PRNC 82

PUERTO RICO NUCLEAR CENTER

ANNUAL REPORT 1965

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ANNUAL REPORT 1965

PREFACE

The objective of the Puerto Rico Nuclear Center (PRNC) is to maintain a comprehensive program of research and training in nuclear science and engineering and in the applications of nuclear energy in medicine, agriculture, and industry. This Annual Report is a review of the program accomplishments and activities during the year 1965.

TABLE OF CONTENTS

EDUCATIONAL AND TRAINING DIVISIONS

The educational and training divisions (also known as the 07 Program) offer training and research opportunities in the nuclear field for students at the graduate and postgraduate levels. The divisions either carry out individual phases of the training and research or provide guidance and support. This area of Puerto Rico Nuclear Center activities, which represents approximately two-thirds of the over-all program, is sponsored by the United States Atomic Energy Commission (US AEC) Division of Nuclear Education and Training.

NUCLEAR SCIENCE AND TECHNOLOGY DIVISION

Owen H. Wheeler, D. Sc., Head

The Nuclear Science Division actively supports the M.S. degree programs in Chemistry and Physics offered at the Mayaguez campus of the University of Puerto Rico (UPR), both by providing opportunities for thesis research to graduate students and by contributing teaching staff for some of the courses. In addition, facilities are available for research in chemistry and physics at the predoctoral and postdoctoral levels. During the past year, work in solid state physics and hot-atom chemistry continued, with some reduction in effort due to the absence of two senior staff members.

EDUCATIONAL ACTIVITIES

Dr. J. F. Facetti taught a course in advanced inorganic chemistry, and Dr. J. A. Gonzalo a course in nuclear and reactor physics, as services to the Departments of Chemistry and Physics, respectively, of the University of Puerto Rico at Mayaguez. These courses are part of the M.S. programs of these departments. Dr. I. Almodóvar and Miss E. Trabal taught the course in radiochemistry.

In addition to the weekly seminars, Dr. J. F. Facetti organized a series of special seminars on selected topics in radiochemistry during the summer of 1964.

Dr. Facetti also participated in the Atoms in Action Exhibit in El Salvador in February 1965. He gave a series of lectures on neutron activation analysis and on Szilard-Chalmers reactions and directed a research project on the effect of gamma pre-irradiation on neutron activated arsenic compounds, which was carried out by Miss Marta Montes, a student of the Department of Chemistry of the University of San Salvador.

A total of nine graduate students in chemistry and three graduate students in physics carried out research under the direction of members of the division. In addition, six students were enrolled in chemistry courses and two in physics courses taught by division staff members.

THESIS RESEARCH

Edgar A. Paez (M.S., June 1966), conducted research on the study of the distribution in tungsten of recoil ranges of strontium-91 (^{91}Sr) and barium-140 (^{140}Ba) produced during thermal fission of enriched uranium, under the direction of Dr. I. Almodóvar. The recoil ranges of ^{91}Sr and ^{140}Ba (see Figure 1) produced by the neutron fission of uranium-235 (^{235}U) in tungsten were measured by removing successive layers of the metal by an electrochemical process. The values obtained were 9.3 ± 1.3 mg/cm^2 for ^{91}Sr and 7.7 ± 0.15 mg/cm^2 for ^{140}Ba. Mr. Paez came to PRNC on leave of absence from the Instituto de Asuntos Nucleares in Bogotá with a fellowship from the International Atomic Energy Agency in Vienna. He has now returned to Bogotá to set up a nuclear chemistry group at the institute. The samples of enriched uranium used in this work were prepared by Dr. Gaeta of the Junta de Energía Nuclear in Madrid.

R. Montalvo (M.S., June 1965), conducted research on studies in the gamma radiolysis of steroids in solution, under Dr. O. H. Wheeler. The work consisted of a quantitative study of the products formed in the radiolysis with cobalt-60 (^{60}Co) radiation of estrone and related compounds in acetic acid and in aqueous base and aqueous acetic acid (see Table 1). Vapor phase chromatography was used extensively to analyze the complex mixture of products.

E. Rosario (M.S., June 1965), Fatigue Effects in Photomultiplier Tubes, under Rev. Dr. I. Cantarell.

WORK IN PROGRESS

1. Radiation Chemistry of Hydrogen Halides, thesis research of Rupert A. Lee for a Ph.D., University of Alberta, Canada, is being done under the direction of Dr. D. A. Armstrong (PRNC consultant). The radiation yields of hydrogen chloride and hydrogen bromide with gamma rays and fission fragments are being studied. (See Figures 2 and 3.)

2. Hot-Atom Chemistry of Aromatic Phosphorus Compounds, is the title of thesis work by Miss M. Santos, which is being done under the direction of Dr. O. H. Wheeler. The inorganic and organic radiophosphorus compounds formed in the activation of triphenylphosphorus and its compounds is being studied. (See Figure 4.)

