are subject to correction as more detailed data are obtained. To improve the accuracy of the recording of the liquid stage in pit 3, the recorder was mounted directly over the stilling well.

**Chemical and Radiochemical Inventory.** – During 1955, 1,620,000 gal of waste containing 21,340 curies of beta activity was pumped to pit 3. A comparison of gross-beta activity in composite samples of the waste added to pit 3 and of the

TABLE 19. PRELIMINARY ESTIMATE OF EVAPORATION AND SEEPAGE LOSS

Time	Pit Stage Decrease (ft)	Pan Stage Decrease (ft)	Estimated Seepage Loss (ft)
August 19–26	0.165	0.09	0.075
September 2–9	0.165	0.09	0.075
December 27–January 3	0.085	0.015	0.070

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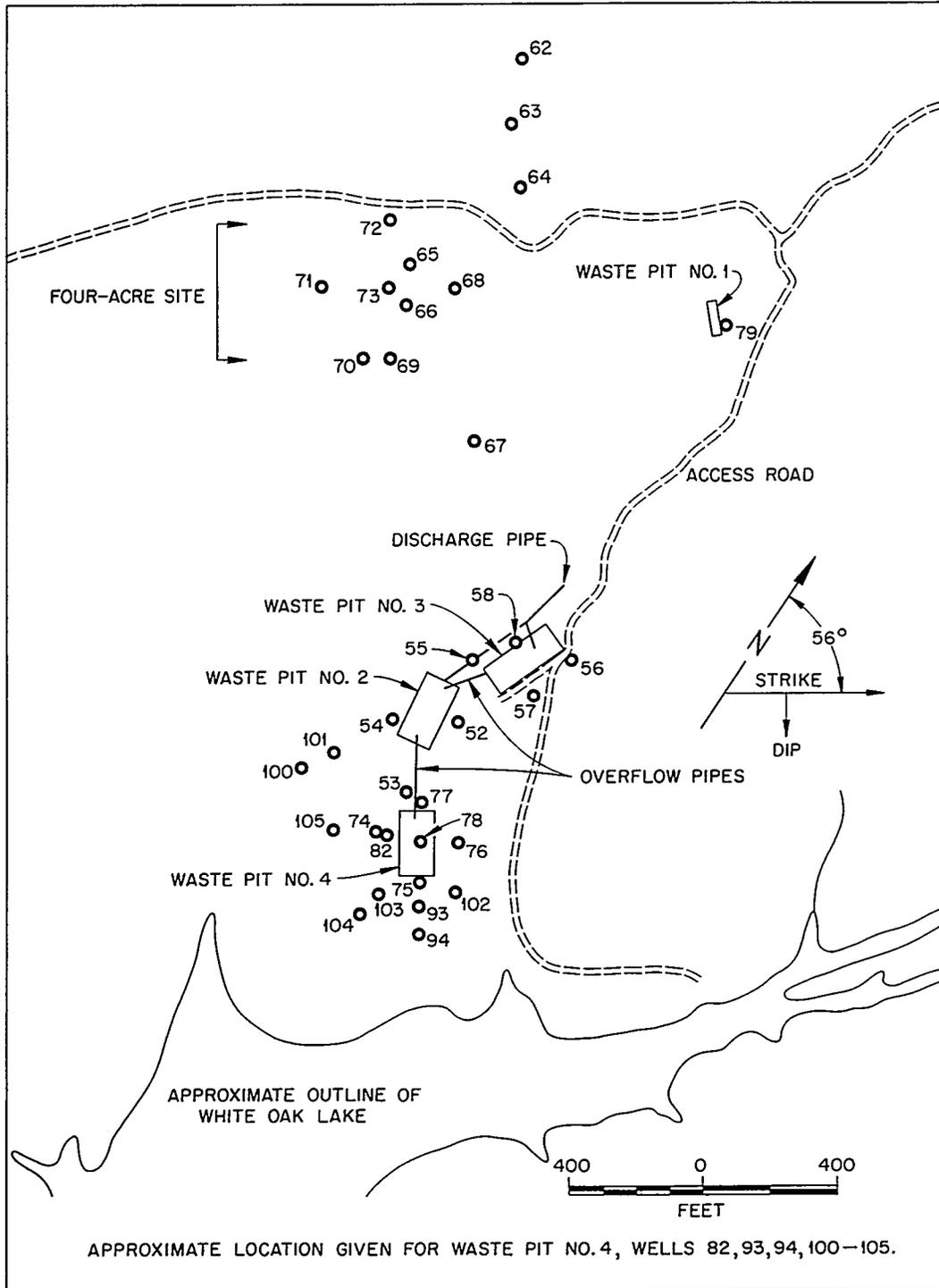


Fig. 10. Waste-Pit Disposal Area.

waste overflowed to pit 2 has shown that the levels of activity were reduced by a factor of approximately 2 as the waste passed through pit 3. Judging by the gross-beta analyses and the volume of waste overflowed, an estimated 2500 curies of beta activity was transferred by overflow to pit 2. The first composite samples were analyzed for the cations Na, Al, and NH<sub>4</sub>, the anions Cl, NO<sub>3</sub>, and SO<sub>4</sub>, the radionuclides Cs<sup>137</sup>, Ru<sup>106</sup>, Sr<sup>90</sup>, and the trivalent rare earths. The above stable elements accounted for 80% of the total solids present and the radionuclides accounted for 90% of the gross-beta activity.

**Definition of Underground Contamination.** – The study<sup>2</sup> for defining the vertical configuration of

waste flow through the soil formations has suggested need for the prevention of direct access of wastes to the observation well. This will assist in interpretation of radiologs by eliminating the influence on probe response of variations in hole diameter, waste stratification, and activity sorption on the side wall of the hole. With assistance of TVA personnel a casing was grouted in place in well No. 82, as shown in Fig. 11. The pattern of waste intercepted by this well will be compared with that of ungrouted well No. 74 to determine the differences of probe response under these varying conditions.

<sup>2</sup>R. J. Morton *et al.*, *HP Semiann. Prog. Rep.* July 31, 1955, ORNL-1942, p 14.

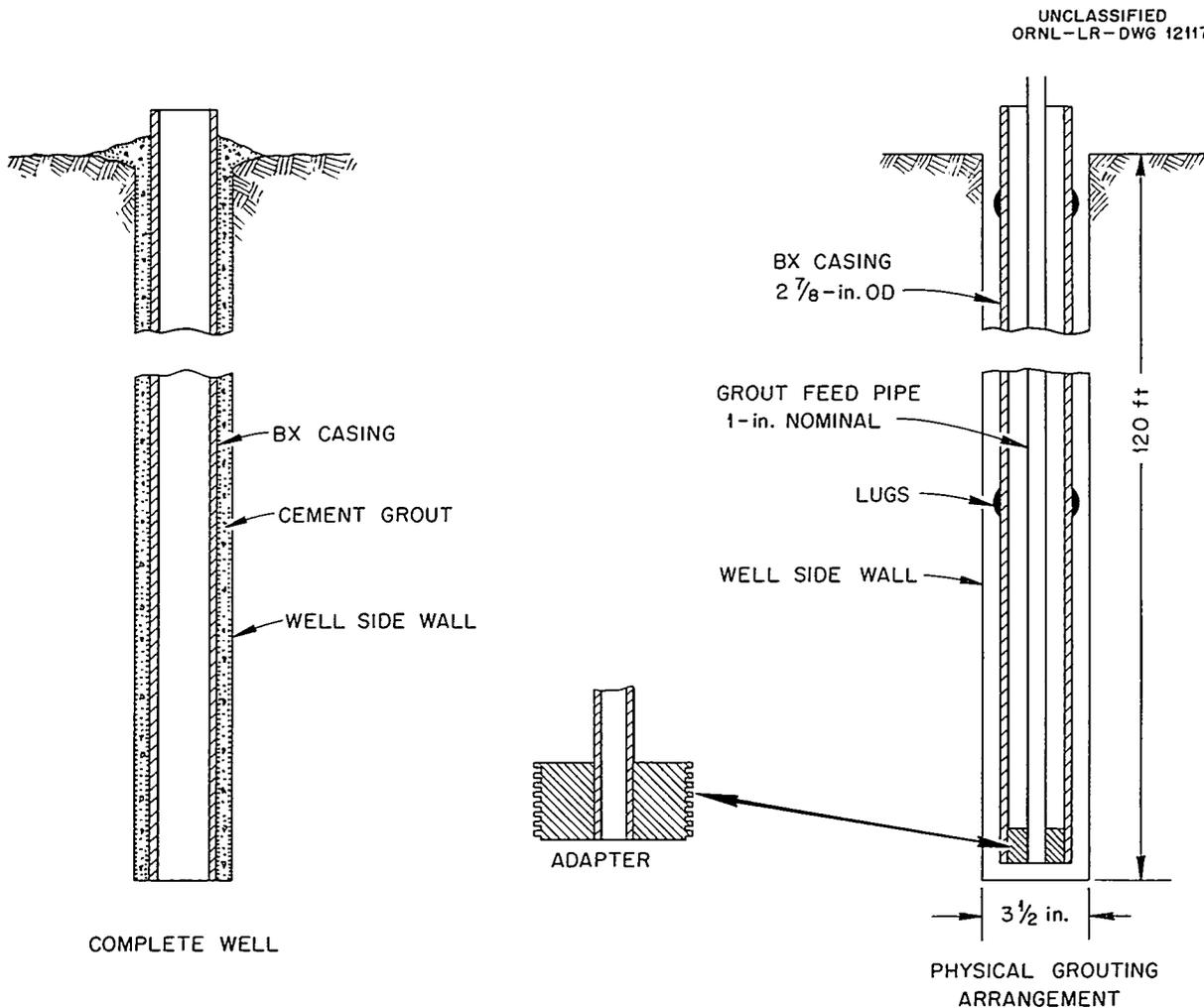


Fig. 11. Details of Grouted Well No. 82.

There has been no observable down-dip movement of radioactive wastes from pit 3 into well 57, which is located so as to detect any such bedding plane influence. Contamination was intercepted by this well after approximately four months of pit operation and was found to extend to a depth of 10 ft below the liquid level in the well.

Wells 100 and 101 were core-drilled in an underground-contaminated area adjacent to pit 2 to delineate the contamination pattern and to allow water-level measurements for use in the preparation of a water-table contour map of the area. From samples collected while wells 100 and 101 were being drilled, it is estimated that 8 and 13 mc of Ru<sup>106</sup>, respectively, were discharged with the drilling water to a White Oak Lake contributory. This amounts to less than 0.5% of the total activity discharged from the X-10 area to the Clinch River during this same period. The concentration of Ru<sup>106</sup> in the drilling water exceeded the maximum permissible concentration value of  $1 \times 10^{-4}$   $\mu\text{c}/\text{ml}$  for approximately 5 hr. The highest concentration of activity encountered was  $4 \times 10^{-3}$   $\mu\text{c}/\text{ml}$  from well 101, which subsequently has revealed concentrations as high as  $6 \times 10^{-2}$   $\mu\text{c}/\text{ml}$ . All smears of the drilling equipment, taken over surface areas of 100  $\text{cm}^2$ , were found to be below 10 d/min/ $\text{cm}^2$ , which is below the allowable surface contamination limit.

To determine the variability of data obtained with the well-sampling equipment employed, duplicate samples were collected from nine different depths in one well and four different depths in another well. The results indicate a precision, as measured by the standard error computed from duplicate samples, of 14.7 counts/min/ml, applicable over a range of counts from 230 to 690 counts/min/ml.

#### Hydrology and Geology

**Four-Acre Site.** — A pumping test was conducted by using a tracer solution consisting of 50 lb of NaNO<sub>3</sub>, 50 lb of NaCl, 100 gal of methanol, and 100 gal of water. The tracer was introduced into well 71, which is located along the strike from the center well 73, which was pumped at a rate of 1 gpm. The tracer first showed up after 70 hr of pumping, or after 4200 gal of water had been pumped. About 8.7% of the chloride had been pumped through after 282 hr, or after about 17,000 gal had been pumped. About an equal proportion of the nitrate also came through, but, since it

appeared in a somewhat erratic pattern, the chloride was judged to be the better tracer. From the shape of the arrival curve (quantity of tracer plotted against time of pumping), it was estimated that the average arrival time for the tracer would have been of the order of 1000 hr, or after 60,000 gal had been pumped. Although the test results are incomplete, they confirm to some degree the impression that water movement is largely in the direction of the strike and that the porosity of the formation is low. The big difference between the time of first arrival and the estimated average arrival time clearly implies that some of the movement of liquid in the rock is along fairly direct channels as compared with the paths followed by most of the liquid. A large safety factor must therefore be applied to any rate of travel estimated on the basis of the average hydrologic properties of the shale. Since the tracer can be moved through 200 ft of shale after only 4200 gal has been pumped, waste can make the reverse journey under similar conditions.

**Chemical Waste Pit No. 4 Site.** — The first group of wells in this area, prior to the construction of the pit, consisted of a central 6-in. churn hole 300 ft deep (well 78) and four core holes 200 ft deep (wells 74, 75, 76, and 77) equally spaced on the circumference of a circle 125 ft in radius. Pumping of well 78 produced markedly different responses in the observation wells. Wells 74 and 76, located along the strike from the central well, showed much the same drawdown pattern. Substitution of the data in the Theis nonequilibrium formula gave a value for the transmissibility of the formation of about 100 gpd/ft, but the validity of the procedure and the meaning of the result are open to question.

Well 75, located down dip, had a much larger drawdown than did the wells along the strike. An anomalous drawdown of this sort in one particular well is subject to several interpretations, among which would be the following:

1. The pumped well may be obtaining more water from the vicinity of this well because the permeability is greater in this direction.
2. The pumped well may be drafting the same amount of water from this direction as from other directions, but the porosity (that is, the water-holding capacity) in this area may be less.
3. The pumped well may draft equal amounts of water from the vicinity of all observation wells,

with a uniform porosity, but there may be an out-lying barrier to the movement of ground water (just beyond well 75) which prevents the inflow of water to this particular observation well.

4. The large drawdown may be due to a pressure effect, with the amount of water actually removed being small and even immaterial.

Because the beds originally were thought to dip to the southeast in this area it seemed possible that the large drawdown in this well was a pressure effect. If so, the pressure changes should be more marked in the lower part of well 75, which intercepts beds that are also cut by the pumped well. To test this possibility a packer was set at a depth of 101 ft, just above the deepest large opening as determined by pressure testing. Drawdowns observed in the upper and lower portions of the well, while well 78 was being pumped, showed the more rapid response and larger drawdown in the upper part of the well. This suggests, but does not prove, that the drawdown is due to the more rapid removal of water from this direction.

The response in well 77 during the early part of the pumping test was apparently due to pressure effects. The water level in this well rose about 0.4 ft in the first 8 hr of pumping, and then fell a total of  $1\frac{1}{2}$  ft during the next four days. When the pump was shut off, the water level fell about 0.4 ft in the first 8 hr and then recovered in a normal fashion. A reverse response, somewhat similar in its anomaly, was observed in one of the wells in the Four-Acre Site during several pumping tests, although the magnitude and duration of the anomaly were smaller and shorter. Although not yet explained, two facts appear to bear on the condition of the pit 4 site. The first is an abrupt 10-ft difference in the elevation of the water table, which stands higher in well 77 and in the adjacent, older well 53 than it does in the observation wells to the southwest, south, and southeast. This suggests that the movement of the ground water is blocked by a barrier extending northeast-southwest past the northwest end of the pit. The second fact is the geologic structure which came to light when the pit was dug. The beds of shale exposed in the pit are in contorted, small, tight folds. This type of structure ends abruptly at the northwest end of the pit; northwest of this the shale is in uniform beds which dip to the southeast at about 30 to 35 deg. These relations suggest that the folding in the pit area forms a barrier to the

movement of ground water, that in some way it is responsible for the anomalous water-level fluctuations in well 77 during test pumping, and that it may be the cause of the large drawdown in well 75. If this folding is a barrier to ground water movement, it may also be the cause of the radioactive seep southwest of pit 2, for this seep appears about on the strike of the structure.

#### Water Decontamination Study

Ion-exchange materials and processes on a laboratory scale have been used effectively for removing radioactive ions from contaminated water. Therefore a study was undertaken to determine the influence of various factors on resin capacity for hardness and on the per cent removal of  $\text{Sr}^{89}$ .

