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HEALTH PHYSICS DIVISION

QUARTERLY PROGRESS REPORT

FOR PERIOD ENDING JANUARY 20, 1953

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HEALTH PHYSICS DIVISION QUARTERLY PROGRESS REPORT

for

Period Ending January 20, 1953

K. Z. Morgan, Director

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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.[1]

[1] 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.

[1] 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

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.

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[1] (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[2] 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 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.[3] 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,

(1) University of Tennessee research and development contract.

(2) 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.

(3) 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,[4] which has been well verified experimentally,[5] and by using the Bureau of Standards values of mass attenuation coefficients,[6] 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,[6] 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.

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.[7]

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

[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).

[7] J. S. Cheka, *H-P Quar. Prog. Rep. Oct. 20, 1952*, ORNL-1420, p. 7.

maximum permissible dose of neutrons from a polonium-boron and a polonium-beryllium source. These doses were 5.33×10^6 and 4.46×10^6 neutrons/cm^2, 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.

AIRBORNE RADIOPARTICULATE CONTAMINATION

E. G. Struxness
W. D. Cottrell
R. L. Bradshaw
J. W. Thomas
B. G. Saunders
E. E. Grassel

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 ±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 sylphon 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 μ in diameter and having a uniformity of ±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
F. L. Cobler
H. L. Krieger
W. J. Lacy
D. A. Pecsok
O. R. Placak
M. S. Seal
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
M. J. Cook
J. M. Garner
B. Kahn
F. Kalil
R. J. Morton
R. L. Nichols
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

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 increases as the activity of the mud decreases. The statistics are not sufficiently good to give a value for this ratio.

Accumulation of Cs^{137} and Sr^{89} 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		
Zorball	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_4^{---}			99+				99+	25-75	0-25	99+	99+	
100 ppm PO_4^{---}						75-90	99+	95-99	0-25	99+		99+
Coagulation												
$FeSO_4$, 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		
$FeCl_3$, 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[1] 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^{137}, Sr^{89}, and a combination of Cs^{137} + Sr^{89}); 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^{89}	50,606	11,105 (6,167 to 16,492)*	10,637 (6,203 to 14,638)	35,104 (25,902 to 50,727)
Cs^{137}	87,767	8,066 (5,471 to 12,899)	12,571 (8,221 to 20,839)	29,436 (16,833 to 44,328)
Cs^{137} + Sr^{89}	121,580	22,599 (14,543 to 44,838)	25,541 (14,316 to 47,267)	71,830 (25,520 to 225,305)
Sr^{89}	20,206	6,089 (3,574 to 9,708)	7,149 (3,132 to 10,747)	16,189 (12,131 to 28,653)
Cs^{137}	24,922	3,779 (1,619 to 6,300)	3,068 (2,003 to 4,367)	7,527 (3,801 to 12,520)
Cs^{137} + Sr^{89}	40,173	4,884 (2,066 to 11,388)	5,496 (1,834 to 10,884)	9,076 (5,240 to 16,056)
Sr^{89}	3,918	1,174 (574 to 1,733)	1,158 (664 to 1,834)	2,873 (1,151 to 4,383)
Cs^{137}	5,164	936 (455 to 1,220)	1,073 (759 to 1,680)	2,930 (1,646 to 4,200)
Cs^{137} + Sr^{89}	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.