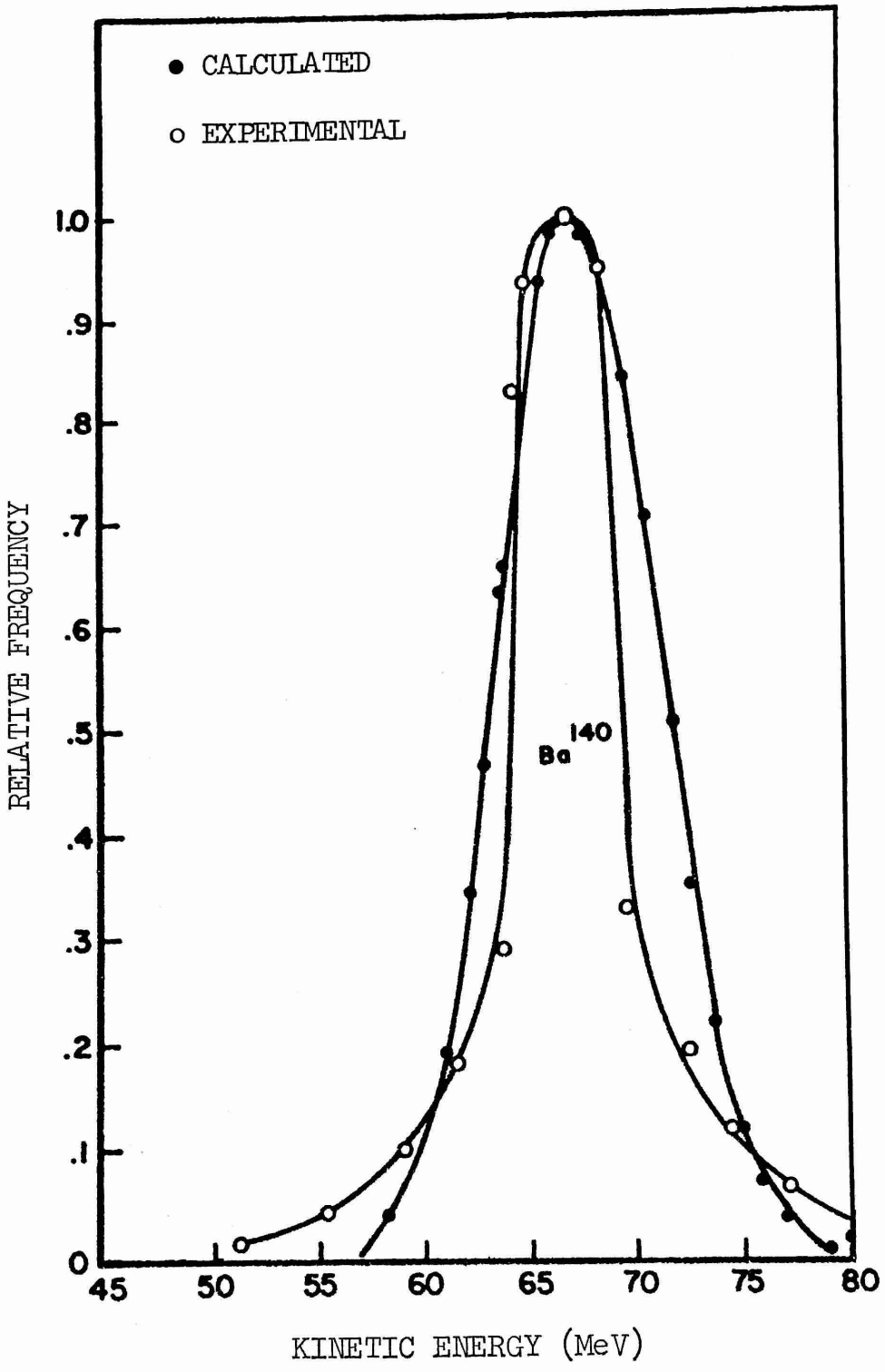


Figure 1. Calculated and experimental recoil ranges for ^{140}Ba produced by the neutron fission of ^{235}U in tungsten.

TABLE 1

Radiolysis Products

Compound	Solvent	Dose[a]	Product[b]	Yield (%)
Estrone	1 N NaOH	3.74	s.m.	50
			2-Hydroxyestrone	13
			Oils	5
Estradiol	1 N NaOH	3.38	s.m.	54
			2-Hydroxyestradiol	9
			Oils	3
			Salts	8
Estrone	80% AcOH	3.53	s.m.	52
			2-Hydroxyestrone diacetate	3
			4-Hydroxyestrone diacetate	2
			Oils	6
Estrone acetate	80% AcOH	4.34	s.m.	53
			2-Hydroxyestrone diacetate	4
			4-Hydroxyestrone diacetate	1
			Oils	8
Estrone	90% AcOH	3.39	s.m.	57
			2-Hydroxyestrone	2
			Oils	4

[a]Total absorbed dose in megarads. [b]s.m. denotes starting material.