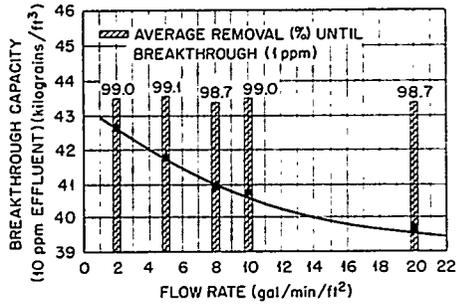
In all studies on the hydrogen cycle Amberlite<sup>3</sup> IR-120 was used as the exchange material and  $\text{Sr}^{89}$  was employed as the radioactive tracer. This tracer was contaminated with about 2% of  $\text{Sr}^{90}$ - $\text{Y}^{90}$ . Oak Ridge tap water was used, and a standard ion-exchange column operating procedure was followed. Graph I of Fig. 12 indicates that there is a decrease in resin capacity when the flow rate is increased. The plot also contains a bar graph of the average per cent removal until breakthrough (the point at which 1 ppm of the tracer appears in the effluent). Increased flow rate only slightly decreases the efficiency of removal of  $\text{Sr}^{89}$ . Graph II shows the influence of exchange-resin depth or of column length on capacity for and removal of radiostrontium. It can be seen that the breakthrough capacity (in kilograins per cubic foot) becomes greater with increasing length of column.

The total capacity, the total number of exchanging groups in the column, and the breakthrough capacity (number of milliequivalents or kilograins retained until a leakage of 1 ppm is observed) in percentage of the total capacity all increase when the column length is increased.

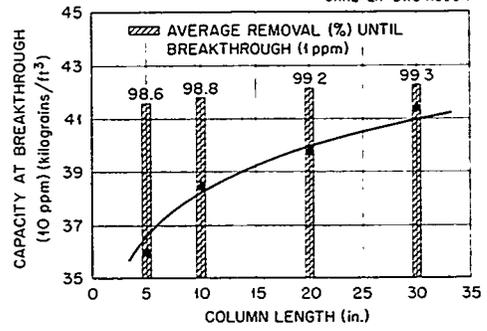
The influence of resin particle size on hardness capacity and removal of  $\text{Sr}^{89}$  was investigated by using for comparison the same resin, bed diameter, pH, and rate of flow that were used in the previous experiments. About 60% of the commercial technical grade resin is of 30-mesh size. The range of particle sizes used was U.S. Standard Sieve 20,

<sup>3</sup>Amberlite is the registered trade mark of the Rohm and Haas Co., Philadelphia, Pa.

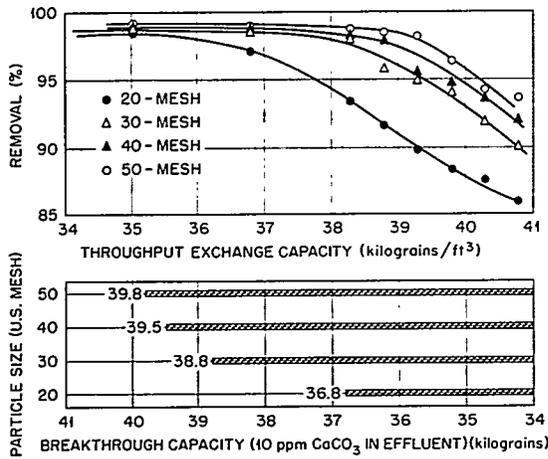
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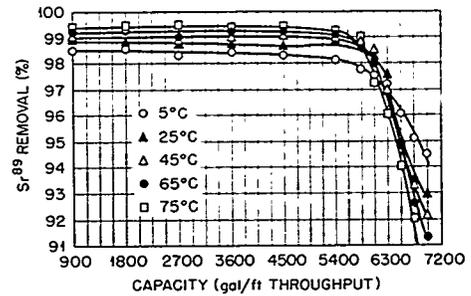
I. FLOW RATE



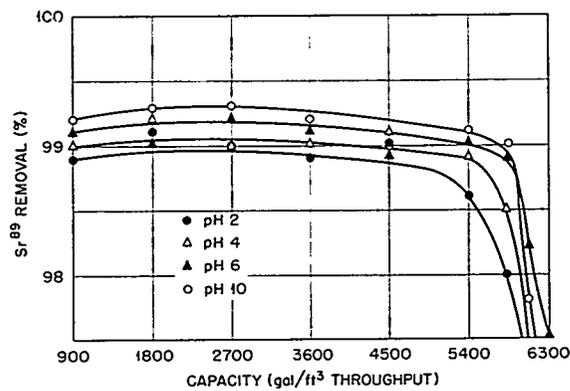
II. COLUMN LENGTH



III. RESIN PARTICLE SIZE



IV. TEMPERATURE OF FEED SOLUTION



V. ACIDITY OF FEED SOLUTION

Fig. 12. The Influences on Calcium Carbonate Capacity and Sr<sup>89</sup> Removal.

30, 40, and 50 mesh. Graph III shows that the hardness capacity and the radiostrontium removal increase with decreasing resin particle size.

In the next series of tests the influence of feed-water temperature on the capacity of the ion-exchange resin for calcium carbonate and on the effectiveness of removing  $\text{Sr}^{89}$  from aqueous solutions was investigated. The tests were made by using the procedure followed in the previous experiments and changing only the temperature of the feed solution. Graph IV on temperature effects indicates that increased temperature of the feed solution resulted in a slightly higher removal of  $\text{Sr}^{89}$  and a sharper breakthrough of hardness.

The fifth parameter studied in these tests was the effect of hydrogen ion concentration (acidity) of the feed solution on the calcium carbonate capacity and per cent removal of radiostrontium-89. The range of pH values studied was from 2 to 10.

It can be seen from Graph V that within the range of hydrogen ion concentrations studied there is a slight increase in the efficiency of removal of  $\text{Sr}^{89}$  with increasing pH. The increasing pH of the feed solution also increases the hardness capacity of the resin studied.

These are not the only parameters that should be considered during the operation of an ion-exchange process. The quantitative results reported here are applicable to only the particular cationic resin studied under the test conditions. However, the experimental results are qualitative for the general class of resins of this type.

## CHEMISTRY AND SOILS ENGINEERING

C. P. Straub (USPHS)	M. I. Goldman (USPHS)
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## Chemical Laboratory Studies

In April 1955 Hahn and Straub<sup>4</sup> published procedures for the identification of radiostrontium and radiobarium in natural waters. The development of methods for identifying radioisotopes present at low concentrations has continued, and procedures for cesium, yttrium, zirconium, niobium, and the lanthanide fission products are being evaluated. Cesium may be concentrated and separated from mixed fission products by means of phosphomolybdate or cobaltinitrite precipitation techniques. A bismuth phosphate procedure for the separation and identification of zirconium and niobium is under study, and a solvent extraction procedure is being tried for the separation of low concentrations of yttrium and the lanthanide fission products. These procedures are followed by standard radiochemical separation, which gives further purification.

Some preliminary findings in the use of solvent extraction procedures for the separation of the fission products from an acid aluminum nitrate waste solution are summarized in Table 20. Cesium

<sup>4</sup>R. B. Hahn and C. P. Straub, *J. Am. Water Works Assoc.* 47:4, 335-340 (1955).

TABLE 20. EXTRACTION OF FISSION PRODUCTS FROM 50-ml ACID  $\text{Al}(\text{NO}_3)_3$  SOLUTION INTO FOUR CONSECUTIVE 5-ml PORTIONS OF ORGANIC SOLUTIONS

Radionuclide	Solvents Used	Cumulative Activity Extracted (%)			
		1st Pass	2nd Pass	3rd Pass	4th Pass
$\text{Sr}^{90}$	100% TBP*	6.3	7.6	13.7	15.2
$\text{Y}^{90}$	100% TBP	96.8	97.5	99.0	99.6
$\text{Ru}^{106}$	100% TBP (9 months old)	79.9	89.3	94.7	96.0
$\text{Ru}^{106}$	100% TBP (new solution)	66.7	75.3	77.1	79.4
$\text{Ce}^{144}$	100% TBP	94.7	99.6	99.98	99.99
$\text{Zr}^{95}$	0.5 M TTA** in benzene	95.5	96.0	96.0	97.6
Total $\text{Zr}^{95}$ - $\text{Nb}^{95}$	0.5 M TTA in benzene	91.1	93.9	95.1	95.9
$\text{Cs}^{137}$	TTA or TBP	0	0	0	0

\*TBP - tributylphosphate.

\*\*TTA - thenoyltrifluoroacetone.

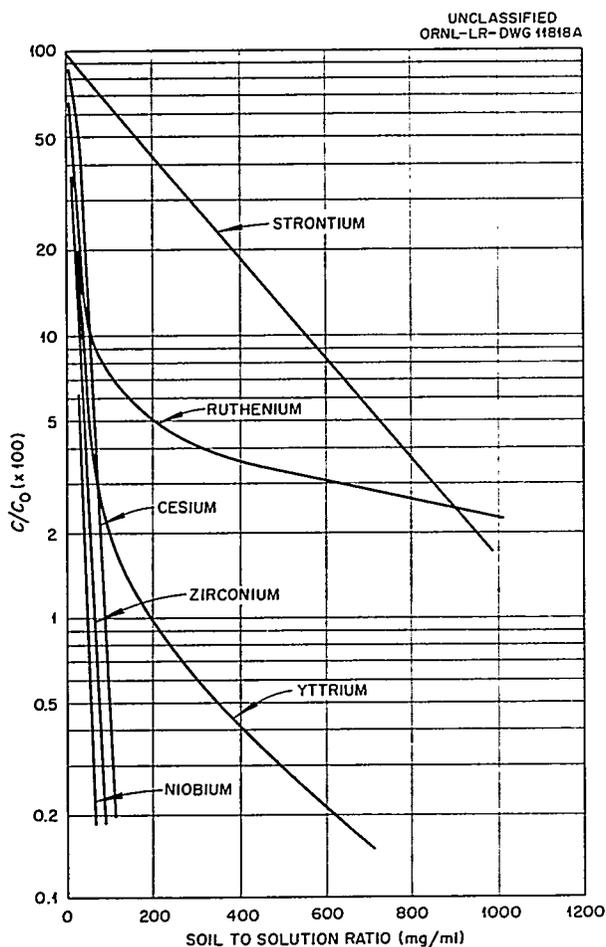
and strontium are not removed by solvent extraction following four passes of either thenoyltrifluoroacetone (TTA) or tributylphosphate (TBP).

**Soils and Engineering Studies**

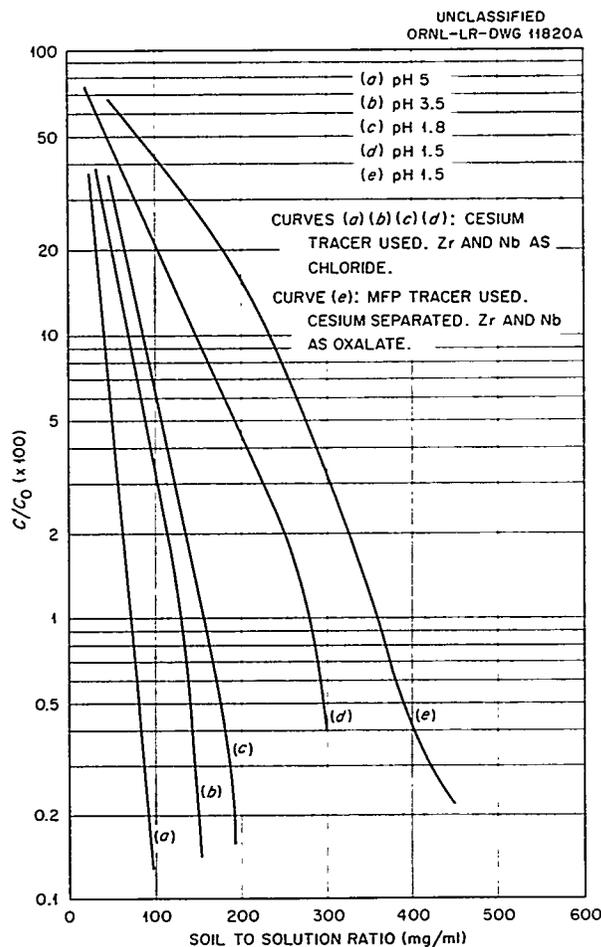
Typical results of passing an aqueous solution containing fission radionuclides through a column of Conasauga shale are shown in Fig. 13. These values were obtained with the solution adjusted to a pH of 2.3. It will be seen that the strontium moves most rapidly through the soil mass; that is, it is adsorbed more slowly than the other indicated ions. The effect of pH of the solution on removal of cesium by Conasauga shale is shown in Fig. 14. As the pH is increased from 1.5 to 5.0 the amount

of soil required per milliliter of waste solution decreases.

The effect of an acid aluminum nitrate waste and of a neutralized sodium aluminate waste on a Tennessee ball-clay liner material has been under investigation for several months. The changes taking place may be noted from an examination of Figs. 15 and 16. Figure 15 indicates the appearance of the liner material as set in a model flume on November 10, the start of the test, and Fig. 16 shows the appearance of the liner material on December 21. Continued observation since November 10 has indicated spalling of the clay liner in contact with the acid medium and a discrete cracking of the clay liner in contact with the alkaline medium. Crystallization at the leakage



**Fig. 13. Removal by Conasauga Shale of Specific Radionuclides from an Aqueous Solution (pH 2.3) Containing Mixed Fission Products.**



**Fig. 14. Effect of pH on Uptake of Cesium from Aqueous MFP Solution by Conasauga Shale.**

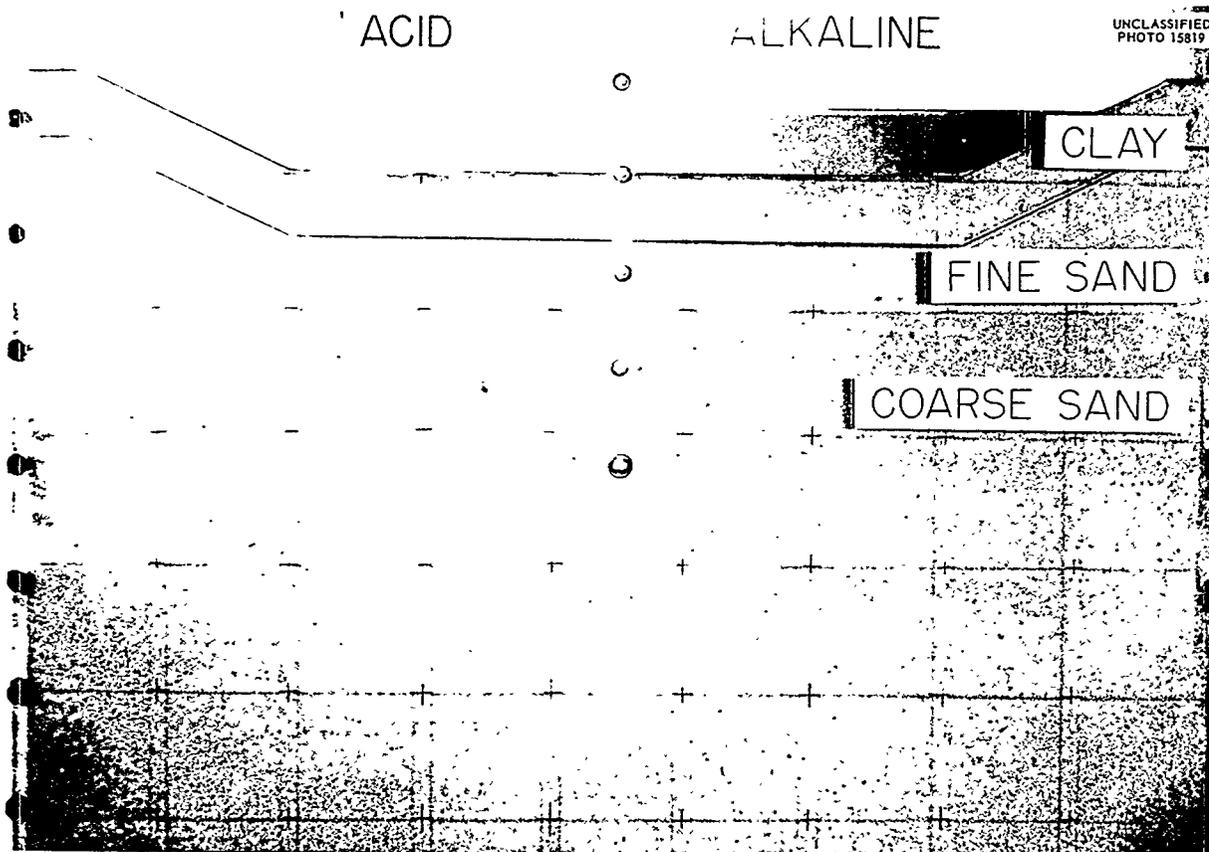


Fig. 15. Appearance of Liner at Beginning of Test - November 10, 1955.

sites and the presence of dye tracer in the underlying sand are further indications of the deterioration of the clay liner in contact with the alkaline wastes. The studies are being continued to determine the significance of the above observations upon the permeability of the liner material and upon its useful life.

