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PHYSICS DIVISION
QUARTERLY PROGRESS REPORT
FOR PERIOD ENDING SEPTEMBER 20, 1951

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PHYSICS DIVISION
QUARTERLY PROGRESS REPORT
for Period Ending September 20, 1951

A. H. Snell, Director
E. O. Wollan, Associate Director

EDITED BY

C. G. Shull

DATE ISSUED

FEB 15 1952

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Unclassified work for the period between November, 1948 and September 20, 1951 is reported in the following reports: ORNL-325 supplement, ORNL-366, ORNL-481, ORNL-577, ORNL-694, ORNL-782, ORNL-865, ORNL-940, ORNL-1005, ORNL-1092, and ORNL-1164.

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PHYSICS DIVISION QUARTERLY PROGRESS REPORT

SUMMARY

Classified work in the Physics Division during the period June 20 to September 20, 1951 is included in this report. The unclassified research activities of the division are reported in a companion report, ORNL-1164.

Pile oscillator studies on the neutron-capture cross sections of U^{234}, U^{236}, and U^{238} are reported. Shielding measurements as made with the Lid-Tank and Thermal-Column facilities of the X-10 graphite pile and with the new Bulk-Shielding Reactor are summarized here. Brief reports of the critical-mass experiments on aircraft reactor assemblies are given with reference to more complete descriptions.

NEUTRON-CAPTURE CROSS SECTIONS

H. Pomerance and T. Arnette

Pile-oscillator measurements of the thermal-neutron-capture cross sections have been made possible with the recent availability of some rare uranium isotopes prepared at Y-12. The values are found by comparison with gold which has a value of 95 barns at a neutron velocity of 2200 m/sec (0.0252 ev). Should there be a capture resonance at less than 1 ev, the comparison is not valid. The correction for the U^{235} contribution was established empirically because the absorption of neutrons is countered by the production of neutrons in fission. Two barns of fission cross section give the same signal as one barn of capture. The samples were all oxides, U_3O_8, except one which was UO_2. The estimated errors assume no fault in the mass assays and chemical analyses. Values of thermal-neutron-capture cross sections at 2200 m/sec are given in Table 1.

A more complete account of capture measurements of these three uranium isotopes will appear in the April issue of *Reactor Science and Technology*.

TABLE 1

Thermal-Neutron-Capture Cross Sections at 2200 m/sec

ISOTOPE	SAMPLE WEIGHT	ENRICHMENT (%)	CORRECTION FOR U^{235} (barns)	ISOTOPIC VALUE (barns)
U^{234}	95.6 mg	95.99	11.5	88* ± 7%
U^{236}	255.9 mg	96.65	{11.7 1.3**	8.7 ± 20%
U^{238}	5.1 g	99.99+		2.86 ± 5%
	5.6 g	99.97	0.13	2.78 ± 5%
	5.2 g	99.99+		2.78 ± 5%
	Average			2.81 ± 3%

*Does not include 0.65 barns for fission.

**Correction for the 75 ppm of boron in the sample.

SHIELDING MEASUREMENTS

E. P. Blizard

Lid-Tank Facility (C. E. Clifford, J. D. Flynn, T. V. Blosser, M. C. Marney, R. M. Burnett, and T. M. Hubbard). In the KAPL design of a nuclear-powered submarine, which is based on a sodium-cooled reactor, the crew is shielded from the reactor and radioactive sodium coolant by a bulkhead of lead and water with a total thickness of 3 ft. The sodium is distributed throughout a rather large compartment by pipes, heat exchangers, etc., so as to become essentially an infinite source, which is unshielded at the hull periphery. Some of the gamma rays from this large sodium source penetrate the hull (2-in. steel), are scattered in the surrounding sea water, and enter the hull into an adjacent occupied compartment. A calculation of this shielding problem by Allard and Blizard indicated that sufficient attenuation was obtained by this tortuous path to give a tolerable dose in the occupied compartment.

A mockup of this geometry was installed in the Lid-Tank facility. It consisted of flat, rectangular steel and lead plates surrounded by water. The steel (1¾ in. thick) was placed at right angles to the lead (9½ in. thick) and measurements were taken at a fixed point 3 ft from the source side of the lead bulkhead. A point sodium source of approximately 6 curies was moved about in the reactor compartment so that the effect of a sea of sodium was obtained. Self-absorption in the sodium was assumed identical with the absorption of the water in the reactor-compartment mockup.