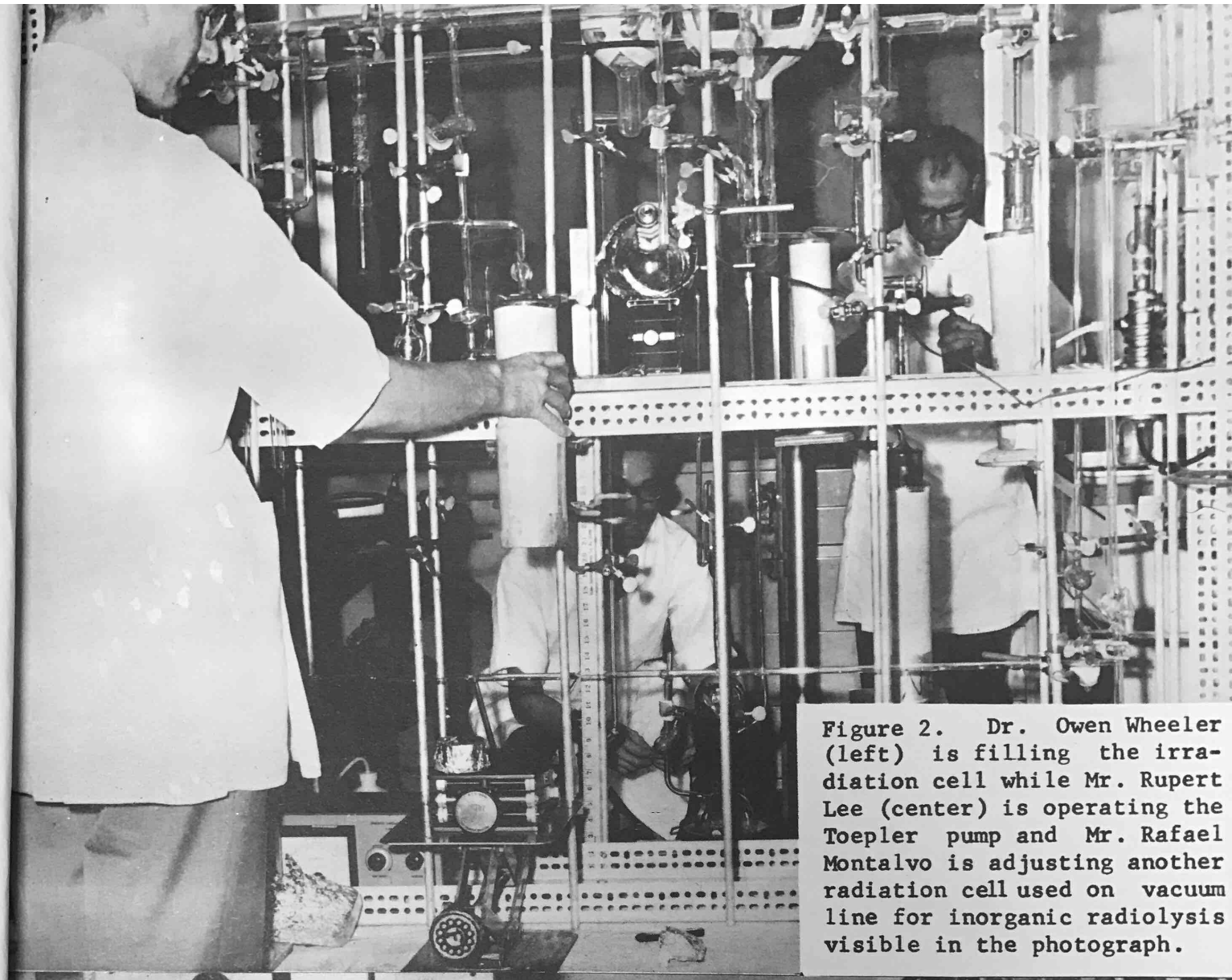
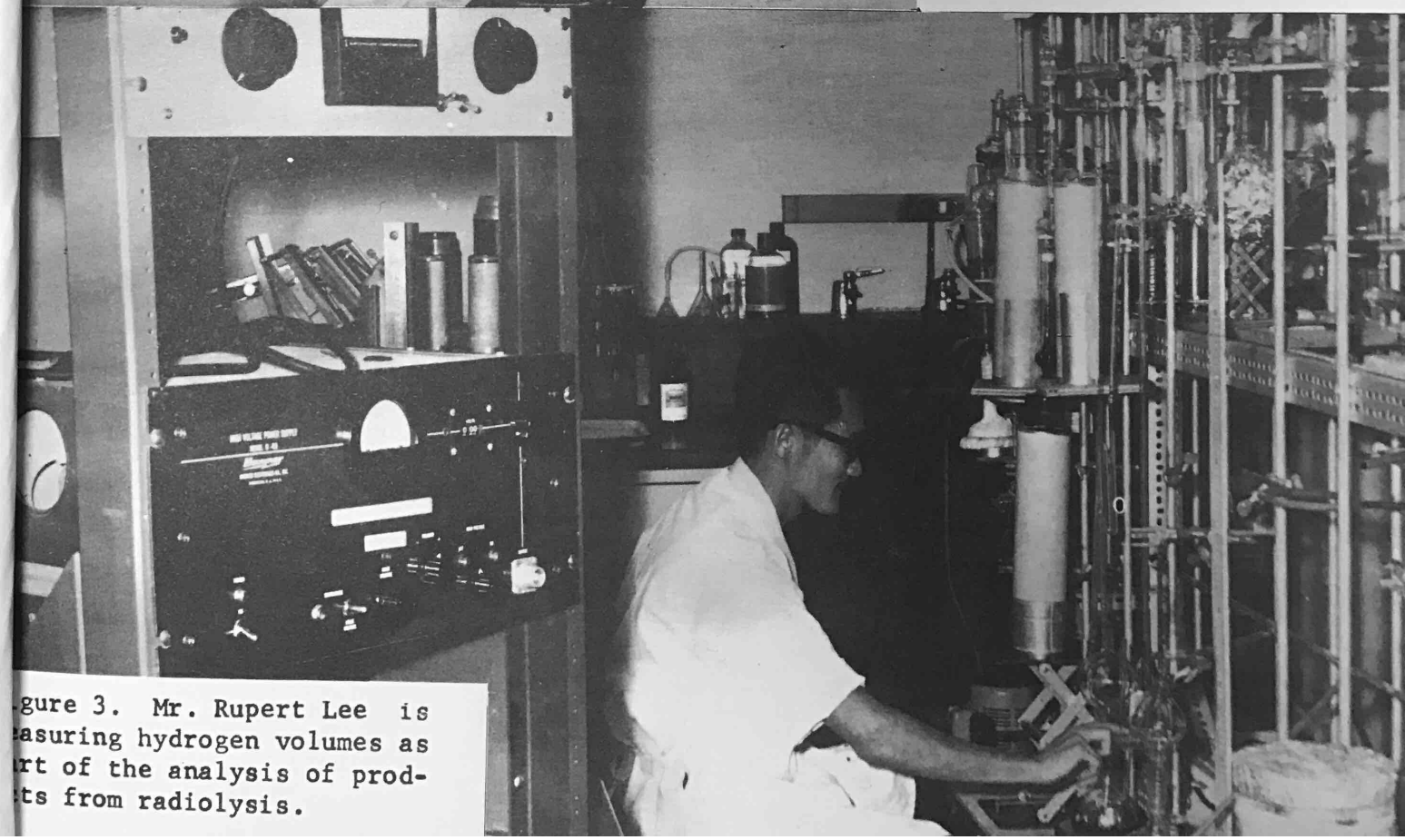


Figure 2. Dr. Owen Wheeler (left) is filling the irradiation cell while Mr. Rupert Lee (center) is operating the Toepler pump and Mr. Rafael Montalvo is adjusting another radiation cell used on vacuum line for inorganic radiolysis visible in the photograph.



gure 3. Mr. Rupert Lee is
asuring hydrogen volumes as
rt of the analysis of prod-
ts from radiolysis.