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^{89}	63,402	17,280 (13,030 to 28,766)*	26,421 (18,271 to 37,390)	56,888 (37,498 to 85,676)
Cs^{137}	88,564	25,073 (11,097 to 57,514)	57,947 (15,825 to 255,221)	146,549 (91,759 to 240,513)
$Cs^{137} + Sr^{89}$	127,882	63,385 (20,079 to 126,293)	91,778 (52,789 to 159,674)	451,642 (207,185 to 808,752)
Sr^{89}	20,201	5,548 (2,344 to 9,748)	11,979 (6,997 to 19,534)	26,149 (8,767 to 63,436)
Cs^{137}	25,561	7,396 (5,114 to 14,158)	22,386 (9,452 to 65,784)	40,635 (14,420 to 77,900)
$Cs^{137} + Sr^{89}$	37,420	15,304 (5,740 to 31,956)	38,256 (11,565 to 80,600)	175,662 (50,470 to 680,304)
Sr^{89}	3,936	1,131 (221 to 2,580)	3,314 (1,923 to 7,045)	6,399 (2,372 to 12,689)
Cs^{137}	4,953	3,362 (952 to 6,937)	4,080 (1,295 to 10,594)	6,389 (2,511 to 11,264)
$Cs^{137} + Sr^{89}$	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^{89}	52,826	25,964 (20,215 to 39,071)*	46,207 (4,601 to 73,709)	128,992 (66,564 to 247,431)
Cs^{137}	49,123	111,585 (8,361 to 224,257)	183,452 (75,870 to 380,332)	365,916 (137,420 to 616,560)
$Cs^{137} + Sr^{89}$	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^{89}	15,328	11,002 (4,151 to 22,662)	22,321 (7,669 to 60,129)	51,625 (23,651 to 115,253)
Cs^{137}	21,173	5,839 (2,119 to 16,002)	12,264 (4,585 to 37,716)	80,106 (13,736 to 167,478)
$Cs^{137} + Sr^{89}$	44,668	15,389 (6,755 to 33,505)	71,803 (19,795 to 365,756)	107,799 (44,867 to 213,782)
Sr^{89}	3,015	1,786 (530 to 4,236)	3,570 (1,622 to 6,856)	13,586 (4,903 to 26,667)
Cs^{137}	4,909	7,363 (1,267 to 24,336)	16,298 (2,162 to 53,788)	16,854 (4,584 to 36,168)
$Cs^{137} + Sr^{89}$	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.

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 between 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