#### AIRBORNE-RADIOACTIVITY STUDIES

J. W. Thomas  
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#### Evolution of $K^{42}$ from Hot and Boiling Solutions

In a study of the evolution of  $K^{42}$  from hot and boiling solutions, air was bubbled through a solution of  $K_2CO_3$  at room temperature with the use of both fritted-disk and open-end bubblers. The decontamination factor is defined as the activity per milliliter of  $K_2CO_3$  solution divided by the activity per milliliter of air. The concentration

of  $K_2CO_3$  and the air flow rate were varied through the ranges indicated in Table 21.

The data in Table 21 indicate that increased  $K_2CO_3$  concentration, increased bubble size, and decreased flow rate result in a higher decontamination factor.

Preliminary tests at the aerosol entrainment well indicated that  $K^{42}$  was being evolved at a temperature below the boiling temperature of the solution. To get confirmation of these results, dry filtered air was blown across the surface of a hot  $K_2CO_3$  solution in a flask and then passed through a Liebig condenser to remove the entrained material. The flow rate of air used was 4 liters/min. For some runs the solution was acidified with HCl. The decontamination factors, which in this case were defined as the activity per milliliter of  $K_2CO_3$  solution divided by the activity per milliliter of condensate, are listed below. The data indicate

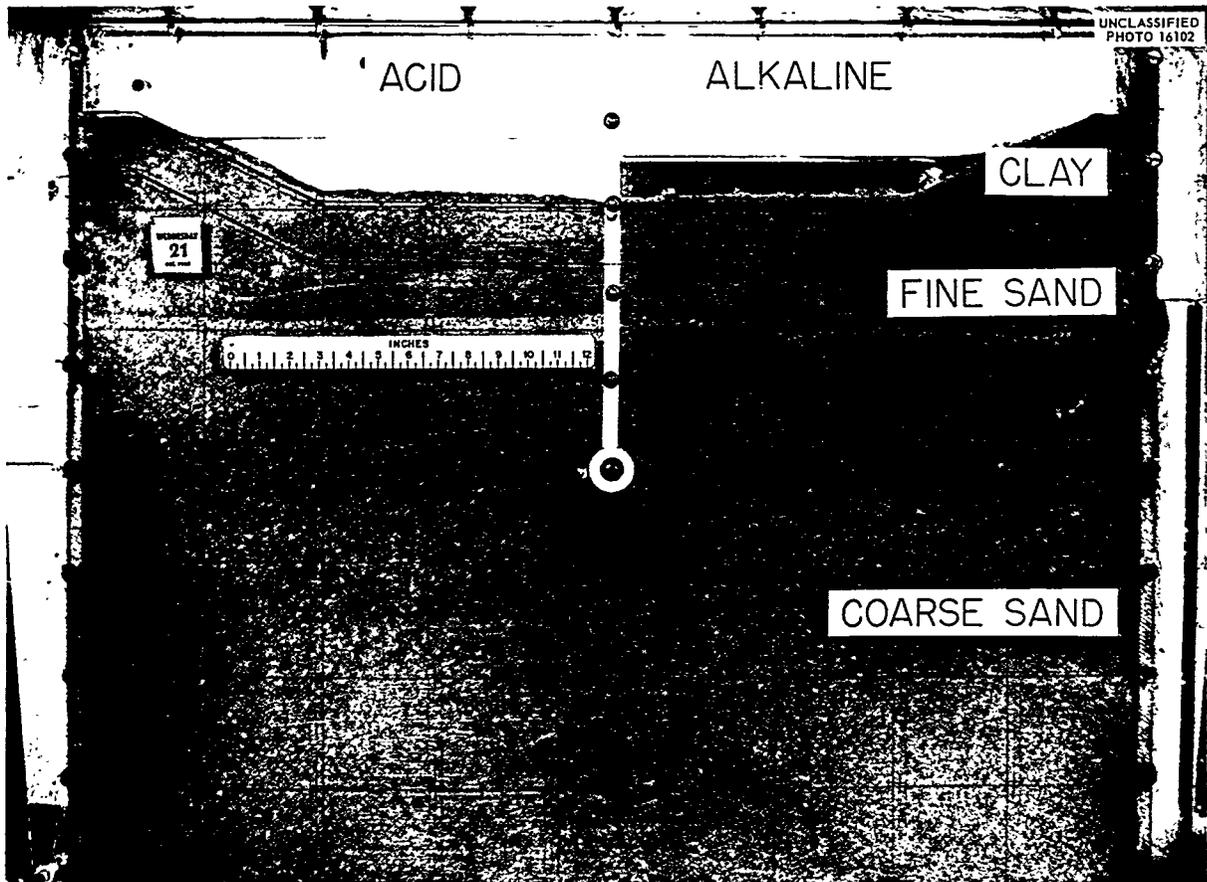


Fig. 16. Appearance of Clay Liner after Six-week Contact with Either Acid Aluminum Nitrate or Sodium Aluminate Solutions.

that lower pH or higher temperature results in a lower decontamination factor.

Temperature (°C)	Decontamination Factor	
	Basic Solution	Acid Solution
90	$2.0 \times 10^7$	$2.6 \times 10^6$
98		$4.9 \times 10^5$
Boiling	$3.1 \times 10^5$	$3.6 \times 10^4$

**Sand Filters**

The main objective of the sand-filter work is to study the removal of aerosols generated in pits containing high-level radioactive wastes. The gas

TABLE 21. RELATION OF CONCENTRATION AND FLOW RATE TO DECONTAMINATION

$K_2CO_3$ Concentration (mg/ml)	Flow Rate (ml/min)	Decontamination Factor
Fritted-Disk Bubbler		
0.006	500	$0.98 \times 10^7$
800	500	$5.9 \times 10^7$
165	150	$3.7 \times 10^7$
165	4000	$0.38 \times 10^7$
Open-End Bubbler		
165	500	$5.0 \times 10^9$
165	4000	$3.0 \times 10^9$

velocity in the filter is expected<sup>5</sup> to be 0.002 cm/sec. The lowest gas velocity through sand filters attained so far in the laboratory has been 0.054 cm/sec.

Two types of sand have been studied: Pennsylvania sand, used for sand blasting, and the Clinch River sand. The grains of these two sands showed variations in filtration which were probably due to different grain shapes. The Pennsylvania sand was separated into fractions collected on screens numbered 12, 16, 20, and 30. The Clinch River sand was collected on screens numbered 20, 30, 35, 40, and 50. A number 8 screen was the largest sieve used. The sieved sand was placed in columns 5½ in. in diameter; the columns varied in height, by incremental factors of 2, from 1½ to 12 in.

The aerosol penetrations through the sand column are determined as a function of gas velocity, particle radius, and sand grain size. Figure 17 shows data taken on both types of sand under comparable conditions. The size of the sand grain ( $D_g$  = grain diameter) is determined by taking the mean value of the openings of the collecting and preceding screen.

<sup>5</sup>R. A. Charpie *et al.*, ORNL-1638 (Jan. 21, 1954). (Secret)

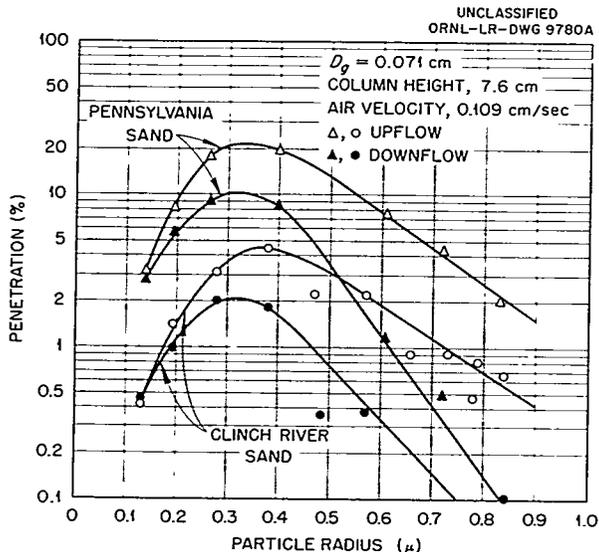


Fig. 17. Aerosol Penetration of Pennsylvania and Clinch River Sands.

The Pennsylvania sand gives penetrations as much as five times greater, at the size for maximum penetration, than the Clinch River sand. The void fraction, or the ratio of the interstitial volume to total volume, is approximately the same for both sands: 0.41 for the Pennsylvania sand and 0.385 for the Clinch River sand. Microscopic examination of the sand grains showed the Pennsylvania sand to have a smooth surface, even though it is an angular sand with a prismatic shape. The Clinch River sand was not so angular but had a much rougher or porous surface. The data indicated that the rougher the collecting sand grain, the greater its efficiency as an aerosol filter.

Figure 18 was plotted from the Clinch River sand data for the largest sand grain fraction,  $D_g = 0.161$  cm, and the smallest sand grain fraction,  $D_g = 0.036$  cm. The advantage of using a small-grained sand is clearly indicated. At the aerosol size for maximum penetration, 0.109 cm/sec, the largest sand grain fraction gives penetrations 100 times greater than the smallest sand grain fraction at the same velocity.

The expression for the filtration of aerosols by sands initially takes the form of the equation

$$C = C_0 e^{-Kz}$$

where

- $C$  = effluent concentration of aerosol from the filter,
- $C_0$  = influent concentration of aerosol to the filter,
- $K$  = attenuation function,
- $z$  = column height.

Recent data indicate that the value of  $K$  as presented in a previous report<sup>6</sup> should be modified. These data indicate that the accuracy can be expressed to  $\pm 15\%$  if

$$K = \frac{10^{-3}}{D_g} (1 - \alpha) \left( 1 + \frac{0.087}{r} \right) \times (2.09 V^{-0.57} + 22 V^{-0.78} r^3)$$

where  $\alpha$  is the void fraction and  $V$  is the superficial velocity.

<sup>6</sup>E. G. Struxness *et al.*, *HP Semiann. Prog. Rep.* July 31, 1955, ORNL-1942, p 19.

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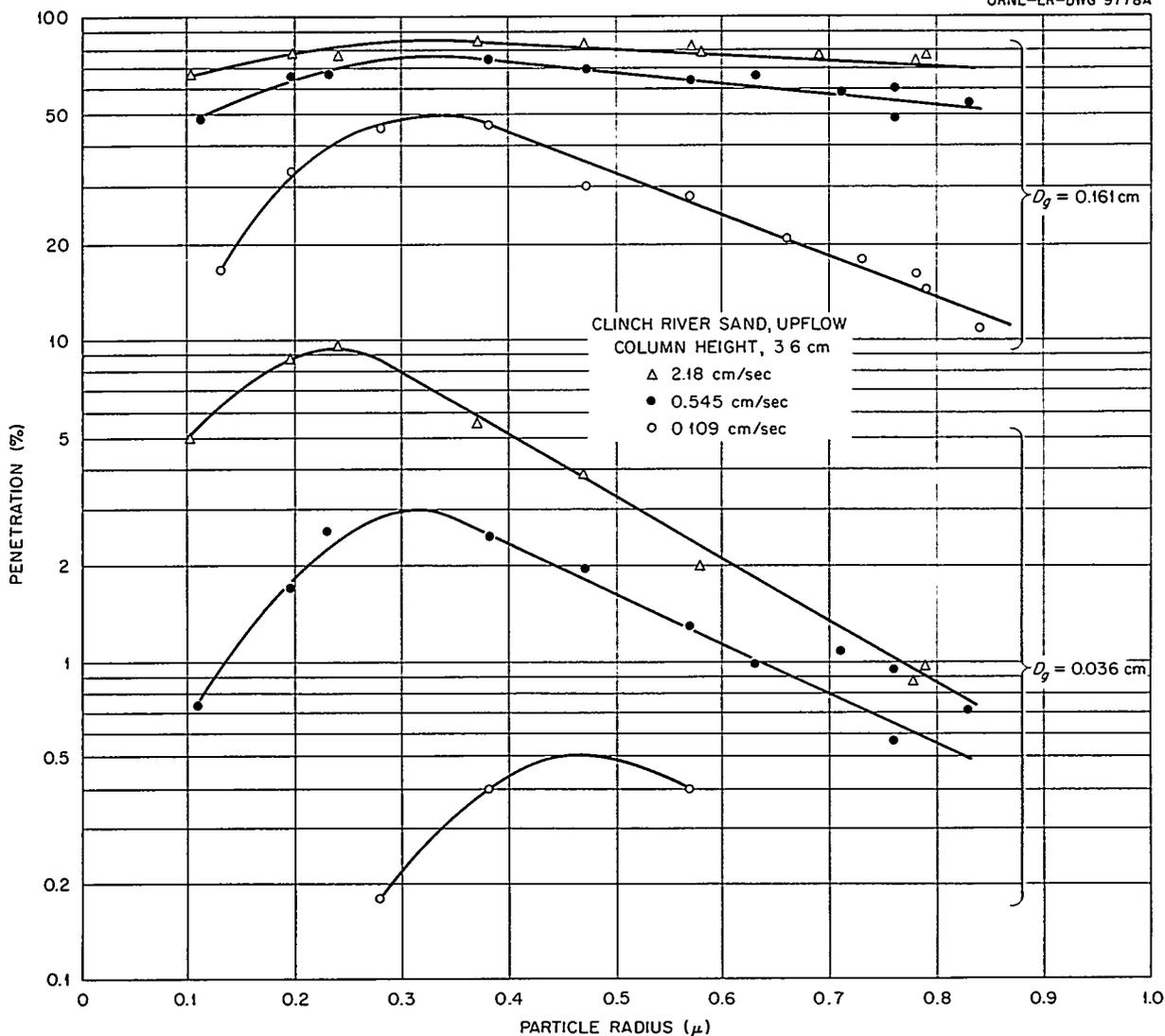


Fig. 18. Penetration of Aerosol Through Largest and Smallest Grain Fractions of Clinch River Sand.

**Packed Bead Method of Particle Size Estimation**

More recent data on the lead shot column indicate that the calibration curves as presented previously<sup>7</sup> are slightly incorrect. In the 0.2- to 0.4- $\mu$ -radius range the curves have been redrawn (see Fig. 19),

giving sharper peaks, thus providing a more accurate determination of particle size.

<sup>7</sup>J. W. Thomas et al., *HP Semiann. Prog. Rep. Jan. 31, 1955*, ORNL-1860, p 20-21.

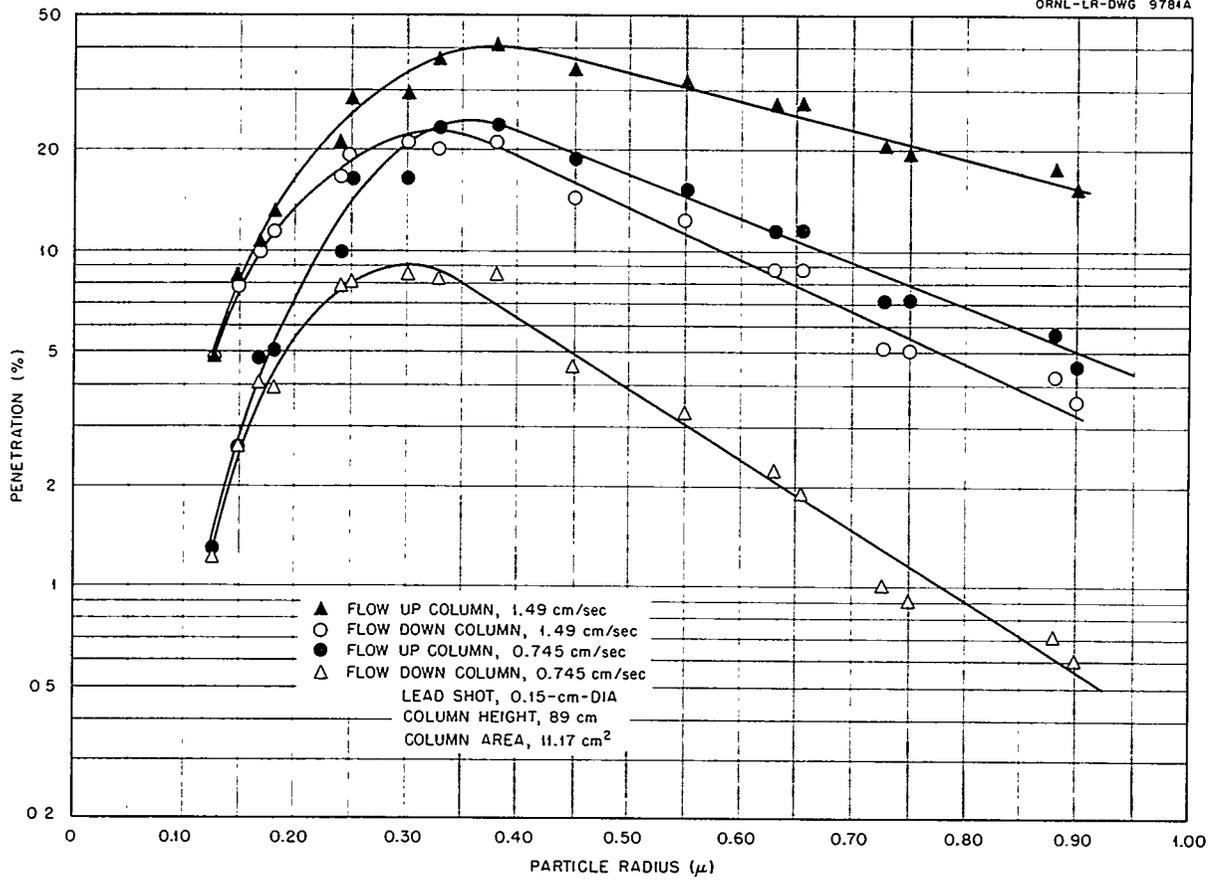


Fig. 19. Aerosol Penetration Through Lead Shot Column.