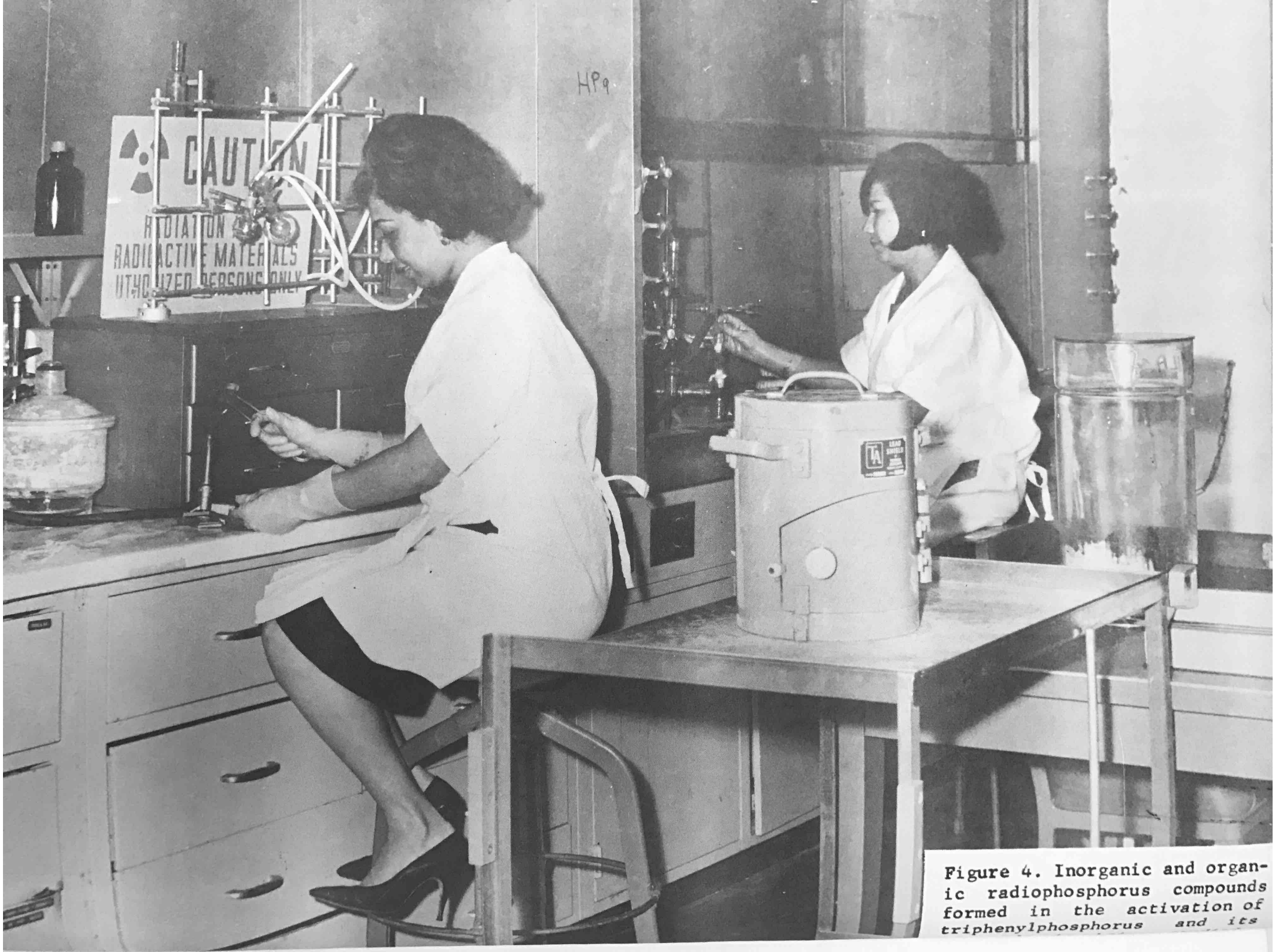


Figure 4. Inorganic and organic radiophosphorus compounds formed in the activation of triphenylphosphorus and its

3. Hot-Atom Chemistry of Aromatic Sulfur Compounds, thesis work of Miss C. L. Berríos, is being directed by Dr. O. H. Wheeler and Dr. J. F. Facetti. (See Figure 5.)

4. Hot-Atom Chemistry of Rhenium Compounds, thesis research of Mrs. M. Santiago, is being done with Dr. J. F. Facetti. The valency states of radioactive rhenium formed in the neutron activation of rhenium oxide and potassium perrhenate are being investigated. (See Figure 6.)

5. Magnetic Spiral in Manganese Dioxides, is being investigated by Dr. J. A. Gonzalo with Dr. G. Shirane and Dr. D. Cox (Brookhaven National Laboratory). The magnetic structure of manganese dioxide is being studied by neutron diffraction.

6. Ferroelectric Properties and Radiation Damage Effects in Impure Colemanite is the thesis research of J. M. Rivera, being conducted under the direction of Dr. J. A. Gonzalo. The ferroelectric hysteresis curves of colemanite at different temperatures and at varying frequencies are being measured. (See Figure 7.)

7. Dielectric Properties of Lithium Hydrogen Selenite at High Frequencies is the thesis research of N. R. Ortiz, which is directed by Dr. J. A. Gonzalo. A comparison is being made of the dielectric properties of this compound at low and high frequencies up to the microwave region.

8. Physical Organic Chemistry is a book by Dr. O. H. Wheeler. The manuscript of this introductory textbook has been submitted to the Elsevier Publishing Company, Amsterdam.

9. Girard and Related Reagents by Dr. O. H. Wheeler is a book to be published by Holden-Day, San Francisco. The manuscript was nearly completed during the tenure of a Guggenheim Fellowship.

COMPLETED RESEARCH

Projects on which results have been written for publication are briefly described below. Journal references are given in the Appendix.

1. Chemical State of ^{125}Sb Formed by Neutron Irradiation in Tin Compounds by Dr. J. F. Facetti. The chemical state of antimony-125

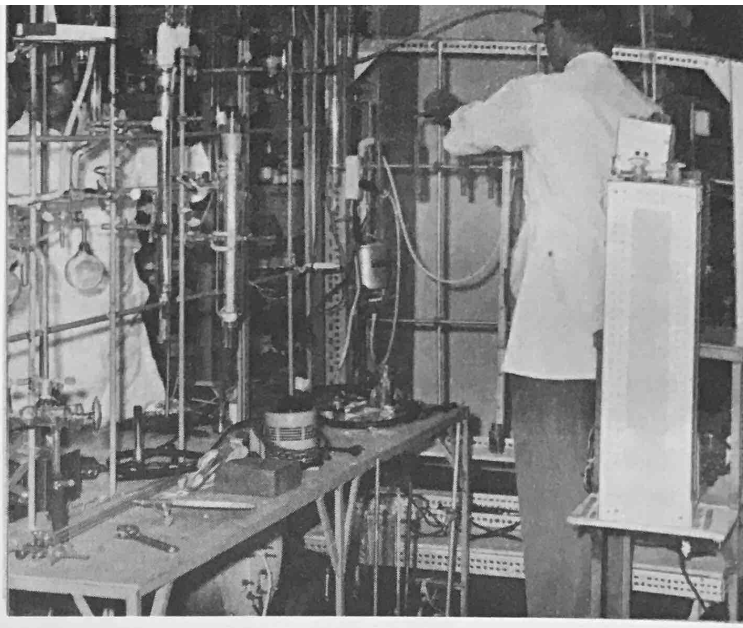


Figure 5. Mr. R. Montalvo (behind vacuum lines for radiation samples) is purifying gas samples while Dr. O. H. Wheeler (center) is operating a gas chromatography unit.

