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QUARTERLY PROGRESS REPORT
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ORNL 786
Progress Report

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HEALTH PHYSICS DIVISION

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

QUARTERLY PROGRESS REPORT
for Period Ending July 15, 1950

DATE ISSUED

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164-168. University of California Radiation Laboratory
169-170. University of Rochester
171. University of Washington
172-173. Western Reserve University
174-177. Westinghouse Electric Company

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 Engeries 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 Labtoratory Weekly Progress Report.

INSTRUMENT DEVELOPMENT

Portable Fast Neutron Dosimeter. The special design of a recoil proton proportional counter, applicable to a fast neutron dosimeter[1] 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 Terrestial 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 Terrestial 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,[2] 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 5×10^{-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 coagulent, 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 Maintanence 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.[1] 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.^{2} 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,[1] 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 $h^{1.4}$. 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 μ from the slope of the curve. At heights in the neighborhood of 500 feet above the 2 gram Ra source the mass absorption coefficient μ/ρ_1 where ρ_1 is the density of the air was 0.071 cm^2/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^2/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^2/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 μ_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:

$$R = \frac{\rho_2 \, KSe^{-\mu h}}{\mu_2}$$

where S is the source concentration to be measured in gms of Ra/gm, ρ_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 2×10^{-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.[1]

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 accidential 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.