The results of the experiment indicate that the dose to be expected from a sodium sea of infinite volume is 2.0 r/hr/curie/ml, ±50%, in the geometry measured. This was somewhat higher than expected since the bulkhead was not black, as had been assumed by Allard and Blizard, but rather allowed radiation through its corners. Recent recalculations by Allard agreed closely with the experiment.

Thermal-Column Duct-Testing Facility (C. E. Clifford, M. K. Hullings, and J. L. Hull). During the past quarter the thermal-column duct-testing facility has not produced any reliable new data, because several mechanical difficulties have appeared.

The first of these came about as a direct result of the longer duct mockups which were to be tested. The low flux to be measured was masked by background leaking into the water tank from other nearby experiments. This situation was rectified by extending the tank from 5 by 5 by 6 ft high to 5 by 5 1/2 by 7 2/3 ft high.

Considerable difficulty was encountered with the source box due to water leakage. The box was altered so that it no longer leaked, and it was in addition pressurized with nitrogen so that in the event another leak occurred it would not let water in. The cadmium shutter had electroplated somewhat onto the aluminum-clad uranium slugs, so these were replaced. The facility is now in good working order and the research is again in progress.

Bulk-Shielding Reactor (J. L. Meem, R. G. Cochran, M. P. Haydon, K. M. Henry, L. B. Holland, H. E. Hungerford, E. B. Johnson, J. K. Leslie, F. C. Maienschein, G. M. McCammon, and T. N. Roseberry). Objections have been raised to the designation of the reactor at the Bulk-Shielding Facility as the Shield-Testing Reactor because of the initials (STR). This reactor is now identified as the Bulk-Shielding Reactor (BSR).

The measurements on the mockup of the aircraft unit shield have been completed and a report is being written. The results will be discussed in the next ANP quarterly report. General Electric has completed construction on the divided-shield mockup and the shield has been delivered to ORNL. Installation of this shield in the "swimming pool" is to be started immediately. Preliminary to the measurements on the divided shield, a short experiment on the effect of a shadow shield for gamma rays has been completed.[1]

Gamma-Ray Spectroscopy. The multiple-crystal gamma-ray spectrometer has been used to obtain a preliminary spectrum from the BSR through about 130 cm of water. The spectrum is shown in Fig. 1. Details of the experiment are given by Maienschein.[2] The spectrometer has been calibrated against gamma sources of known strength and the efficiency curve is shown in Fig. 2. A report describing the instrument and the method of calibration is being prepared by Maienschein.

Fast-Neutron Spectroscopy. The report on the nuclear plate camera[3] has been submitted for declassification. Figure 3 gives the results of an exposure of nuclear plates to the U^{235} fission spectrum. This measurement was quite rough but showed the method to be feasible for shielding studies. The slope of the line drawn through the experimental points is the same as that obtained from the same source with the proton-recoil counter.[4] The latter instrument has been used against the BSR, but because of electronic difficulties consistent results have not yet been obtained.

In preparation for the construction of the He^3 counter, a series of experiments have been completed on the field tubes to be used on each end of the center wire. By applying the proper voltages to these field tubes, it was found that an electric field could be obtained that varied less than 6% along the center wire. The final design of the counter to be used for neutron spectral measurements is now well under way at the Instrument Department and construction of the instrument will be started during the next quarter.

Cockcroft-Walton Accelerator. The Cockcroft-Walton machine, formerly at NEPA, has been loaned to the Bulk-Shielding Facility and is now being assembled. This accelerator will be used to furnish neutrons or gamma rays for calibration of the various spectrometers under development.

CRITICAL-MASS EXPERIMENTS

A. D. Callihan

An extended program in which data were obtained as bases for some Hanford and Idaho Chemical Processing Plant procedures has been completed during the period reported here. The experiments consisted essentially of determining the configurations and quantities of right solid cylinders of enriched uranium-aluminum alloy required for a critical array. Operational procedures that are free from nuclear hazards can be prescribed from the results. The cylinders were 8 in. long by 1.35 in. in diameter and each contained about 39 g of U^{235}. Water, plexiglas, and natural uranium were studied as moderating materials, and water, lead, natural uranium, and

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(1) H. E. Hungerford, *Experiment 5 at the Bulk-Shielding Facility - The Shadow Shield*, ORNL CF-51-8-252 (Aug. 20, 1951).