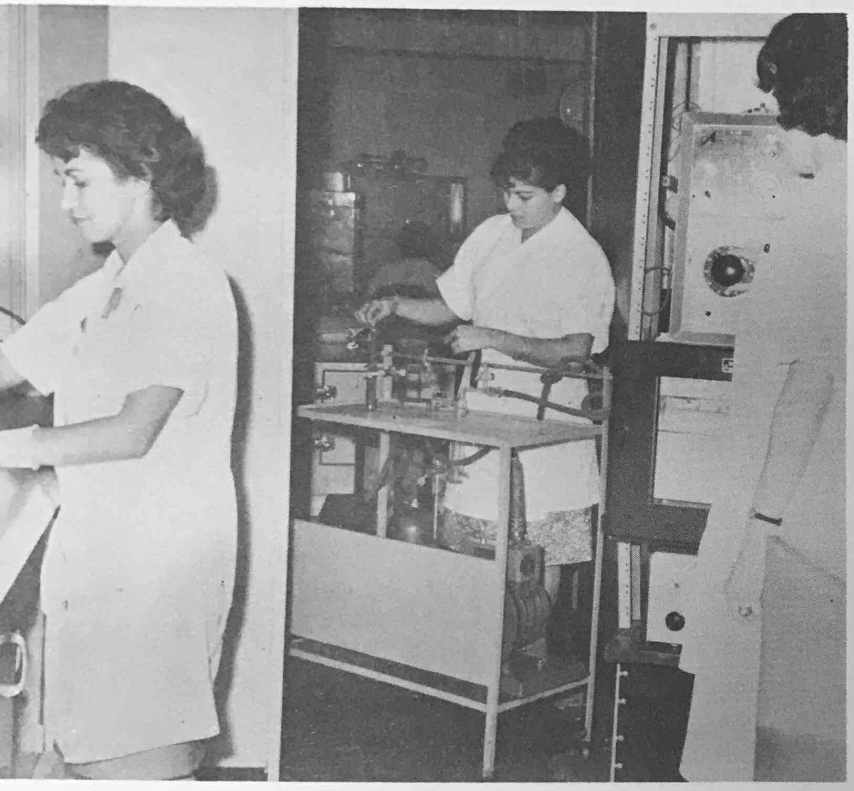


Figure 6. Miss M. L. Cruz (left) is working at a lead-lined hood, Mrs. E. E. Rodríguez (center) is evacuating a sample container prior to irradiation, and Miss J. E. Trabal is adjusting the gas chromatography unit.

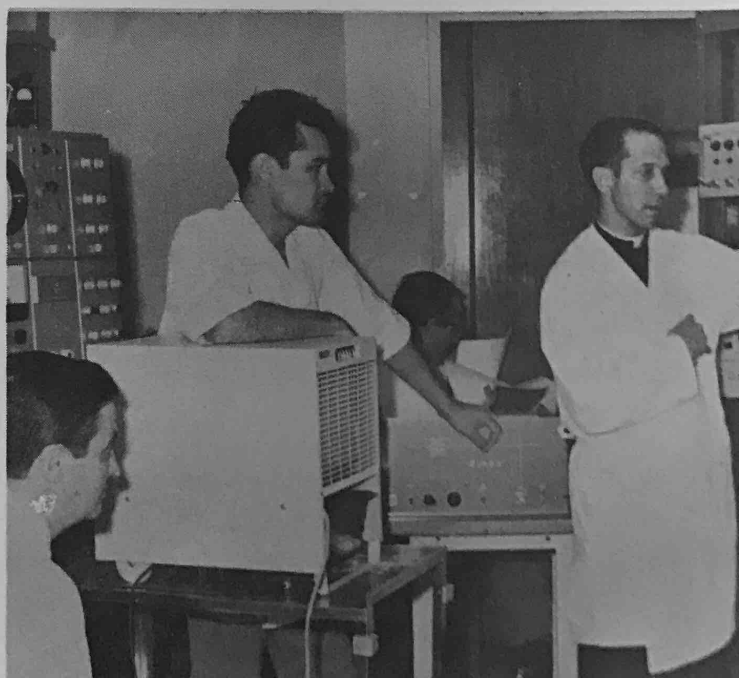


Figure 7. View of the solid state physics laboratory with Rev. Dr. I. Cantarell (right) operating a multichannel analyzer.

formed in the beta decay of neutron activated tin compounds was measured, and the distribution between the 3 and 5 valence states was found to depend on their oxygen content.

2. Radiation Induced Bromination of 2,3-Dimethylbutane by Dr. O. H. Wheeler and Mrs. H. Batlle de Fabón. The gamma induced bromination of 2,3-dimethylbutane affords only 2,3-dibromo-2,3-dimethylbutane, with a G value of 2760.

3. Gas Chromatography of Estrone and Related Compounds by Mr. R. Montalvo and Dr. O. H. Wheeler. The retention times of a series of estrone derivatives and substituted estrones were measured on polar (QF-1) and nonpolar (SE-30) columns.

4. Irradiation of Estrone and Derivatives in Acetic Acid by Dr. O. H. Wheeler and Mr. R. Montalvo. The products formed in the radiolysis of estrone, estradiol, estrone acetate, and estrone methyl ether in glacial acetic acid were determined.

5. Oxidation of Anilines With Manganese Dioxide by Dr. O. H. Wheeler. The use of carbon-14-labeled aniline showed that substituted anilines are oxidized randomly to substituted azobenzenes. Part of this work was carried out at Imperial College, London, during the tenure of a Guggenheim Fellowship.

6. Effects of Gamma Irradiation on Triglycine Sulfate by Dr. J. A. Gonzalo and Dr. R. A. Arndt (BNL). The heat capacity for the change from the ferroelectric to the antiferroelectric state was markedly reduced by irradiation, and the Curie temperature was lowered. The internal bias and the coercive field of the hysteresis loop increased linearly with radiation dose. This work was carried out while Dr. Gonzalo was on leave at Brookhaven National Laboratory.

STAFF

Dr. Owen H. Wheeler, Head of this Division, holds a part-time appointment at the University as Professor of Chemistry, and during the past year he was on sabbatical leave from August 1, 1964, to July 31, 1965, on a John S. Guggenheim Inter-American Fellowship. From August through October, Dr. Wheeler spent full time at the Puerto Rico Nuclear Center. Then, on leave from PRNC, he spent November and December working at the Radiochemistry Laboratory of the Department of Organic Chemistry, Imperial College, London. He spent February through June 1965 at Brookhaven National Laboratory,

working on the hot-atom reactions of carbon-11 with oxygenated organic compounds, with Dr. A. P. Wolf of the Brookhaven Chemistry Department. Dr. Wheeler was awarded a D.Sc. degree by the University of London in March 1965. He already held a Ph.D. from the same institution.

Rev. I. Cantarell went on leave in August 1964 to work in the low energy electron diffraction project in the Department of Physics, Brooklyn Polytechnic Institute, on the effect of the degree of cleanness of surfaces on the emission properties of the surfaces. In may 1965 he went to Spain to present his Ph.D. thesis, "Color Centers in Magnesium Oxide and Alkali Halides," to the University of Santiago de Compostela. and the degree was awarded the same month.

Mrs. Hilda Batlle de Pabón, who obtained her M.S. degree in May 1964, resigned her position as Research Assistant at the Nuclear Center to take up an appointment as Instructor in the Chemistry Department, University of Puerto Rico at Mayaguez.

Dr. J. F. Facetti, Associate Scientist, returned to Paraguay in March 1965 to accept the Chair in Radiochemistry at the University of Asunción.

Mr. R. A. Lee, M.Sc. (University of London), took an appointment as Research Associate in September 1965, to initiate work on the radiolysis of inorganic compounds.