## RADIATION DOSIMETRY

G. S. Hurst

R. H. Ritchie

## EXPERIMENTAL PHYSICS OF DOSIMETRY

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T. E. Bortner	B. G. Saunders	R. M. Johnson <sup>1</sup>
J. S. Cheka	W. G. Stone	H. J. Moe <sup>1</sup>
H. H. Hubbell	H. P. Yockey	T. B. Smiley <sup>1</sup>

## Physics of Tissue Damage Studies

Because of the enormous complexity of human tissue, studies of the fundamental effects of radiation on inorganic and simple organic materials have been initiated. Advances in the knowledge of the effects of radiation on matter of less complexity will enable this laboratory to select more complex samples for future study.

The low-temperature irradiation facility in the LITR has been given a trial run. Minor flaws in the measuring circuit are being corrected so that properties of matter may be observed continuously and recorded while the samples are undergoing irradiation at low temperatures where any lattice defects are frozen in place. Migration of defects will be observed during the slow warmup to room temperature.

Single crystals of quartz cut for fundamental thickness shear have been irradiated by Co<sup>60</sup> gamma rays with doses up to  $5 \times 10^8$  r. Both resonant and antiresonant frequencies decreased about 1 cps per million roentgens.

The resonant and antiresonant equivalent resistances decreased sharply at a dose of  $1.2 \times 10^8$  r and remained approximately constant to about  $4.5 \times 10^8$  r. At approximately  $4.5 \times 10^8$  r the resistance approximately doubled. There has been no observable change in the static capacitance. The crystal piezoelectric activity appears to be unaffected.

Single crystals of Rochelle salt, ammonium dihydrogen phosphate, potassium dihydrogen phosphate, and several other piezoelectric materials have been supplied by the Clevite Research Center.<sup>2</sup> The behavior of the piezo and elastic constants as a function of neutron dose will be studied.

A study is being made of the application of information theory to health physics and radio-

biology. Radiation damage, recovery, and natural aging have been considered from the point of view of this theory. An equation relating dose, dose rate, and life span has been derived. This formula can be put in the same form as an empirical equation studied by Blair.<sup>3</sup> A paper on this subject has been submitted to *Radiation Research*.

## Application of Information Theory to the Physics of Tissue Damage

Recent advances in knowledge of the structure of deoxyribonucleic acid (DNA) and in the theory of communications make promising an attempt to develop a mathematical theory of those biological events governed by genetic specificity. Watson and Crick<sup>4</sup> have given a structure for DNA and suggest that the genetic specificity is stored as a message coded in a four-letter alphabet along a helical chain of deoxynucleotides. Protein synthesis is thought to be associated with DNA, possibly through the medium of ribonucleic acid (RNA). Regardless of the details of the process, it is believed that protein receives its specificity from DNA. Therefore, if errors occur in the genetical code, script proteins lose their specificity and their function. Some errors may be tolerated, but when too many are introduced the cell dies.

In the application of communication theory to health physics and radiobiology these errors are thought to be introduced by a radiation field and by natural aging. By use of these ideas and some ideas from the theory of chemical rate processes, it is possible to develop expressions for the specificity lost from the genetical code script. The communication theory developed by Shannon and Weaver<sup>5</sup> makes it possible to assign a measure

<sup>3</sup>H. A. Blair, *A Formulation of the Injury, Life Span, Dose Relations for Ionizing Radiations*. I. *Application to the Mouse*, UR-206 (May 13, 1952); II. *Application to the Guinea Pig, Rat, and Dog*, UR-207 (July 3, 1952); *The Shortening of Life Span by Injected Radium, Polonium, and Plutonium*, UR-274 (Sept. 8, 1953); *Recovery from Radiation Injury in Mice and Its Effect on LD<sub>50</sub> for Durations of Exposure Up to Several Weeks*, UR-312 (Feb. 10, 1954); and J. N. Stannard, H. A. Blair, and R. C. Baxter, *The Effects of a Maintained Body Burden of Polonium in the Rat*. III. *Mortality, Life Span, and Growth*, UR-395 (June 6, 1955).

<sup>4</sup>J. D. Watson and F. H. C. Crick, *Nature* 171, 964-967 (1953).

<sup>5</sup>C. E. Shannon and W. Weaver, *Mathematical Theory of Communications*, Univ. of Ill. Press, Urbana, 1949.

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to the ability of DNA to transmit specificity to proteins. This measure minus the measure of the specificity lost due to radiation effects and aging gives a measure of the ability of the damaged DNA to transfer specificity. The equation expressing this measure of ability has the same form as an empirical equation used by Blair<sup>3</sup> to represent the data in certain radiation exposure experiments. The experimental justification of the present theory rests on this fact at this time.

This work has a very practical application in that it may be possible to calculate the probable damage resulting from a given dose schedule.

#### Ionization Produced by Recoil Atoms

The previously reported<sup>6</sup> work on  $W$ , the average energy required to produce an ion pair, for recoil atoms resulting from the decay of thorium C and thorium C' has been extended and improved. A new alpha recoil counter has been designed by R. K. Abele<sup>7</sup> and assembled by K. A. Miller.<sup>7</sup>

The major improvements on the earlier efforts are as follows:

1. use of a stronger ThB source, giving improved counting statistics;
2. addition of a 20-channel analyzer;

3. replacement of the A-1 amplifier by DD-2 amplifiers, giving better resolution at the higher counting rates;
4. use of a new counter design, giving calibration pulses and recoil pulses of about the same order of magnitude, thus extending the range of usable pressures;
5. collimation of the recoil atoms so as to decrease the effect of columnar recombination.

In the previously reported experiment, columnar recombination was possible for the recoil tracks but not for the calibration alpha tracks. In this experiment the situation is reversed. The difference in values could be fully accounted for by assuming 8% loss of ions by recombination when the track is perpendicular to the counter wire.

As shown in Fig. 20, the present design consists of three cylindrical proportional counters whose axes are parallel and lie in the same plane. All pulse-height measurements are made in the center counter, which contains the source material. The two outside counters serve only to single out by coincidence circuitry the specific decay events in which there is interest.

The source of recoil atoms is  $Pb^{212}(ThB)$  collected in an electric field from a  $Th^{228}$  source.

<sup>6</sup>G. S. Hurst *et al.*, *HP Semiann. Prog. Rep. Jan. 31, 1954*, ORNL-1684, p 8.

<sup>7</sup>Instrument Department, Instrumentation and Controls Division.

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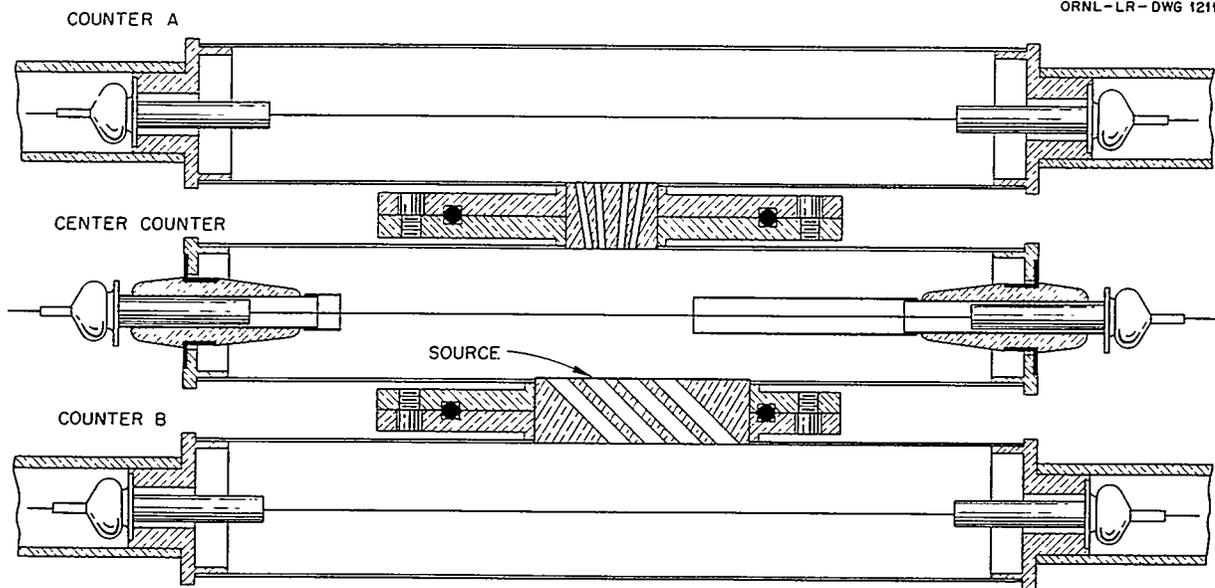


Fig. 20. Alpha Recoil Counter.

The ThB is collected on the inner face of a thin mica window sealed into the wall of the center counter at the mid-point. The half life of  $Pb^{212}$  is 10.5 hr; so a very active source is obtained with a deposit having an average thickness which is very small compared with a single molecular layer. The mica window holding the deposited source and the opposite window, also in the wall of the center counter, were made conducting, opaque, and of such a thickness that recoil particles cannot pass through but alpha particles can pass through readily. The gas pressure used in the counters is such that recoil particles are stopped in less than 1 in. but are not stopped in less than 0.1 in.

For calibration the center counter and counter A are connected to the circuit shown in Fig. 21. By the use of coincidence pulses from counter A to gate the signals from the center counter which reach the 20-channel analyzer, effective collimation of the alpha particles is accomplished. By observing the resulting pulse-height distribution on the 20-channel analyzer and using the data of Hirshfelder and Magee,<sup>8</sup> the number of ion pairs corresponding to the observed pulse heights can be calculated, since the energies of the alpha particles from the ThC and ThC', the gas pressure, and the  $W$  values for alpha particles in the gases are known. In methane at pressures above 4 cm Hg

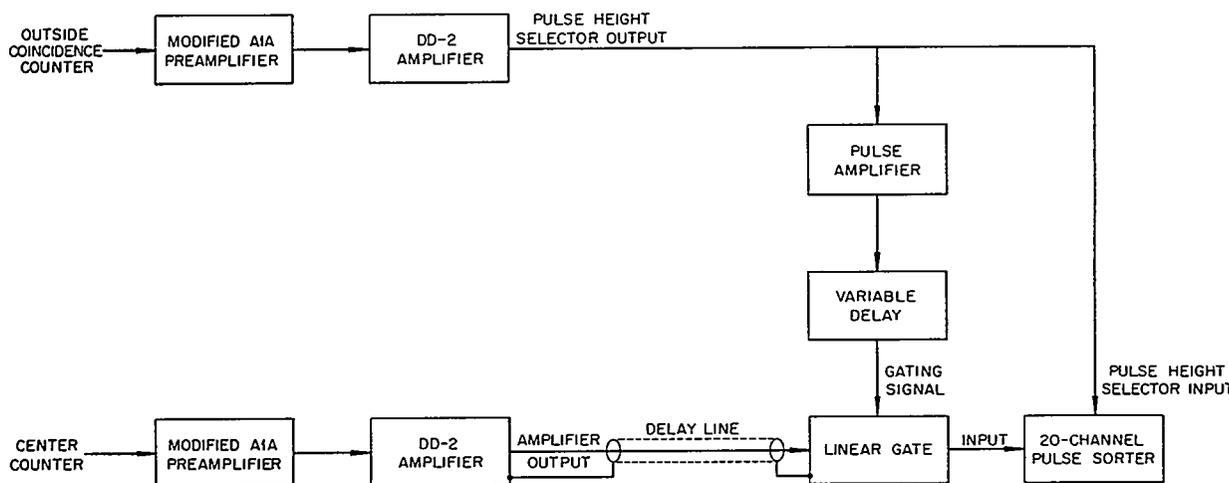
the peaks due to the alphas from ThC and ThC' are well resolved, as illustrated in Fig. 22.

To study the pulses caused by the recoil atoms, the center counter is not disturbed but counter B is connected in place of counter A in the circuit shown in Fig. 21. In this operation alpha particles entering counter B correspond to recoil particles traveling diagonally across the center counter. The pulses in counter B gate the pulses reaching the 20-channel analyzer from the center counter and produce a pulse-height distribution that represents the spectrum caused by the recoil atoms from ThC and ThC'. It has been possible to resolve these two peaks in methane at gas pressures as low as 1 cm Hg.

From the calibration data and the known energies of the recoil atoms the value of  $W$  for the recoil atoms is calculated. Results have been obtained for methane at a pressure of 4.75 cm Hg and for hydrogen at a pressure of 4.86 cm Hg. The value of  $W$  in units of electron volts per ion pair for the ThC recoil atom is found to be 121 for methane and 82 for hydrogen. The value of  $W$  for the ThC' recoil atoms is found to be 99.5 for methane and 63 for hydrogen.

It is planned to extend these measurements to carbon dioxide, argon, ethylene, and cyclopropane as well as to other pressures of methane and hydrogen.

<sup>8</sup>J. O. Hirshfelder and J. L. Magee, *Phys. Rev.* 73, 207 (1948).



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Fig. 21. Schematic Diagram of Circuit for Both Recoils and Calibrating Alphas.

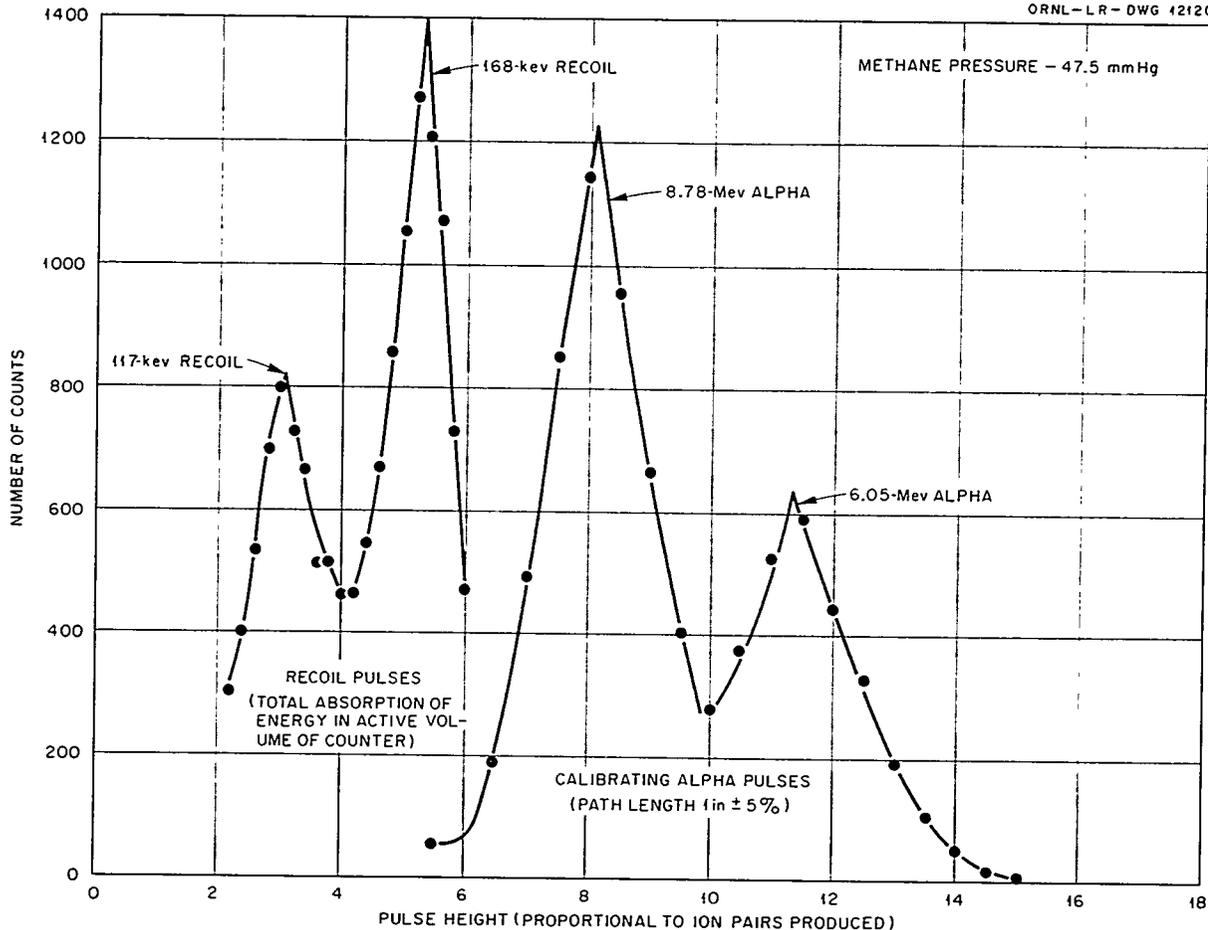


Fig. 22. Peaks of Alpha Particles from ThC and ThC'.