(2) F. C. Maienschein, *Preliminary Gamma-Ray Spectral Measurements at the Bulk-Shielding Facility*, ORNL CF-51-8-253 (Aug. 27, 1951).

(3) J. L. Meem and E. B. Johnson, *A Nuclear Plate Camera for Fast Neutron Spectroscopy at the Bulk-Shielding Facility*, ORNL-1046 (Jan. 11, 1952).

(4) F. J. Muckenthaler and K. M. Henry, *Neutron Energy Spectrometer*, ORNL CF-51-7-75 (July 16, 1951).

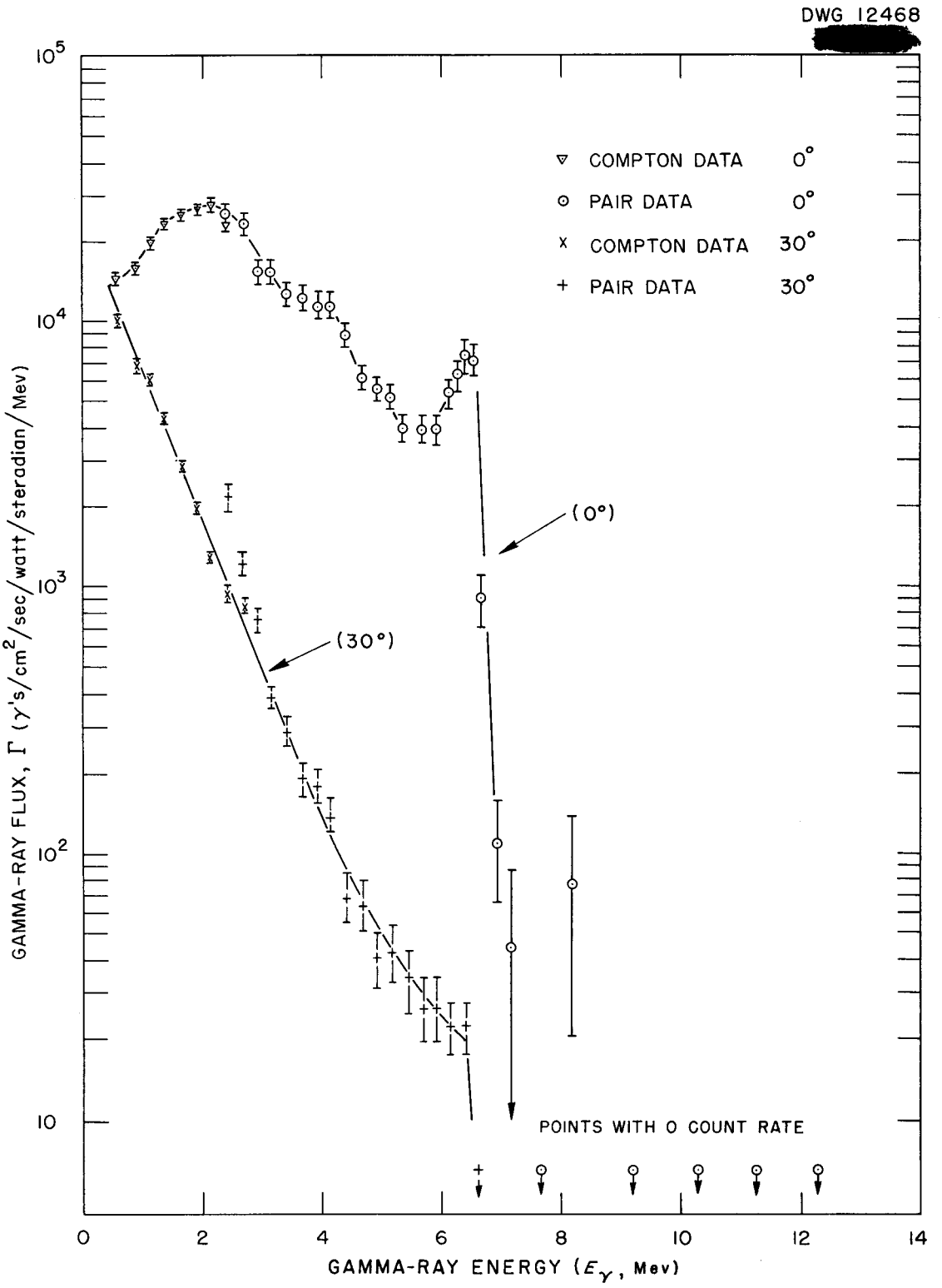

Fig. 1. Gamma-Ray Flux.