During the past year, several members of the Nuclear Science and Technology Division presented papers at scientific meetings; these are listed in the Appendix.

NUCLEAR ENGINEERING DIVISION

Donald S. Sasscer, Ph. D., Head

The primary function of the Nuclear Engineering Division is to teach courses for graduate students studying nuclear engineering at the University of Puerto Rico at Mayaguez and to direct their research, and the thesis research of students from other universities in the United States and Latin America. In addition, this division offers occasional short courses for scientists, engineers, and technicians, and the members of the staff engage in individual research projects.

The University of Puerto Rico (UPR) at Mayaguez offers the Master of Science degree in Nuclear Engineering. The requirements are 30 hours of graduate work, including the satisfactory completion of a thesis. Applicants for admission to this program must have a bachelor's degree in engineering or physics. The PRNC Nuclear Engineering Division maintains a close relationship with the degree program in nuclear engineering at UPR. The closeness of this relationship is illustrated by the fact that the faculty of the UPR Department of Nuclear Engineering is composed exclusively of staff members of the PRNC Nuclear Engineering Division, and the director of the UPR department is also the head of the PRNC division. In addition, the PRNC Nuclear Engineering Division provides the classrooms, offices, laboratories, equipment, and administrative personnel necessary for the education and training of the UPR nuclear engineering students.

The basic pedagogical method used by the Nuclear Engineering Division is the presentation of lectures, strongly reinforced by laboratory work with various types of radiation counting equipment the subcritical reactor, the L-77 low power reactor, and the PRNC 1-MW Reactor. Each student is also required to use both an analog and a digital computer and to present a seminar on his research to the PRNC staff. The students are encouraged to choose research topics related to their specific interests and those of their sponsoring countries or organizations.

A description of the courses included in the nuclear engineering curriculum follows.

CORE COURSES

1. Nuclear Reactor Technology I (Nu Eg 601), 3 credit hours. Three lectures each week. Corequisite: Math 675. Terminology of nuclear reactors and their component parts; and production, transfer, and utilization of heat in nuclear reactors.

2. Nuclear Reactor Technology II (Nu Eg 602), 4 credit hours. Three lectures and one three-hour lab demonstration period each week. Prerequisite: Nu Eg 601. Steady-state and transient thermal conduction in fuel elements; thermal convection in heat-exchanger design; reactor engineering design problems.

3. Nuclear Measurements and Instrumentation (Nu Eg 603), 3 credit hours. One lecture and two three-hour lab sessions each week. Characteristics of operation of instruments and thorough familiarization with the use and application of specialized techniques such as coincidence and anticoincidence counting, pulse analysis, neutron spectrometry, and gamma-ray spectrometry.

4. Reactor Laboratory (Nu Eg 626), 2 credit hours. Two three-hour lab sessions each week. Prerequisite: Nu Eg 621. Laboratory problems involving the nuclear reactor. (See Figures 1 to 3.)

Figure 1. A graduate student observing the control console of the L-77 homogenous reactor with a reactor operator.

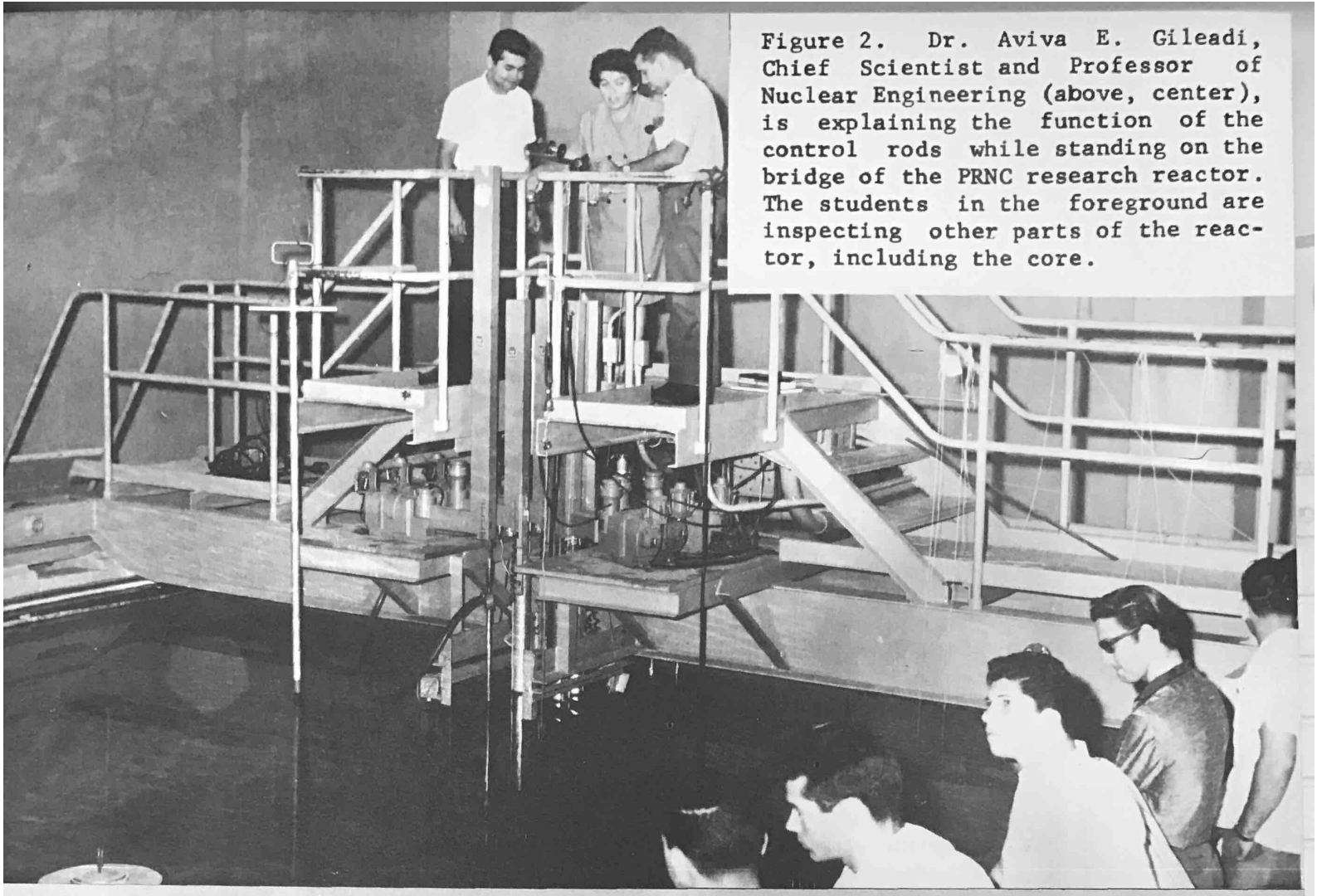


Figure 2. Dr. Aviva E. Gileadi, Chief Scientist and Professor of Nuclear Engineering (above, center), is explaining the function of the control rods while standing on the bridge of the PRNC research reactor. The students in the foreground are inspecting other parts of the reactor, including the core.