#### Attachment Coefficient and Drift Velocity of Electrons

The apparatus in Fig. 23 was designed for measuring the effect of attaching gases in ionization chambers and proportional counters on the electron pulse height. A collimated alpha source released free electrons by ionization, all at the same distance from the collector plate in the lower chamber. Some of the electrons are captured before collection, and thus, if the pulse amplifier has a time constant  $t_1$  which is comparable to electron transport time  $\tau_0$ , the pulse height permits measurements of the probability of electron attachment per centimeter of travel in the field direction and per millimeter of pressure of the attaching gas. The output pulse height from the linear amplifier also

depends on the time  $\tau_0$ ; the latter is measured in the upper part of the chamber by the two proportional counters.

**Pulse Height.** - The pulse height due to free electrons is measured by means of an A-1 linear amplifier (with  $t_1 = 15 \mu\text{sec}$ ) and a single-channel pulse analyzer with a motor-driven base line.

Figure 24 shows the decrease in pulse height as a function of the electric field and the amount of the attaching gas - in this case, oxygen in nitrogen. Figure 25 shows in the same manner the effect of oxygen in methane. Under the above conditions, tube mechanism for electron capture is the straightforward attachment process  $\text{O}_2 + e^- \rightarrow \text{O}_2^-$ .

**Electron Drift Rate.** - Figures 26 through 30 show the electron drift rate as a function of the

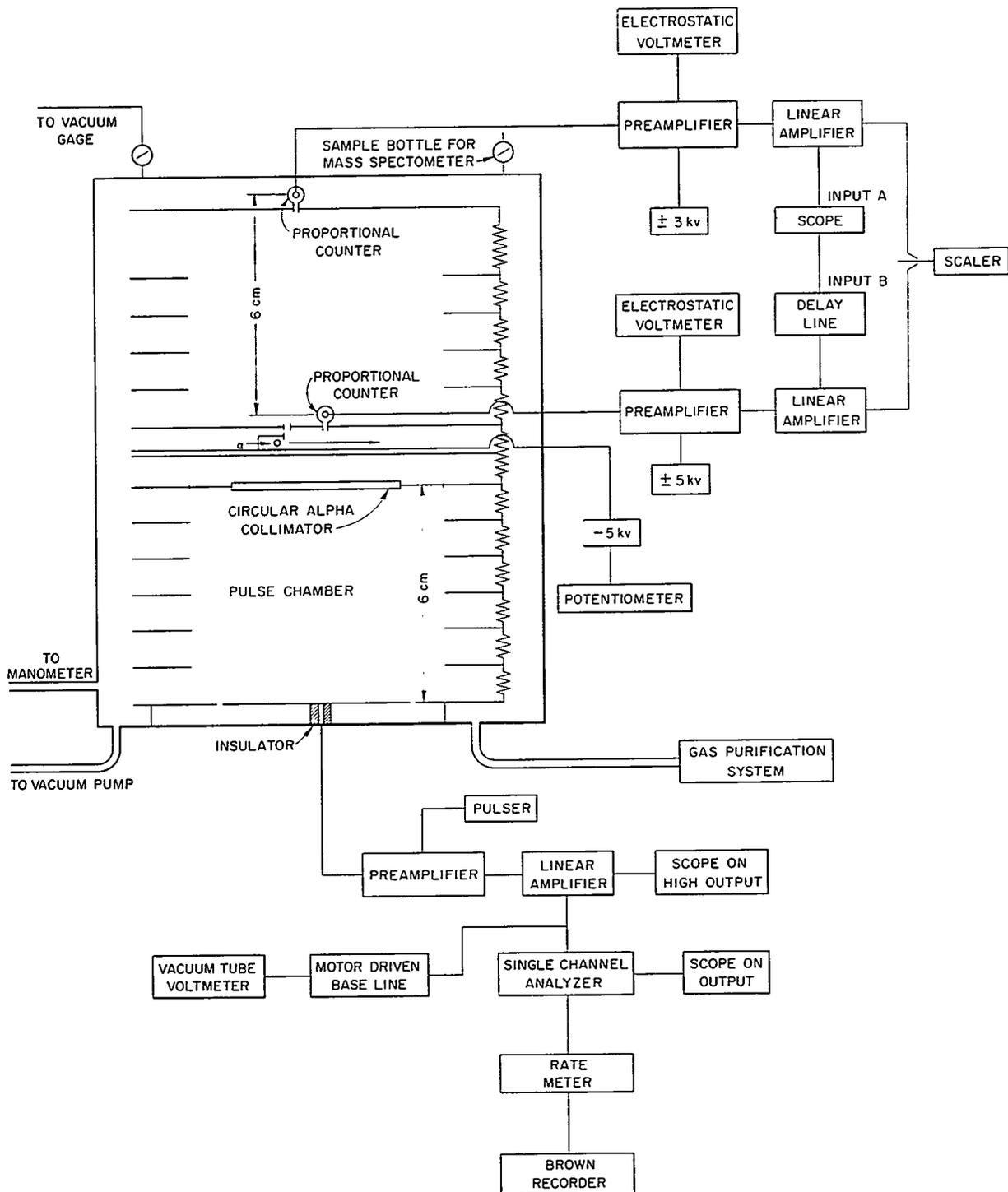


Fig. 23. Electron Attachment and Drift Rate Apparatus.

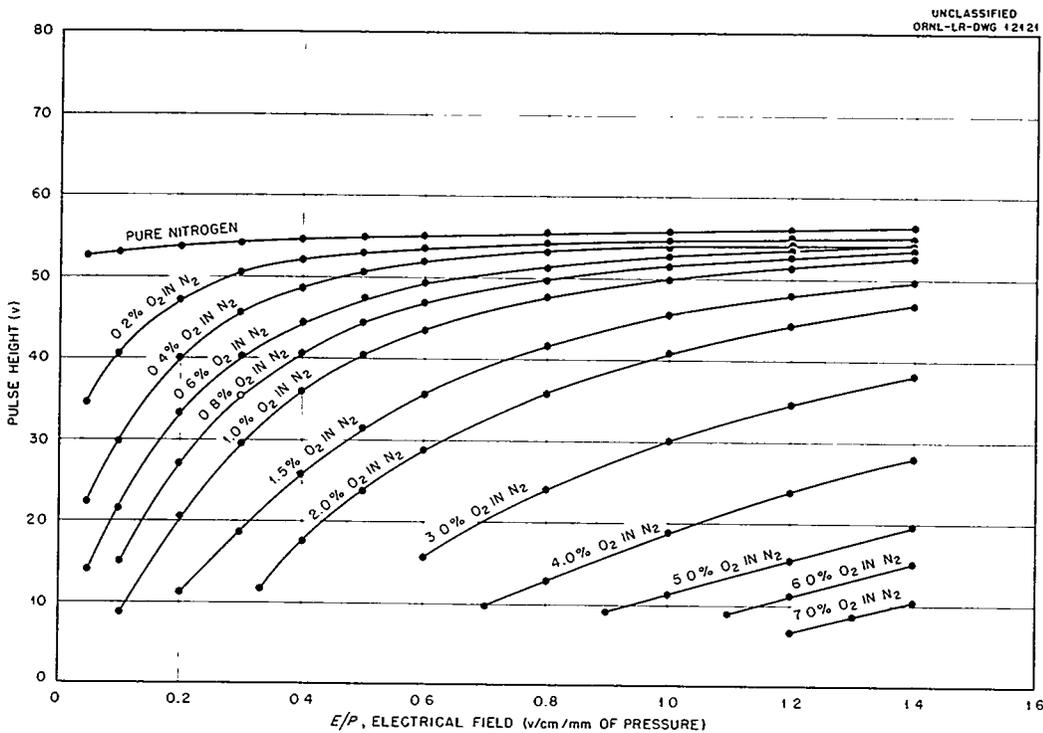


Fig. 24. Pulse Height vs the Electrical Field in Pure Nitrogen and in Nitrogen-Oxygen Mixtures at 40 cm Total Pressure.

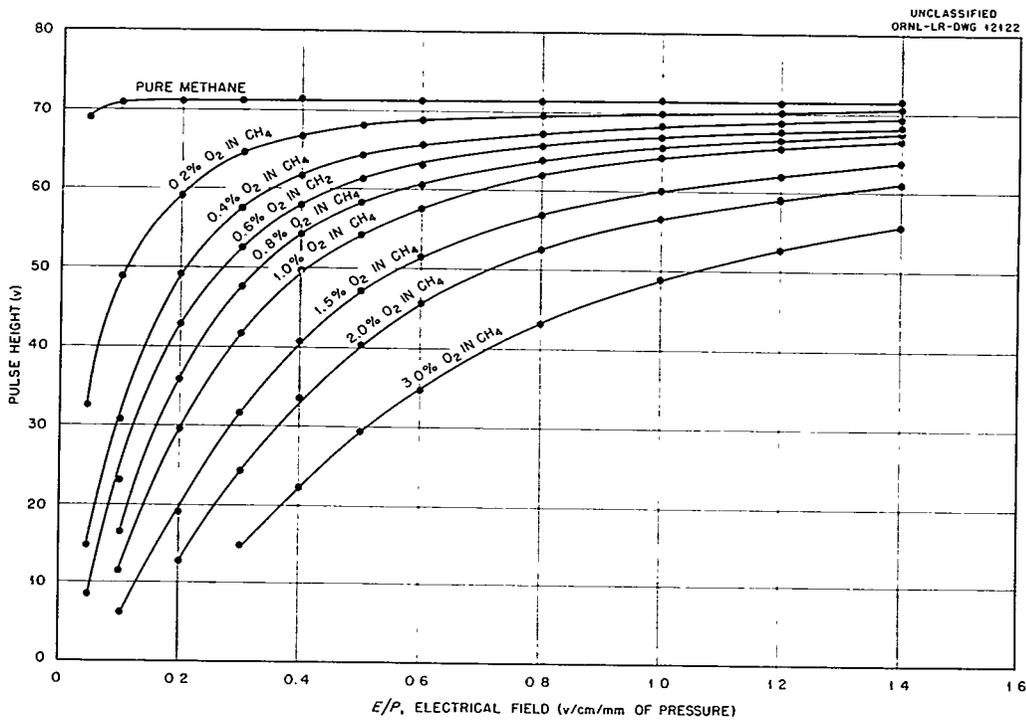


Fig. 25. Pulse Height vs the Electrical Field in Pure Methane and in Methane-Oxygen Mixtures at 40 cm Total Pressure.

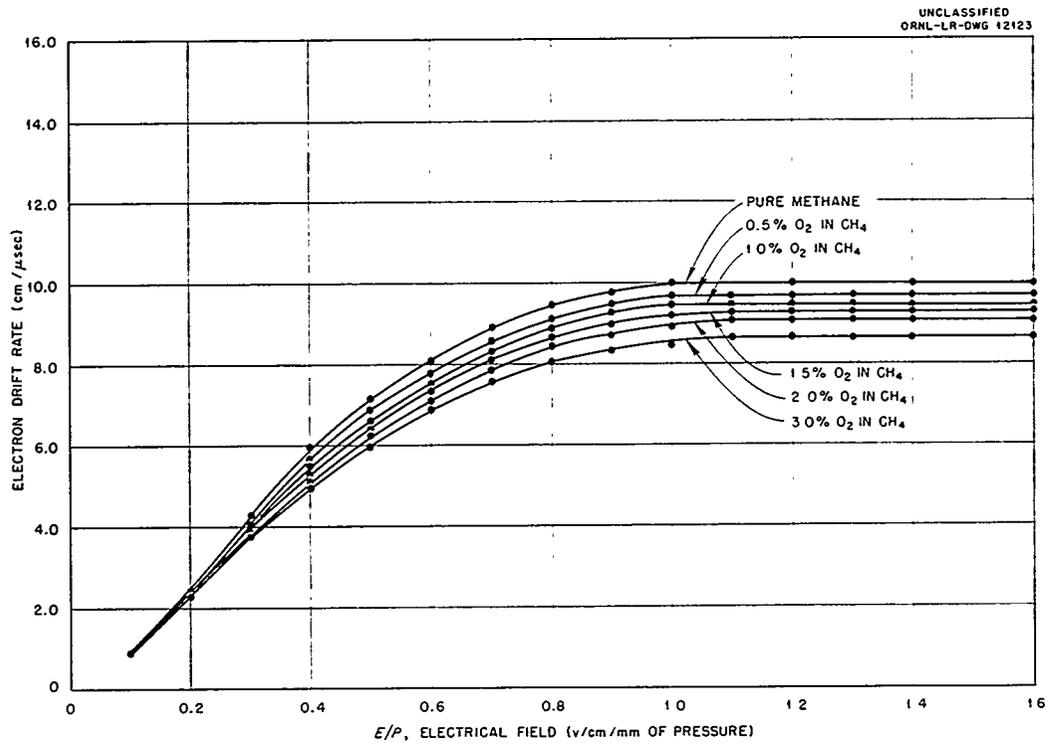


Fig. 26. Electron Drift Rate vs the Electrical Field in Pure Methane and in Methane-Oxygen Mixtures at 40 cm Total Pressure.

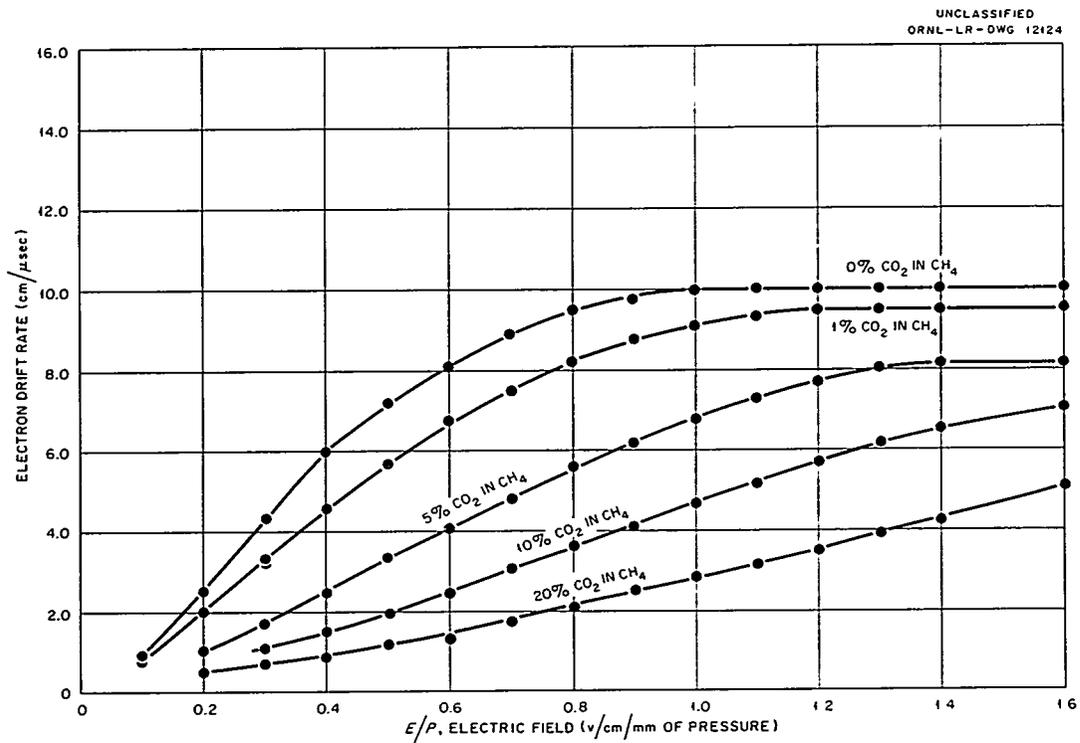


Fig. 27. Electron Drift Rate vs the Electrical Field in Mixtures of Methane and Carbon Dioxide. Pressure 40 cm Hg.