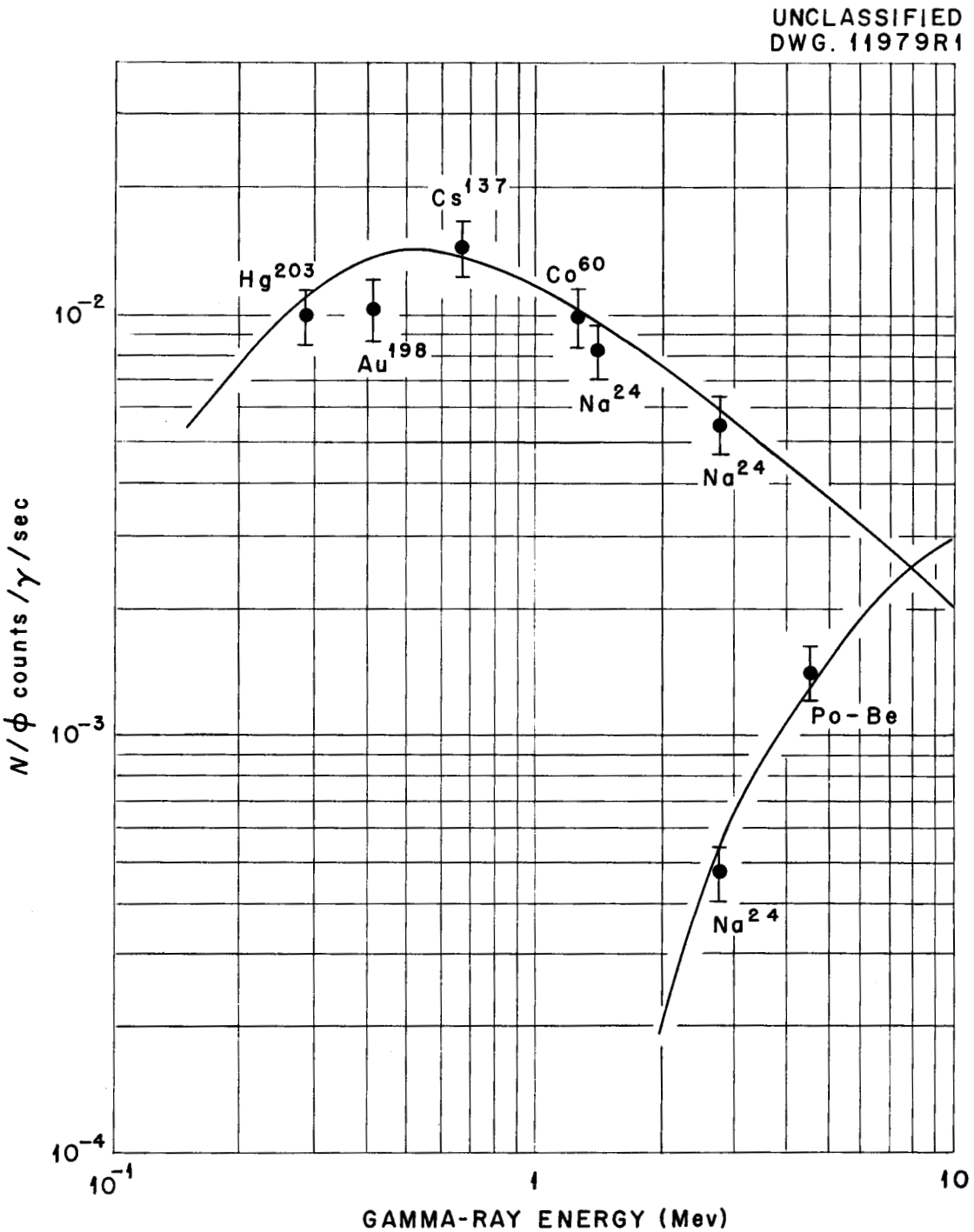

Fig. 2. Sensitivity of Multiple-Crystal Gamma-Ray Spectrometer.