Figure 3. Members of the reactor physics class observing startup of the PRNC research reactor. Mr. Juan C. Alemañy, a reactor operator, is seated at the console, while Dr. Gileadi explains the changes being recorded.

5. Nuclear and Reactor Physics (Phys 616), 4 credit hours. Four lecture discussions each week. Theory of alpha, beta, and gamma emission, nuclear resonance theory, nuclear force theory, nuclear fission, the diffusion equation, and neutron slowing down.

6. Reactor Theory (Nu Eg 621), 3 credit hours. Three lectures each week. Prerequisite: Phys 616. Homogeneous and heterogeneous reactors, various slowing-down theories, determination of critical size for different geometries, calculation of lattice constants, elementary transport theory, perturbation theory, physics of the time-dependent reactor, and other related topics.

7. Mathematics of Modern Science I (Math 675), 3 credit hours. Three lectures each week. Determinants and matrices, finite differences, Fourier series and integrals, and Laplace transformation.

8. Mathematics of Modern Science II (Math 676), 3 credit hours. Three lectures each week. Prerequisite: Math 675. Partial differential equations, Bessel functions and Legendre polynomials, and complex variables. (See Figure 4.)

Figure 4. Graduate students participating in advanced mathematics course offered by the Nuclear Engineering Division.

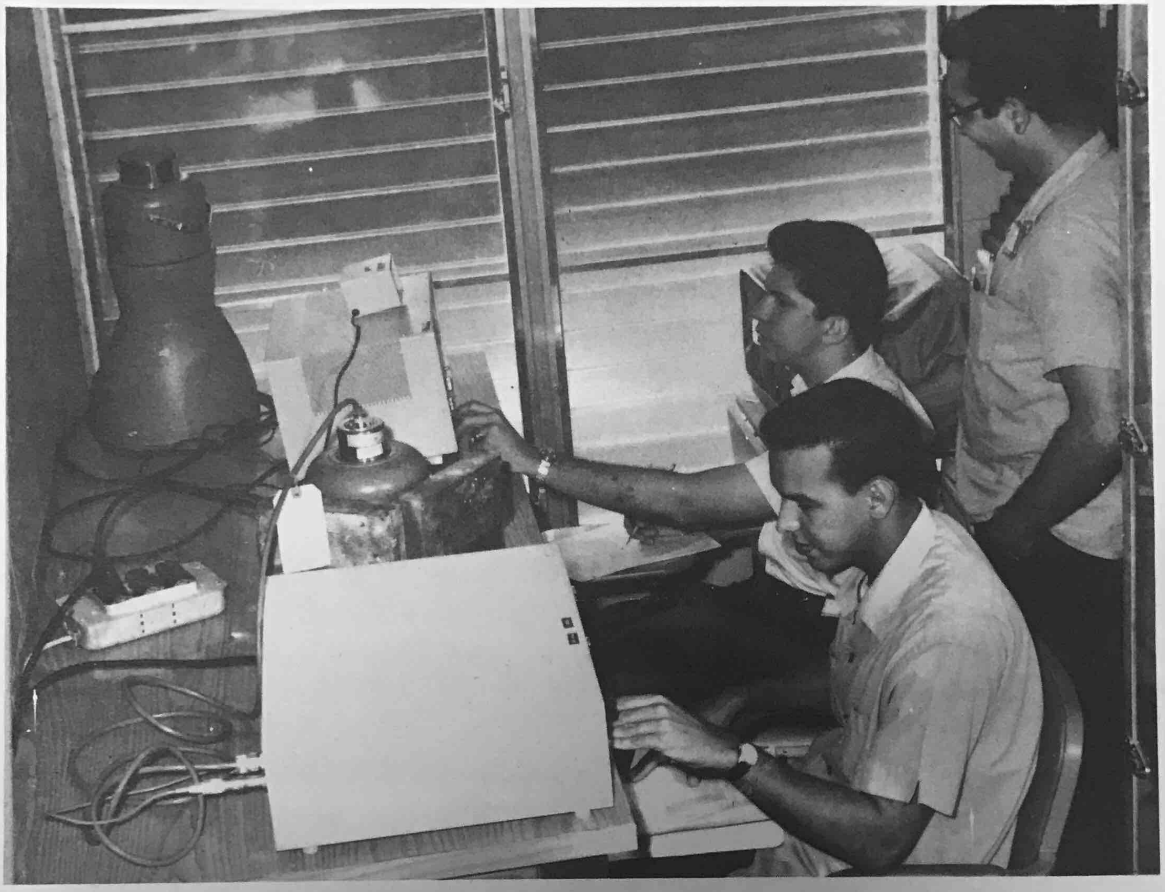


Figure 5. Graduate students working in the nuclear measurement laboratory.

9. Seminar (Nu Eg 616), 1 credit hour. Two hours per week. Reports and discussion on special topics in science and engineering.

SUPPLEMENTARY COURSES

1. Reactor Instrumentation (Nu Eg 611), 3 credit hours. Two lectures and one three-hour lab session each week. Corequisite: Nu Eg 601. A course intended to acquaint students with the problems of reactor plant operation and control. A study of the combined reactor instrumentation system under normal and emergency conditions; measurement of neutron flux; gamma intensity and transient response in relation to reactor stability and safety. (See Figures 5 and 6.)