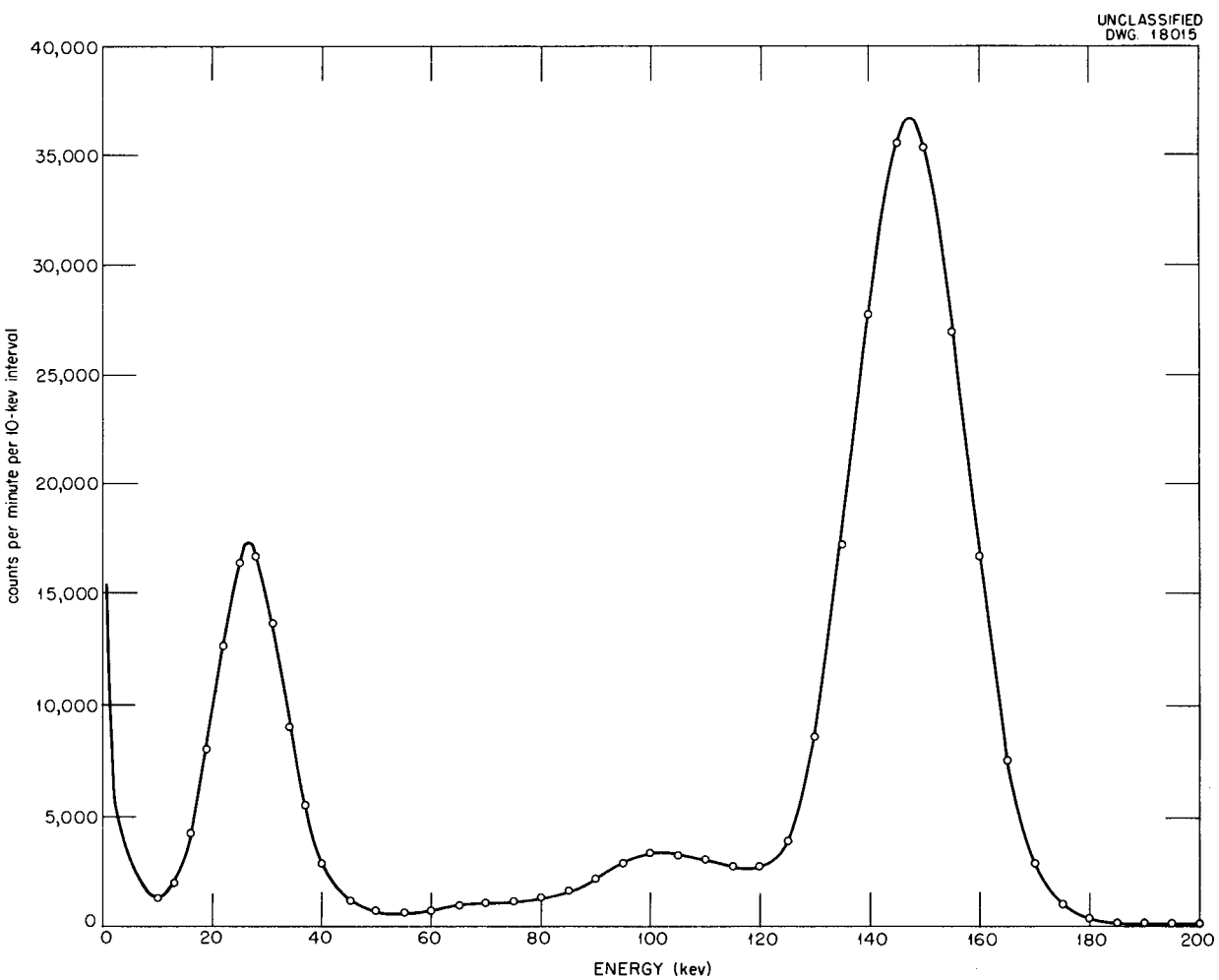

Fig. 1. Gamma-Ray Spectrum of Ce^{141}.

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,[2] 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 similar procedures at a later time to determine the activity discharged to White Oak Creek from the ORNL liquid waste stream.

[2] W. S. Lyon and B. Kahn, *Anal. Chem. Quar. Prog. Rep. Jan. 10, 1953*, ORNL-1474 (to be published).

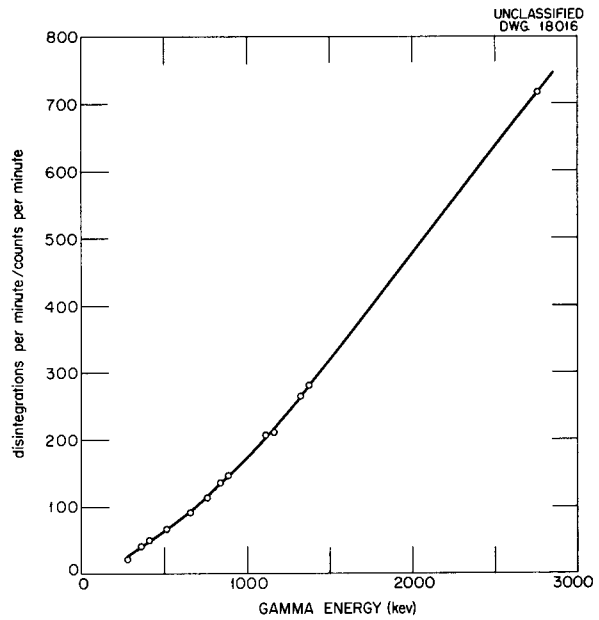

Fig. 2. Variation of Response of Thallium-activated Sodium Iodide Spectrometer with Gamma Energy.

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.

EDUCATION, TRAINING, AND CONSULTATION

E. E. Anderson
M. F. Fair T. H. J. Burnett
M. R. Ford 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 Conference 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.