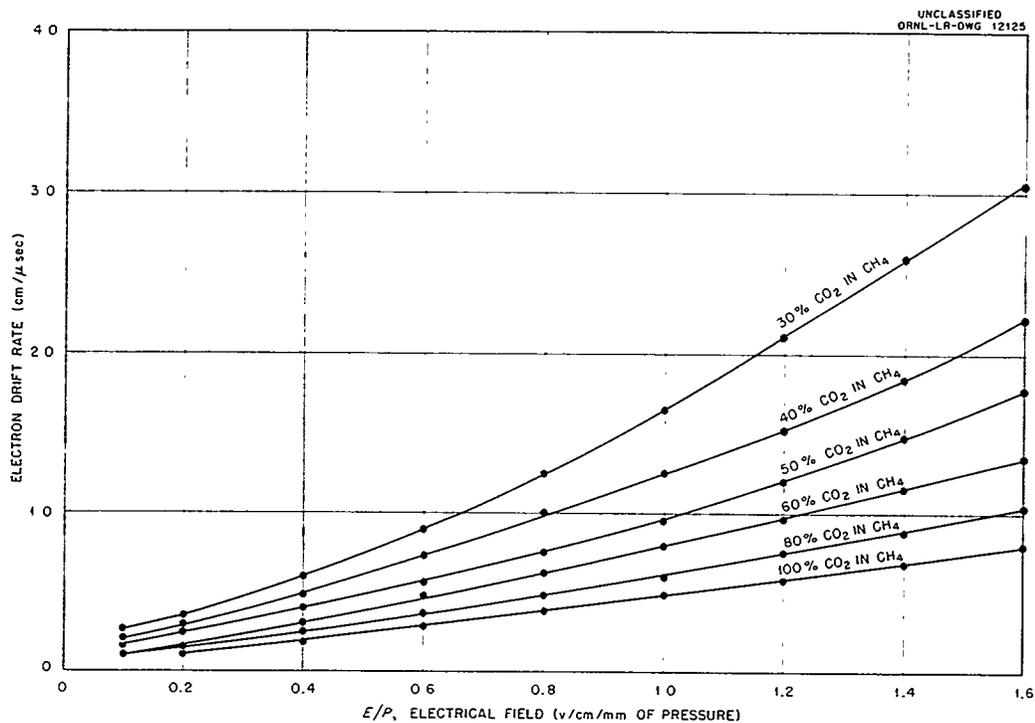


Fig. 28. Electron Drift Rate vs the Electrical Field in Mixtures of Methane and Carbon Dioxide. Pressure 40 cm Hg.

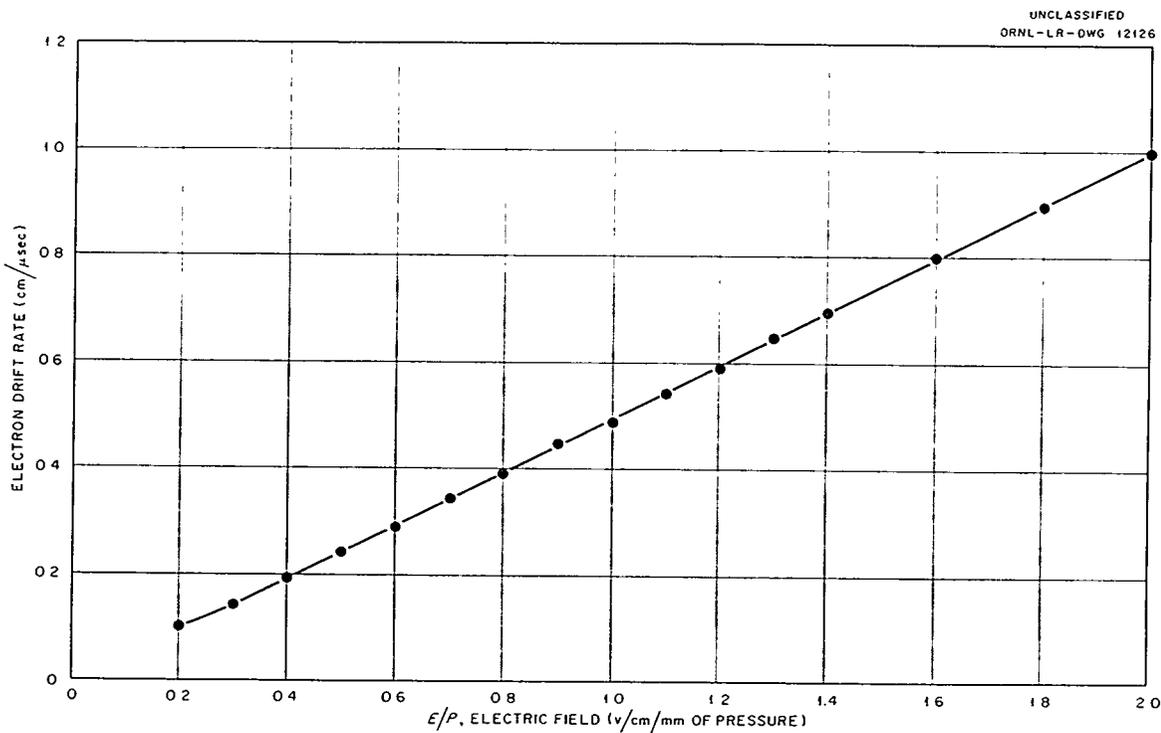


Fig. 29. Electron Drift Rate vs the Electrical Field in Pure Carbon Dioxide at 40 cm Total Pressure.

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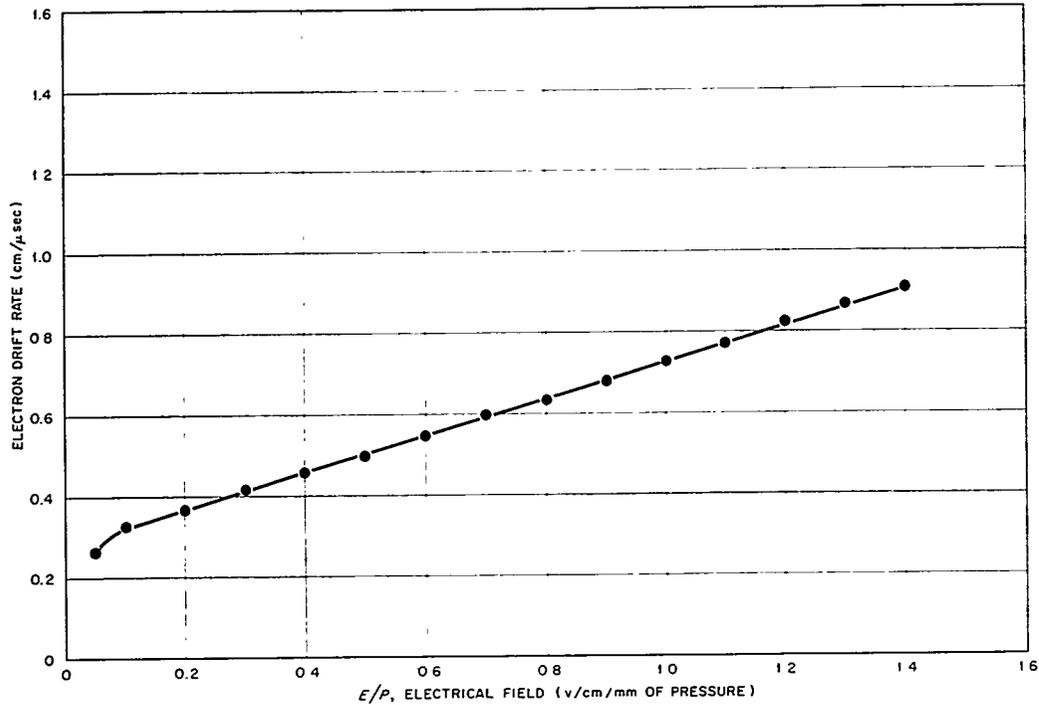


Fig. 30. Electron Drift Rate vs the Electrical Field in Pure Nitrogen at 40 cm Total Pressure.

electrical field for several gases and the effect that oxygen has on the drift rate. In Fig. 24 it is seen that rather small percentages of oxygen decrease the pulse height, but it was found that up to 3% of oxygen in nitrogen had no measurable effect on the drift rate. As can be seen in Fig. 26, the effect of small percentages of oxygen in methane does have some effect on the rate of drift of the electrons. Electron drift rates were measured for mixtures of methane and carbon dioxide, Figs. 27 and 28. Figures 29 and 30 show, respectively, the drift rates in carbon dioxide and nitrogen.

In the case of CH<sub>4</sub> the two signals from the counters are very close together (0.6 μsec), and hence slight changes due to addition of O<sub>2</sub> are

difficult to detect. Because of this a variable delay line, containing a booster amplifier, was placed between the first tube and one of the two inputs on the Tektronix 535 scope. The second tube output is connected to the second input of the scope. By inverting one of the signals and adding time delay, the tips of the two signals can be matched, thus giving a null method of reading a time interval. The data in Fig. 26 were taken in this manner.

**Attachment Coefficient.** - From measurements of the pulse heights and the electron drift velocity, the attachment coefficient  $\alpha$  per centimeter of travel in the field direction and per millimeter of attaching gas can be determined from the following equations:

$$V_{\tau}' = \frac{\text{constant}}{(\tau_0 - t_1 f)} \left[ \left( e^{(\tau_0 - t_1 f)/t_1} - 1 \right) \tau' - e^{(\tau_0 - t_1 f)/t_1} \left( \tau_0 - \frac{t_1 \tau_0}{\tau_0 - t_1 f} \right) - \frac{t_1 \tau_0}{\tau_0 - t_1 f} \right] e^{-\tau'/t_1} ,$$

$$\tau' = t_1 \frac{\left[ e^{(\tau_0 - t_1 f)/t_1} \left( 1 + \frac{\tau_0}{t_1} - \frac{\tau_0}{\tau_0 - t_1 f} \right) + \left( \frac{\tau_0}{\tau_0 - t_1 f} - 1 \right) \right]}{\left[ e^{(\tau_0 - t_1 f)/t_1} - 1 \right]} ,$$

$$f = \alpha d f_1 P ,$$

where

$t_1$  = the time constant for an amplifier having a response  $V(t) = (t/t_1)e^{-t/t_1}$  when a step function of unit height is fed into the amplifier,

$V_{\tau}$  = the maximum pulse height,

$d$  = the distance, cm, from the alpha source to the collector plate,

$f_1$  = the mole fraction of the attaching gas,

$P$  = the total gas pressure, mm Hg,

$\tau_0$  = the time required for electrons to drift the distance  $d$ .

The coefficient  $\alpha$  for  $O_2$  in  $N_2$  and  $O_2$  in  $CH_4$  appears to depend on  $f_1$  as well as on  $P$  for ranges of  $f_1$  from 0.002 to 0.03 and on  $P$  from 350 to 1000 mm. Extensive determination of total pressure and partial pressure dependence is in progress.

#### Accelerator

The studies of the distribution of dose with depth in a solid bombarded with an electron beam have been continued. Extensive revision of existing apparatus has been found necessary in order that an experiment can be performed which may be interpreted with the aid of the Spencer<sup>9</sup> theory. The problem has been one of providing a means for introducing a parallel beam into a solid which extends to infinity in both directions from the plane of incidence. Ionization in a parallel-plate gas-filled ion chamber should then be measured at various distances from both sides of the source plane. The design has been worked out and measurements are in progress. It has been found necessary to construct a differential pumping system for the ion chamber.

The ion source to be used in making measurements of the ionization of gases by heavy particles has been completed.

#### Beta Spectrometer

The measurements of electron straggling in thin foils have been discontinued because of interesting recent developments in electron diffusion theory which currently are awaiting experimental verification. Recent discussions with L. V. Spencer and U. Fano at the National Bureau of Standards have pointed to the feasibility of measuring the energy distribution of the electron flux in a medium result-

ing when radioactive sources are embedded in the medium or when the medium is bombarded with x rays or neutrons. In the material a vacuum cavity with a small hole leading to the outside can be used to supply a sample of the flux, which then may be analyzed by a beta spectrometer. The results should check the Spencer-Fano<sup>10</sup> theory in the region above a few kev where electron collision cross sections are known adequately. Theoretical calculations have been carried out for sources of  $P^{32}$ ,  $Tl^{204}$ , and  $S^{35}$  distributed in water or bakelite, and the flux spectra have been obtained. Experiments with  $P^{32}$  in bakelite are currently going on, using the beta plaque material available locally.

A paper<sup>11</sup> describing the beta spectrometer has appeared recently in the literature.

#### X-Ray Exposure Facility

The need for an accurate beta-ray dosimeter for personnel has led to the building and calibrating of several different versions of the pencil type currently in use in this and other laboratories. Modifications include a perforated version of the usual plastic model, aluminum and magnesium screen-covered variations, and "no-wall" types with 7 and 1 mg/cm<sup>2</sup> conducting films defining the sensitive volume. Calibration has been accomplished by inserting the pencil into a cavity in a beta-radioactive liquid where the dosage is accurately known from a measurement of the specific activity of the liquid. The response of the chambers may be predicted from a knowledge of the Spencer-Attix<sup>12</sup> theory of cavity ionization. The response is found to be a sensitive function of the thickness of the foil used to define the volume. For instance a 7 mg/cm<sup>2</sup> foil absorbs about half the dose in a cavity in a  $P^{32}$  solution. All pencils are designed so that the response to x and gamma rays remains the same as in the conventional model. Further work is progressing with several different beta-emitting isotopes, and it is hoped that the design for practical field models will be available soon.

<sup>10</sup>L. V. Spencer and U. Fano, *Phys. Rev.* 93, 1172 (1954).

<sup>11</sup>R. D. Birkhoff *et al.*, *Rev. Sci. Instr.* 26, 959 (1955).

<sup>12</sup>L. V. Spencer and F. H. Attix, *Radiation Research* 3, 239 (1955).

<sup>9</sup>L. V. Spencer, *Phys. Rev.* 98, 1597 (1955).

**Ionization in Acetylene Mixtures by Pu<sup>239</sup> Alpha Particles**

The ionization produced by Pu<sup>239</sup> alpha particles in acetylene mixed with helium, neon, argon, carbon dioxide, and nitrogen has been determined. The results yielded  $W$  values (average energy used in producing an ion pair) for the mixtures. Huber, Baldinger, and Haeberli<sup>13</sup> introduced the formula

$$\frac{1}{W_m} = \left( \frac{1}{W_1} - \frac{1}{W_2} \right) Z + \frac{1}{W_2},$$

where  $Z = S_1 P_1 / (S_1 P_1 + S_2 P_2)$ ,  $W_m$  is the  $W$  for a gas mixture having two components at pressures  $P_1$  and  $P_2$  and molecular stopping powers  $S_1$  and  $S_2$  with  $W$  values for the pure gases equal to  $W_1$  and  $W_2$ , respectively. This formula is based on the assumption that the presence of a second gas does not contribute to the ionization of the first.

It has been found<sup>14</sup> that for certain combinations of gases, a general formula

$$\frac{1}{W_m} = \left( \frac{1}{W_1} - \frac{1}{W_2} \right) Z + \frac{1}{W_2},$$

where  $Z = P_1 / (P_1 + aP_2)$ , in which  $a$  is an empirical constant, does hold whereas the equation for the special case given above does not. The purpose of this work was to determine whether acetylene and the group of gases studied would be among those mixtures for which this more general formula held and if so, to determine the empirical constant  $a$ . The mixtures shown below gave a good fit to the second equation.

Mixture	$S_2/S_1$	$a$
N <sub>2</sub> -C <sub>2</sub> H <sub>2</sub>	1.768	0.267
A-C <sub>2</sub> H <sub>2</sub>	0.577	3.550
CO <sub>2</sub> -C <sub>2</sub> H <sub>2</sub>	1.321	0.927
He-C <sub>2</sub> H <sub>2</sub>	0.312	0.058

The  $a$  values are compared with  $S_2/S_1$ , which is the value of  $a$  whenever the general formula is reduced to the special case. The results for the mixture of neon plus acetylene could not be fitted to either equation.

<sup>13</sup>P. Huber, E. Baldinger, and W. Haeberli, *Helv. Phys. Acta* 23, Suppl. III, 85 (1950).

<sup>14</sup>T. E. Bortner and G. S. Hurst, *Phys. Rev.* 93, 1236-1241 (1954).