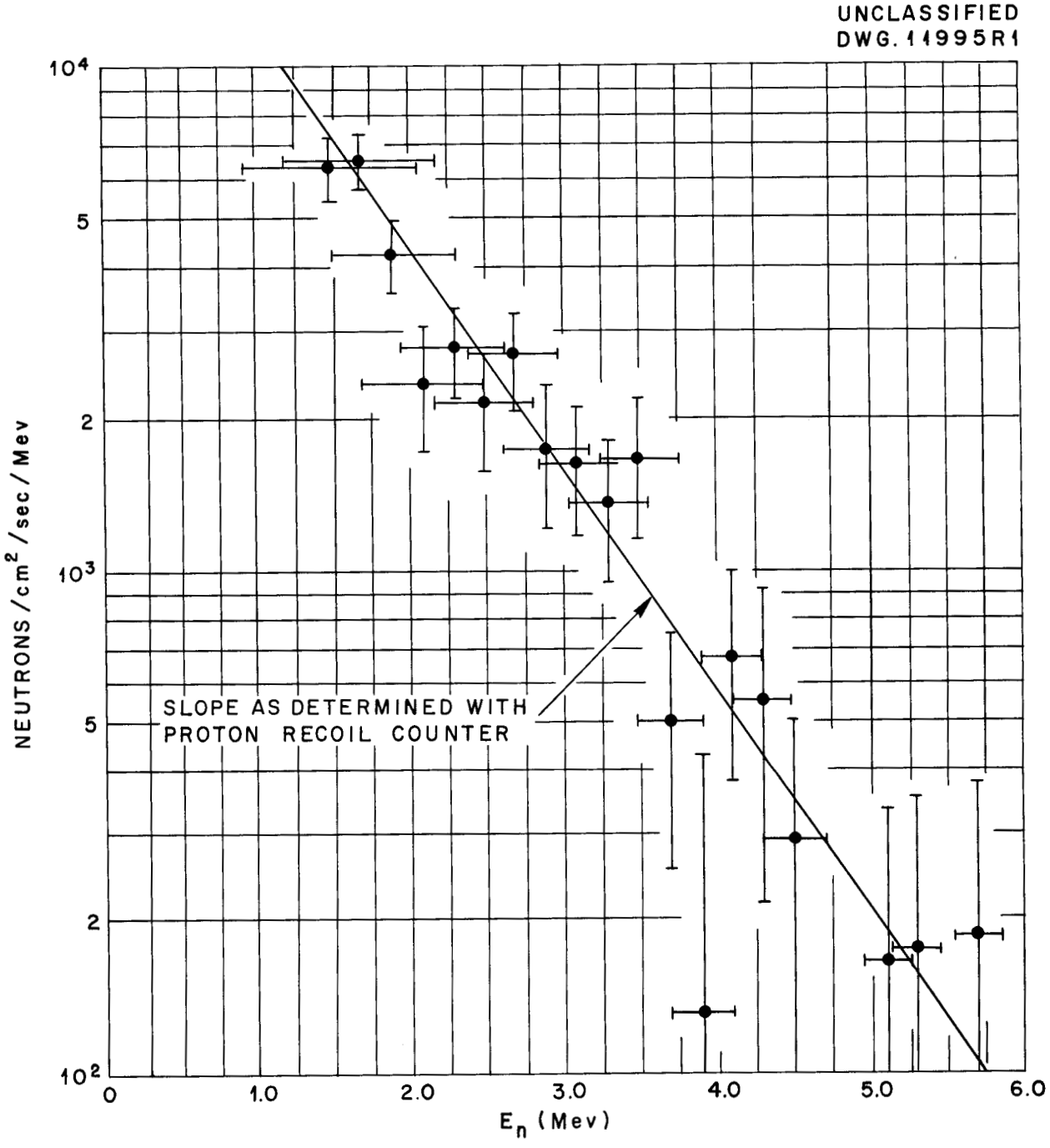

Fig. 3. Fast-Neutron Spectrum from U^{235} Fission.

plexiglas as neutron reflectors. The program has been reported elsewhere.[5]

Preliminary Aircraft Reactor Assemblies.[6] *Air-Water-Cycle Reactor.* The mockup of the proposed aircraft reactor embodying water as a neutron moderator and air as a heat-transfer medium, which was described in a preceding ANP quarterly report,[7] was investigated through the cooperative effort of the General Electric Company and the laboratory group responsible for the study of preliminary reactor assemblies. Metallic uranium of high U^{235} enrichment interspersed among blocks of graphite simulated the uranium-silicon carbide mixture, and a methacrylate plastic was an adequate substitute for water. The plastic was in 1½-in.-thick horizontal layers between 4½-in.-thick layers of graphite containing the uranium. The critical mass of the assembly was about 29 kg. Measurements of the thermal-neutron distribution through a unit cell showed a high concentration in the hydrogenous material. The thermal flux in the plastic was 1.8 times the average in the graphite, and 3.6 times that at the surface of the uranium.