**THEORETICAL PHYSICS OF DOSIMETRY**

J. Neufeld      R. H. Ritchie      W. S. Snyder

**Number of Vacancies Created by Corpuscular Radiation<sup>15</sup>**

In the previous work<sup>16</sup> on disordering of solids by neutron radiation summarized in the last semi-annual report,<sup>17</sup> the number of displacements has been computed under the assumption that a displacement occurs when the struck atom receives energy  $y$  larger than  $a$ . In this work the number of vacancies is calculated by taking into account replacements that occur when  $y > a$  and  $x - y < a$ , where  $x$  is the energy of the striking atom before collision. Then the mean number of vacancies is determined by  $g(x) = 1$  for  $0 < x < 2a$  and by

$$g(x) = \int_0^{x-a} dy K(x, y) g(x-y) + \int_a^x dy K(x, y) g(y-a)$$

for  $x > 2a$ , where  $K(x, y)$  is the scattering kernel. The above equation yields  $g(x) \sim x/3a$  for hard-sphere scattering.

**Effect of Boundaries on Energy Loss of Charged Particles Passing Through Thin Foils**

Recent work<sup>18</sup> on the determination of the mean free path for discrete energy loss of electrons in thin metal foils compares experimental results with theoretical predictions of the energy loss. The transient electrodynamic disturbance created by the passage of an electron through the boundaries of thin foils gives rise to an energy loss which may be comparable with that predicted by conventional energy loss formulas which do not include this transient effect. A formula has been derived for this "transient" energy loss in the case of a relativistic charged particle incident on a foil having a dielectric constant  $\epsilon(\omega)$ . It is shown that for conduction electrons this transient effect may be neglected only if the foil thickness is much greater than  $v/\Omega$ , where  $v$  is the velocity of the

<sup>15</sup>J. Neufeld and W. S. Snyder, *Phys. Rev.* 99, 1326 (1955).

<sup>16</sup>W. S. Snyder and J. Neufeld, *Phys. Rev.* 97, 1636-1646 (1955).

<sup>17</sup>J. Neufeld, R. H. Ritchie, and W. S. Snyder, *HP Semiann. Prog. Rep.* July 31, 1955, ORNL-1942, p 22.

<sup>18</sup>A. W. Blackstock, R. H. Ritchie, and R. D. Birkhoff, *Phys. Rev.* 100, 1078 (1955).

particle and  $\Omega$  is the "plasma" resonance frequency. Since  $v/\Omega$  is of the order of hundreds of angstroms for 100-kev electrons in certain metals, measurements of the kind described by Blackstock, Ritchie, and Birkhoff<sup>18</sup> may show this effect. A more complete account of this work will be submitted for publication.

#### Asymptotic Solutions of the Heat Conduction Equation in Cylindrical Geometry

The formal solutions of many problems involving transient heat conduction in infinite internally bounded cylindrical solids may be obtained by the standard Laplace transform method. Such solutions are of importance in many physical applications such as heat flow, gas flow through porous media, slowing down of neutrons, and other diffusion phenomena. Asymptotic series representing these solutions for large values of the "time" parameter have been derived. They are expressed in terms of functions related to the derivatives of the reciprocal gamma function, and it has been shown that they are asymptotic in the sense of Poincaré's definition. These results have been applied to selected physical problems in heat conduction. They include cases in which (1) a cylindrical surface is maintained at constant temperature in a medium which is initially at a lower temperature, (2) a constant flow occurs over a surface, and (3) a constant cylindrical shell source exists in the medium. Application is also made to a problem in the flow of gas through porous media. A paper describing this work will be submitted to the *Journal of Applied Physics*.

#### DOSIMETRY APPLICATIONS

F. J. Davis	J. M. Garner
P. W. Reinhardt	J. A. Auxier
J. A. Harter	E. B. Wagner
H. E. Gilbert <sup>19</sup>	

#### Neutron-Threshold-Detector Program

A method has been described for measuring the spectrum of fast neutrons with a series of foil detectors.<sup>20</sup> The detectors consist of Au and Au plus Cd for determining the thermal flux, Pu<sup>239</sup> shielded with B<sup>10</sup> for determining the total fast flux, Np<sup>237</sup> for determining the total flux above

0.75 Mev, U<sup>238</sup> for determining the total flux above 1.5 Mev, and S<sup>32</sup> for determining the total flux above 2.5 Mev. From these data the spectrum of fast neutrons can be constructed reasonably well for spectra similar to the fission spectrum. The amount of induced activity in the detecting elements is determined with scintillation counters, which are calibrated by irradiation of suitable foils with thermal neutrons.

Fast-neutron tissue dose can be calculated from the measured spectrum. Since the foil method of measuring spectra works well for high intensity bursts of neutrons, dosimetry may be accomplished under conditions where other methods, such as the ionization chamber and proportional counter, would lead to questionable data.

The trailer containing the counting equipment necessary for determining the sample activation has been maintained in operation for two reasons:

1. It has been maintained as standby equipment for the emergency monitoring program that has been set up in the Applied Health Physics Group.<sup>21</sup> In case of a neutron accident the threshold-detecting elements are recovered and counted on the scintillation counters as quickly as possible. In this way a measure can be determined of the tissue dose that personnel would have received had they been in the area of the accident.

2. The equipment has been used for comparison with similar equipment that was constructed and installed in a trailer by the Army Chemical Corps.

Very close agreement between the two systems was obtained.

A report entitled "Threshold Detectors - Tissue Dose Determination" has been submitted to *Review of Scientific Instruments* and accepted for publication in either the March or April 1956 issue.

#### Fast-Neutron Spectrometer

Neutron spectrometers of the proton-recoil type generally collimate the proton recoils in such a way that only those in one direction are utilized. The present spectrometer is designed to accept protons scattered in a wide angle, thereby greatly increasing the efficiency. The principle of this spectrometer is to shape a chamber to the envelope of the range of the proton recoils from neutrons. At a given gas pressure  $P$ , neutrons of energy  $E_0$  will produce recoil protons which just reach the

<sup>19</sup>AEC Fellow in Radiological Physics.

<sup>20</sup>G. S. Hurst *et al.*, ORNL-1671 (March 30, 1954). (Secret)

<sup>21</sup>F. T. Howard and W. H. Sullivan, ORNL-1955 (Nov. 7, 1955). (Secret)

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envelope regardless of their scattering angle  $\theta$ . The range of the protons can be expressed as

$$R = \frac{k E_{\theta}^n}{P},$$

where  $R$  is the proton range,  $k$  and  $n$  are constants for the gas, and  $E_{\theta}$  is the proton energy scattered at an angle  $\theta$ . Since  $E_{\theta} = E_0 \cos^2 \theta$ , the following relation results:

$$R = \frac{k E_0^n \cos^{2n} \theta}{P}.$$

For the gas xenon the constant  $n$  is very close to the value  $\frac{3}{2}$  for energies above 100 kev; therefore, the envelope equation is

$$R = \frac{k E_0^{3/2}}{P} \cos^3 \theta = D \cos^3 \theta,$$

where  $(k E_0^{3/2})/P$  is the constant  $D$ . If the wall of this egg-shaped chamber is covered with a scintillator to detect the protons and if the output signal is gated to accept only the small pulses caused by protons which just reach the scintillator, then only the protons scattered by neutrons of one energy are counted even if the target is irradiated by neutrons of more than one energy. If then the detector count rate is plotted as a function of the pressure, the neutron energy spectrum can be obtained. More specifically, the wall must be shaped so that all protons, regardless of angle, arrive at the scintillator with energy  $E_1$ , where  $E_1 = E_B + \Delta E$ . The bias energy required to operate above tube noise is  $E_B$ , and  $\Delta E$  is the energy width of the single-channel analyzer. Thus if protons arrive with energy greater than  $E_1$  or less than  $E_B$ , they will not be recorded.

The present design under construction uses a 5-in. 6364 photomultiplier tube and a CsI(Tl) scintillator coupled to a conventional single-channel analyzer.

#### Improved Fast-Neutron Dosimeter

Further improvements in the performance and ease of operation of the "standard" fast-neutron dosimeter, Q-1696, have been made, and the new version,<sup>22</sup> designated as Model II, is shown in Fig. 31.

<sup>22</sup>Designed by R. K. Abele of the Instrumentation and Controls Division, ORNL.

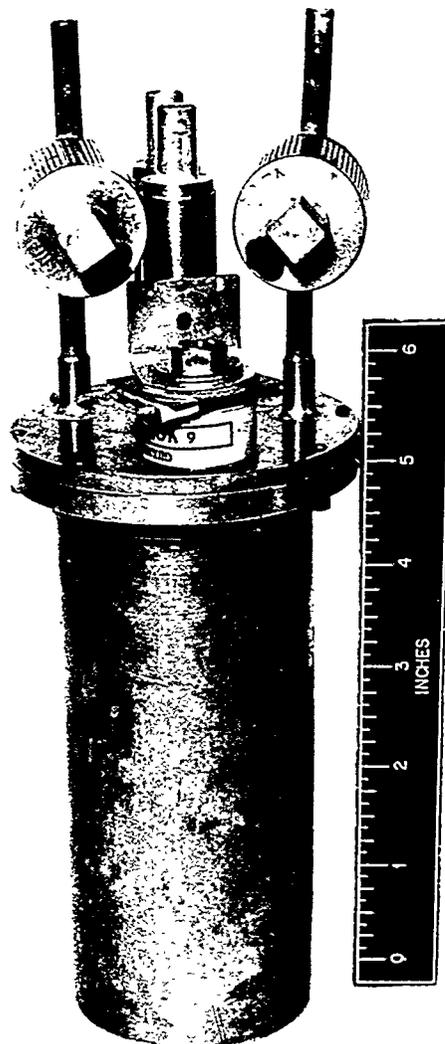


Fig. 31. "Standard" Fast-Neutron Dosimeter, Model II.

For convenience of operation the gas-filling tubes and valves, the electrical connectors, and the solenoid for actuating the alpha-source shutter were all moved to one end of the counter. The brass field tubes were replaced by polyethylene tubes coated lightly with Aquadag, making the chamber a more nearly perfect Bragg-Gray cavity and improving the directional response. The response is uniform to within 5% for neutrons

incident on the end of the chamber at angles from 0 to greater than 100 deg.

Cyclopropane,  $C_3H_6$ , has been studied as a possible counting gas, and preliminary data indicate that it has considerable merit; in particular, the operating potential is significantly lower. Since it has the same hydrogen-carbon ratio as ethylene but one more atom of each per molecule, the same sensitivity is obtained at two-thirds the pressure. The decreased pressure further lowers the operating potential.

The rate and quantity of in-gassing and out-gassing of cyclopropane in polyethylene are greater than for ethylene in polyethylene, indicating that it is important to leave the counter connected to the gas-filling system until equilibrium has been reached at the desired pressure.

After equilibrium had been attained, the resolution and gas amplification of the counters remained stable during a period of three weeks. The counters are still under study.

The pulse-height distributions for ethylene and

for cyclopropane using plutonium alpha particles are shown as functions of electrode potential and of the gain of the electronic system in Fig. 32.

**Neutron-Insensitive Gamma Dosimeter**

In radiation fields composed of gamma rays and fast neutrons, it is desirable to make measurements of each component such that the presence of one does not, at the point considered, contribute to the measurement of the other. One of the most pressing problems in radiation dosimetry is the accurate measurement of the gamma radiation in the presence of high fluxes of fast neutrons.

An examination has been made of the potentialities and limitations of the  $C-CO_2$  ionization chamber,<sup>23</sup> which is used extensively in shielding measurements. The predominant mechanisms by which ionization is indirectly produced in this type of chamber by fast neutrons are elastic neutron-

<sup>23</sup>L. H. Ballweg and J. L. Meem, *A Standard Gamma Ray Ionization Chamber for Shielding Measurements*, ORNL-1028 (July 9, 1951).

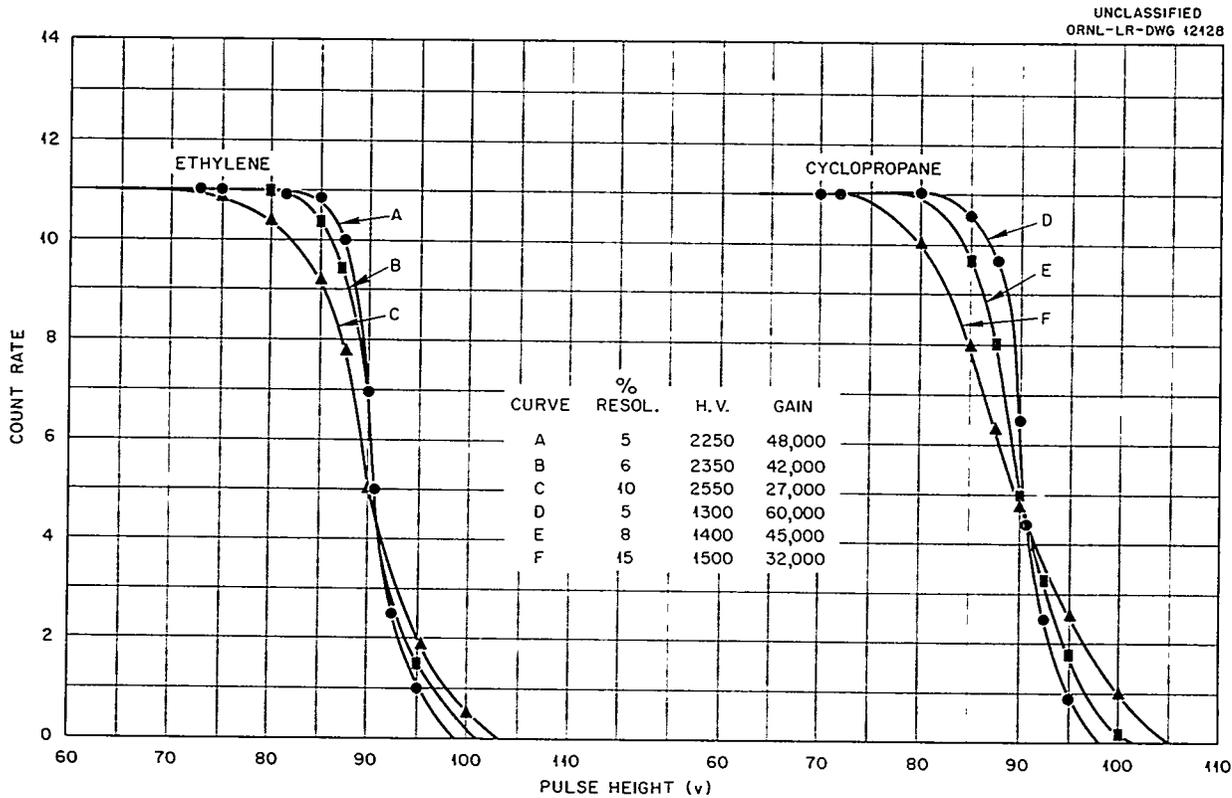


Fig. 32. Resolution as a Function of Electronic Gain and Electrode Voltage.

carbon atom and neutron-oxygen atom collisions resulting in heavy ion recoils and inelastic neutron scattering by the chamber walls and surrounding media.

The ionization current was plotted as a function of collector voltage from 0 to 1500 v for the 900-cc chamber. (The chamber is normally operated at about 200 v.) The curves are shown for  $\text{Co}^{60}$  gamma radiation and Po-Be fast neutrons (Fig. 33). For gamma radiation, saturation commenced at relatively low voltages, but, when fast neutrons were incident on the chamber, the collection current never reached saturation.

An attempt was made to ascertain whether non-saturation of the neutron curve could be attributed

to columnar recombination. The application of the Jaffe theory of columnar recombination<sup>24</sup> as outlined by Zanstra<sup>25</sup> was followed.

The difference between curve A minus curve B (Fig. 33) was found to satisfy the Jaffe theory and therefore is attributed to columnar ionization by heavy ions.

From curves A and B it is noted that the Po-Be source gives a dose rate, from the gamma rays produced by and associated with the source, equivalent to 25% of the dose rate caused by the fast

<sup>24</sup>G. Jaffe, *Ann. Physik* 42, 303 (1913).

<sup>25</sup>H. Zanstra, *Physica* 2, 817 (1935).

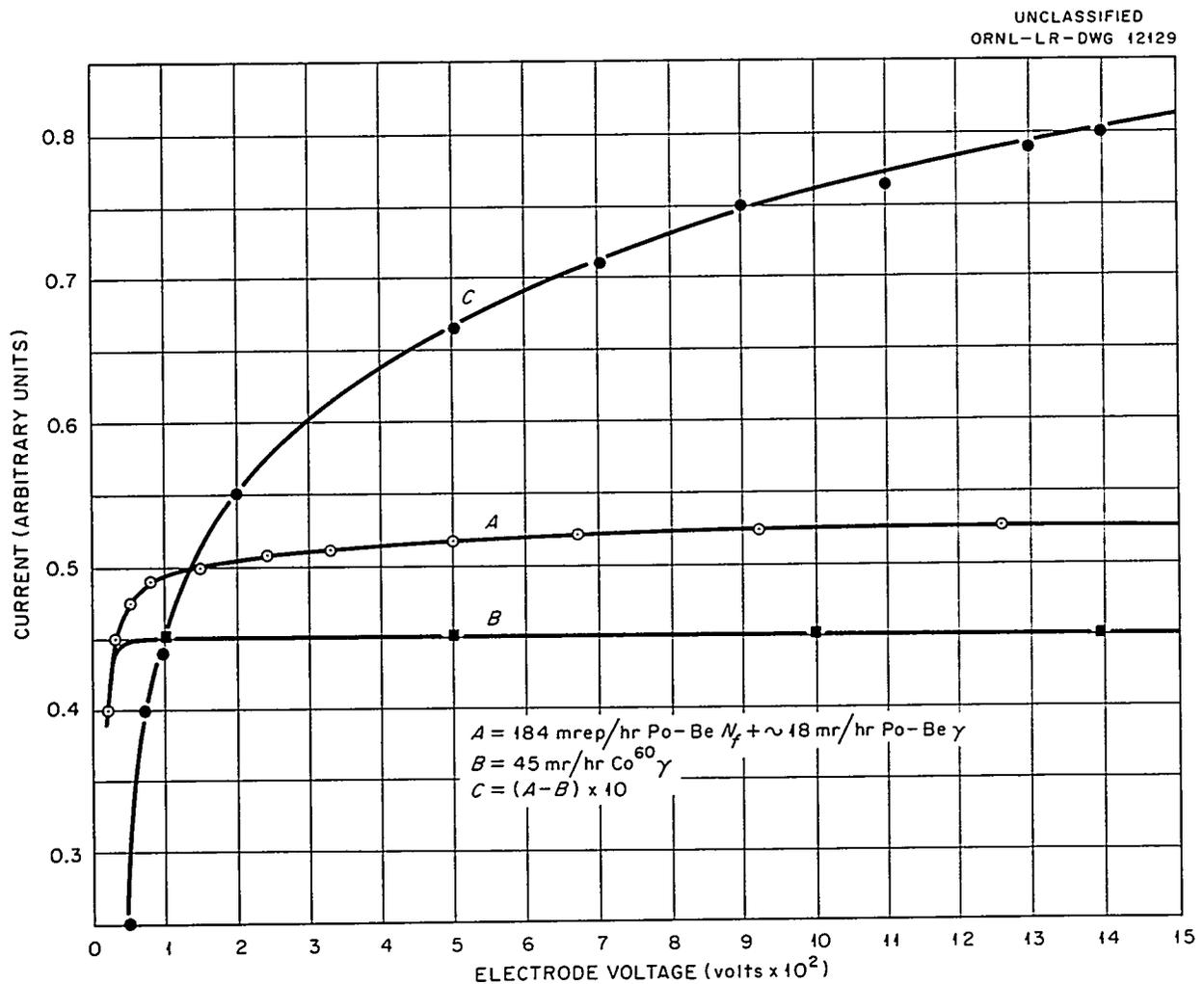


Fig. 33. Chamber Current as a Function of Voltage for Fast Neutrons and Gamma Rays.

neutrons. When a gamma dose of 10% of the neutron dose rate of the Po-Be source was assumed and subtracted from the curve, there was still a response equal to a gamma dose rate of approximately 15% of the neutron dose rate. Some of this was certainly the result of hydrogen capture of thermalized neutrons in the Lucite cover which makes the chamber water- and gas-tight. An aluminum cover  $\frac{3}{16}$  in. thick was substituted for the Lucite, and the gamma response decreased from 15 to about 10%. It seems probable that this part of the neutron response is due to hydrogen capture and to inelastic scattering by the carbon and with surrounding materials.

Therefore, in a mixed field of fast neutrons and gamma radiation, the true gamma dose rate is less than the indicated dose rate by an amount which is a function of true dose rate, relative  $n_f/\gamma$  dose rate ratio, and electrode voltage. Table 22 lists some approximate values for the neutron contribution to the response as compared with the gamma response for dose rates not in excess of a few hundred mrep/hr and at an operating potential of 200 v.

TABLE 22. Po-Be NEUTRON CONTRIBUTION TO IONIZATION

900-cc Chamber, 200-v Electrode Potential

$\gamma/n_f$ Dose	Gamma Dose Added by $n_f$ Response (%)		Total Error in $\gamma$ Dose (%)
	By Columnar Ions	By $n_f$ Inelastic Scatter and $n_t$ Capture	
1/10	30	140	170
1/1	3	14	17
10/1	0.3	1.4	1.7

The dependence of these corrections on energy has yet to be determined. When the chamber is used to measure gamma dose rates in such a medium as water, the inelastic scattering contribution would not be subtracted, assuming the composition of chamber housing and surrounding medium to be about the same.

If the isotropic scatter of fast neutrons in  $\text{CO}_2$  is assumed, the energy absorbed by recoil oxygen

and carbon atoms may be calculated. If curve C (Fig. 33) is extrapolated to infinite voltage in accordance with the Jaffe theory, the total ionization by heavy ions is found. Dividing the calculated value of absorbed energy by the total ionization resulting from heavy ions gives a  $W$  value of about 80 ev per ion pair.

A C- $\text{CO}_2$  chamber with parallel plates and guard ring is currently being used in a more comprehensive study of ion recombination.

#### A New Fast-Neutron Pulse Integrator

The present fast-neutron dosimetry using the binary pulse integrator, while quite satisfactory for laboratory type research, is not well adapted to applications requiring a small, compact instrument, as in applied health physics work and certain radiobiological experiments. One approach to the problem is to scale down the physical size of the present instrument.

The second approach, illustrated in Fig. 34, utilizes a National Union LBS-1 line-beam-switch tube for the pulse amplitude discriminator or pulse sorter. The LBS-1 is similar to a conventional cathode-ray tube in that it contains an electron gun assembly and one pair of deflection plates, but it has ten output anodes which replace the phosphor-coated screen. The number of output anodes swept by the electron beam and the number of resultant output pulses from the paralleled anodes are proportional to the amplitude of the input pulses to the deflection plate. There have been applications of this type of tube to pulse analyzers but not, to the knowledge of this group, to a pulse amplitude integration circuit.<sup>26</sup>

The output pulses from the LBS-1 tube are counted with conventional scaling circuits which are preceded by a fast prescaler utilizing a Haydu DC-1R decade counter tube. The fast prescaler is necessary since the output pulses from LBS-1 are spaced less than 1  $\mu\text{sec}$  apart.

This integrator circuit, at present under development, shows promise of being more compact, simpler to adjust and operate, and more easily adapted for use as a pulse analyzer by switching each of the LBS-1 output anodes to an individual scaler.

<sup>26</sup>W. E. Glenn, *Nucleonics* 9 (6), 24-28 (1951).

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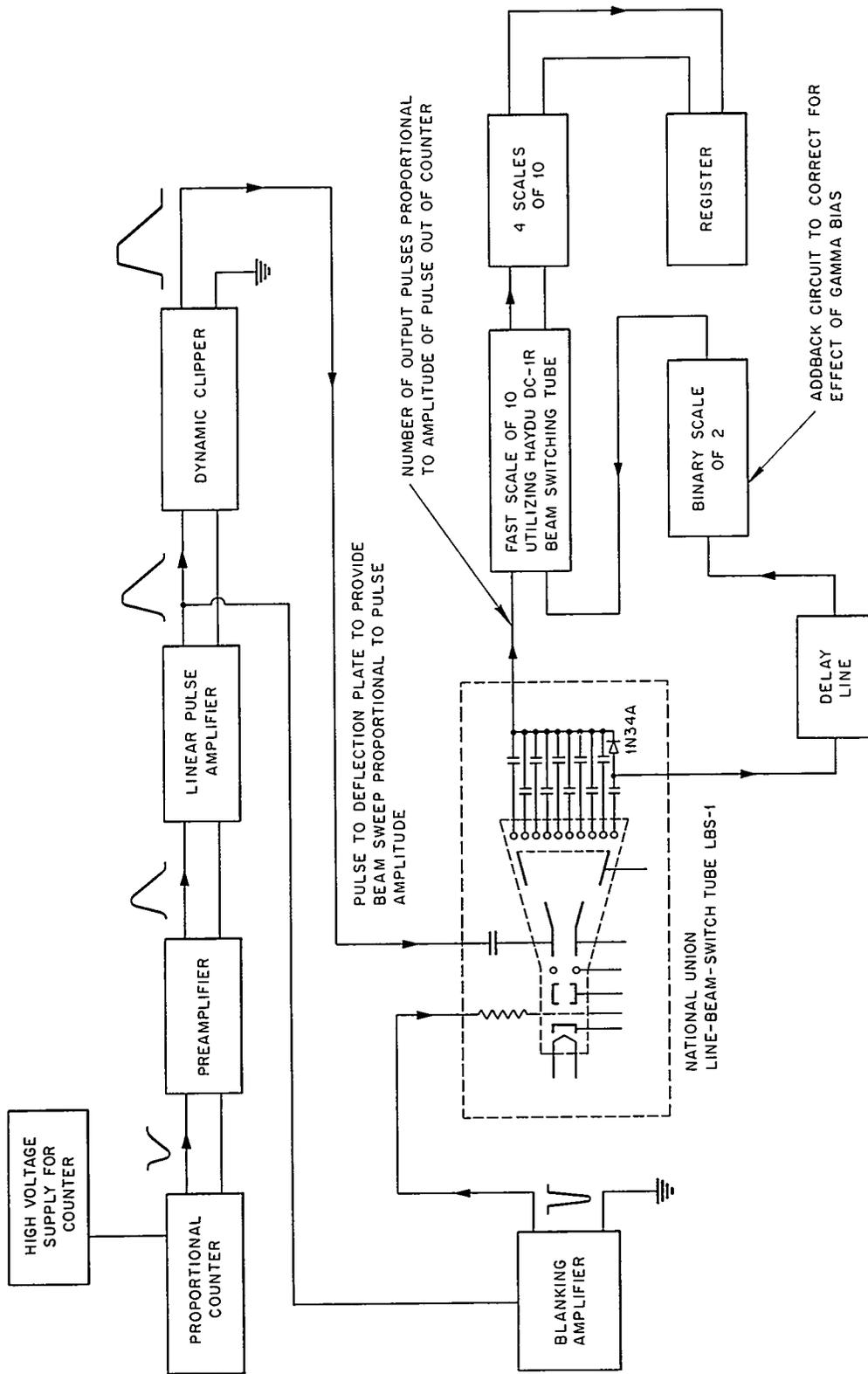


Fig. 34. Block Diagram of New Integrator.

EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson

M. F. Fair

AEC FELLOWSHIP PROGRAM

The AEC Fellows in Radiological Physics for the 1955-1956 program were enrolled at Vanderbilt University in September, and the records for the fall quarter show that 60% of the Fellows have earned an average of B or better.

Of the nine Fellows of the 1954-1955 group who were granted extensions of their Fellowship, five remained at ORNL working on a research problem in the Health Physics Division; the remaining four returned to Vanderbilt.

INTERNATIONAL COURSE IN HEALTH PHYSICS

E. E. Anderson and M. F. Fair conducted a five-week course in Health Physics in Stockholm, Sweden (November 14 through December 16). This course, the first of its kind to be offered in Europe, was conducted at the Institute of Radiophysics of the Karolinska Hospital under the joint sponsorship of the European Division of the World Health Organization, the Swedish Government, and the U.S. Atomic Energy Commission.

Students in the course were from ten European countries - Belgium, Denmark, France, Germany, Iceland, Italy, the Netherlands, Norway, Sweden, and Switzerland. The course was designed for supervisors and instructors in radiation protection.

OTHER ACTIVITIES

Discussions on Health Physics were held with two groups of Maintenance personnel.

One member of the section participated in a Civil Defense Training Course held for the Civil Defense leaders of the State of Virginia at Richmond.

One member of the Nautilus crew, assigned to radiation-protection duties on the submarine, was here for three days of discussion with the Education and Training Section on special personnel monitoring problems.

One member of the section is conducting a course (2 hours per week for 4½ months) in Apprentice Mathematics for the Training Division.

The section organized a five-week laboratory course for six special students of the Reactor Technology School.

A series of seminars was held for the Veterinarians' Course and the Basic Isotopes Course of the Special Training Division of the Oak Ridge Institute of Nuclear Studies.

One laboratory experiment on Health Physics instrumentation was conducted for the Oak Ridge School of Reactor Technology.

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## PAPERS

H. H. Abee, *Disposal of Radioactive Contaminated Waste Material and Equipment*, Sanitary Engineering Conference, December 7, 1955, Cincinnati, Ohio.

S. I. Auerbach and M. Engelmann, *Effects of Gamma Radiation on the Biology and Ecology of Arthropods. A. Preliminary Studies on Certain Tree-Hole Arthropod Populations*, Third Annual Meeting of the Entomological Society of America, November 28, 1955, Cincinnati, Ohio.

T. E. Bortner, *Ionization of Pure Gases and Mixtures of Gases by 5 Mev Alpha Particles*, Radiological Society of North America, December 11-16, 1955, Chicago, Illinois.

F. J. Davis, *Aerial Radiation Surveys for Uranium Prospecting*, Society of Exploration Geophysicists, October 6, 1955, Denver, Colorado.

H. F. Howden, *Effects of Gamma Radiation on the Biology of Onthophagus texanus Schaeffer*, Third Annual Meeting of the Entomological Society of America, November 28, 1955, Cincinnati, Ohio.

K. Z. Morgan, W. S. Snyder, and M. R. Ford, *Maximum Permissible Concentration of Radioisotopes in Air and Water for Short Period Exposure*, International Conference on the Peaceful Uses of Atomic Energy, August 8-20, 1955, Geneva, Switzerland.

K. Z. Morgan, *Maximum Permissible Concentration of Radionuclides in Air and Water*, Nuclear Engineering and Science Congress, December 16, 1955, Cleveland, Ohio.

K. Z. Morgan, *Organization of Professional Health Physicists*, Health Physics Conference, Ohio State University, June 13-15, 1955, Columbus, Ohio.

R. J. Morton and E. G. Struxness, *Ground Disposal of Radioactive Wastes*, American Public Health Association, November 16, 1955, Kansas City, Missouri.

## LECTURES

S. I. Auerbach, *Radiation of Arthropods as Part of the ORNL Ecology Program*, Zoology Department Seminar, University of Tennessee, November 8, 1955, Knoxville, Tennessee.

R. D. Birkhoff, *Energy Measurements of 0.1 Mev Particles by Stopping Potential Techniques*, Traveling Lecture Program, Vanderbilt University, November 10, 1955, Nashville, Tennessee.

M. I. Goldman, *Environmental Radiocontamination and Waste Disposal*, Armed Forces Veterinary Officers Course, Oak Ridge Institute of Nuclear Studies, September 19, October 3, 17, 31 and November 14 and 28, 1955.

K. Z. Morgan, *Control of Radiation by the Health Physicist*, Bethesda Medical School, October 4, 1955, Bethesda, Maryland.

K. Z. Morgan, *Maximum Permissible Levels of Exposure and Ionization*, University of North Carolina, Chapel Hill, North Carolina, December 8, 1955.

R. J. Morton, *Experience at ORNL with Pit Disposal of Liquid Radioactive Wastes*, Conference on Disposal of Radioactive Waste Products, September 10, 1955, Princeton University, Graduate College, Princeton, New Jersey.

R. J. Morton and C. P. Straub, *Removal of Radionuclides from Water by Water Treatment Processes*, Nuclear Engineering and Science Congress, December 16, 1955, Cleveland, Ohio.

C. P. Straub, *Emergency Maximum Permissible Concentration Values for Water*, Nuclear Engineering and Science Congress, December 16, 1955, Cleveland, Ohio.

C. P. Straub, *Problems of Radioactive Waste Disposal*, Joint Meeting Florida Section American Water Works Association and Federation of Sewage and Industrial Waste Association, November 9, 1955, Orlando, Florida.

C. P. Straub (Discussion Leader), *Environmental Problems of the Atomic Energy Industry -- High Level Wastes*, Seminar on the Sanitary Engineering Aspects of the Atomic Energy Industry, December 6-9, 1955, Cincinnati, Ohio.

E. G. Struxness, *The ORNL Concept of Pit Disposal for Reactor Process Wastes*, Conference on Disposal of Radioactive Waste Products, Princeton University, Graduate College, September 11, 1955, Princeton, New Jersey.

H. P. Yockey, *An Application of Information Theory to the Physics of Tissue Damage*, Seminar on Information Theory conducted by Henry Quastler at Argonne National Laboratory, January 17, 1956, Lemont, Illinois.