The thickness of the individual uranium pieces was 0.01 in., and they introduced some self-shielding from incident neutrons. In an experiment to evaluate the extent of this effect, a standard piece of uranium was replaced by five pieces, each 0.002 in. thick, with aluminum foil separating adjacent ones. In this well-known technique, recoiling fission fragments collect on the aluminum and their activity is a measure of the fission rate in essentially the surface layer of the uranium adjacent to the aluminum. A comparison of the activities on the successive aluminum surfaces gives, relatively, the fission rates at 0.002-in. intervals throughout a fuel piece. In the reactor under study the average fission rate throughout a 0.01-in. fuel piece was 84% of that occurring at its surface.

The observed large thermal-neutron concentration in the plastic implied that the moderator-fuel inhomogeneity was causing a significant increase in the uranium requirement. Consequently, the plastic thickness was reduced to ¾ in. and placed between the graphite-uranium layers, maintaining the same H:C:U atomic ratio as before. It was necessary, because of the dimensions of available materials, to alternate the ¾-in. plastic layers between 3- and 1½-in.-thick graphite layers, thereby probably not achieving optimum fuel-moderator homogeneity. The critical mass of this modification of the original assembly was 18.5 kg, and as a result a more uniform distribution of thermal neutrons throughout the components was obtained. The data are reported more fully elsewhere.[8]

Graphite Reactor. The inaugural program for the critical-mass laboratory was the study of simple reactors of good geometry for comparison with theoretical predictions. The first was a bare cube having a beryllium moderator (described in two preceding ANP quarterly reports).[7,9] Further studies were postponed in order to carry out the investigation described in the above paragraphs, and at its conclusion a graphite-uranium assembly

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[5] A. D. Callihan, D. F. Cronin, J. K. Fox, J. W. Morfitt, E. R. Rohrer, and D. V. P. Williams, *Critical Mass Studies, Part VI*, Oak Ridge National Laboratory, Y-12 Area, Y-801 (Aug. 8, 1951).

[6] *Aircraft Nuclear Propulsion Project Quarterly Progress Report for Period Ending September 10, 1951*, ORNL-1154 (Dec. 17, 1951).

[7] R. C. Briant, *Aircraft Nuclear Propulsion Project Quarterly Progress Report for Period Ending June 10, 1951*, ANP-65 (Sept. 13, 1951).

[8] J. A. Hunter, *Report on Critical Experiments for a Water Moderator (CA-2)*, General Electric report DC 51-9-11 (1951).

[9] R. C. Briant, *Aircraft Nuclear Propulsion Project Quarterly Progress Report for Period Ending March 10, 1951*, ANP-60 (June 19, 1951).

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was made. The present reactor consists of the 0.01-in.-thick uranium-metal disks separated by 4-in.-thick blocks of graphite, and the C:U atomic ratio is 990. It is a rectangular parallelepiped 45 by 45 by 44 in. Insufficient materials were available to make the system critical without a reflector, so 3 in. of graphite surround four sides of the core. The loading is about 45 kg of uranium. Measurements of power and flux distributions are being made.

RADIATION-HAZARD STUDIES ON THE ARE

W. K. Ergen

In the course of the continued investigation of radiation hazards in the ARE, further calculations were made on the activation of the BeO moderator,[10] the detection of leaks in the fuel elements by means of radioactive tracers,[11] and the activation of nitrogen and helium in the reactor pit.[12] It was planned to assemble all these calculations and some earlier ones into a comprehensive report, but this plan is at present inactive pending a decision as to whether major changes in the ARE will be made. Further details will be found in the ANP quarterly reports.

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[10] W. K. Ergen, *Activation of Impurities in BeO*, ORNL, Y-12 Site, report Y-F20-14 (May 21, 1951).

[11] W. K. Ergen, *Detection of Leaks in the Fuel Elements by Means of Radioactive Tracers*, ORNL, Y-12 Site, report Y-F20-15 (July 10, 1951).

[12] W. K. Ergen, *Activation of Nitrogen and Helium in the ARE Reactor Pit*, ORNL, Y-12 Site, report Y-F20-16 (July 13, 1951).

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