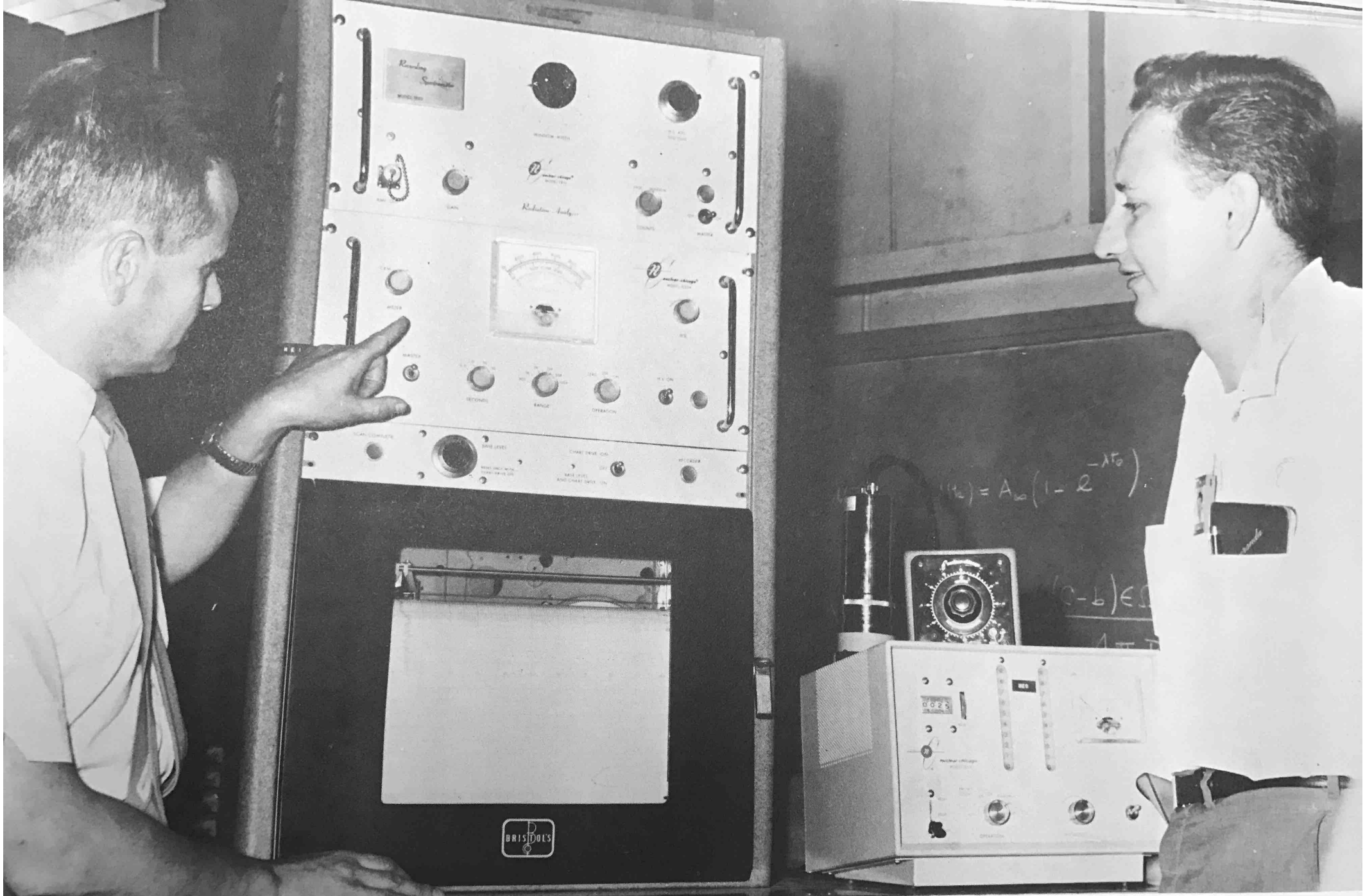


Figure 6. Dr. Willy Smith Pérez, Chief Scientist and Professor of Nuclear Engineering, discusses a single-channel analyzer with Mr. Richard R. Hufty, an electronics

2. Nuclear Reactor Metallurgy (Nu Eg 612), 3 credit hours. Two lectures and one three-hour lab session each week. Corequisite: Nu Eg 601. An introduction to elementary physical metallurgy of the principal reactor materials such as aluminum, zirconium, uranium, and high temperature alloys; mechanical properties; fabrication of nuclear fuels; radiation damage to reactor components.

3. Introduction to Nuclear Engineering (Nu Eg 551), 3 credit hours. This course is offered for advanced undergraduate and non-nuclear engineering graduate students; three lectures each week. Fission and chain reactions, elements of reactor design, utilization of nuclear energy for power, and radiation problems.

During 1965 one Ecuadorian, one Dominican, one Mexican, and 21 Puerto Rican students participated in the program (Table 1.) The Puerto Rico Water Resources Authority sponsored ten of the Puerto Rican students. The PRWRA students are now completing their theses under the direction of PRNC personnel and continuing their nuclear training at the BONUS Nuclear Power Plant of the Authority.

Student progress may be summarized as follows:

Number of students who have completed all course work for degree	13
Number of students who have completed more than one-half of course work	3
Number of students who have completed less than one-half of course work, including three new students	7
Number of students who have completed all requirements for degree	1
Total number of active students	24

The staff of the Nuclear Engineering Division was augmented in 1965 by two new members, Dr. Aviva E. Gileadi, a Senior Lecturer on leave from the Technion, Israel Institute of Technology, Haifa, Israel, and consultant physicist to the BONUS Nuclear Power Plant, and Dr. Willy Smith Pérez, formerly of the Nuclear Engineering Department of the University of Michigan.

TABLE 1

Trainees

ENROLLED IN AUGUST, 1964

José E. Aguiar, (UPR), Puerto Rico

Mario A. Beauchamp, (UPR), Puerto Rico

Melvin B. Cotto, (PRNC), Puerto Rico

Heriberto Cuebas Campos, (BONUS), Puerto Rico

José A. Dávila Navedo, (BONUS), Puerto Rico

Angel R. Escalona, (BONUS), Puerto Rico

Arnoldo de Hoyos, (IAEA), Mexico

Francisco Jiménez, (BONUS), Puerto Rico

Radamés Lamenza, (BONUS), Puerto Rico

Erick Méndez Veray, (UPR), Puerto Rico

Fausto Muñoz Ribadeneira, (PRNC), Ecuador

William Pérez, (BONUS), Puerto Rico

Fernando E. Plá Barby, (BONUS), Puerto Rico

Carlos E. Reoyo, (UPR), Puerto Rico

Ferdinand Rosa, (UPR), Puerto Rico

Angel Sánchez del Río, (BONUS), Puerto Rico

Jorge A. Vega Barrios, (BONUS), Puerto Rico

Gilberto Vélez Delgado, (BONUS), Puerto Rico

ENROLLED IN AUGUST, 1965

Eduardo Gómez Torres, Puerto Rico

Néstor Rubén Ortiz, (ORINS), Puerto Rico

Eduardo Sagredo Robles, (UPR), Santo Domingo

Ramón E. Tristani, (ORINS), Puerto Rico

Francisco Ruiz Ortiz, (UPR), Puerto Rico

Fernando Pérez Braceti, (PRWRA), Puerto Rico

In July Dr. Gileadi attended the Conference on Physics of Quantum Electronics in San Juan. In September Dr. Donald Sasscer presented a series of lectures on neutron diffusion to the College of Physics of the University of San Carlos in Guatemala City as part of the PRNC participation in the US AEC Atoms in Action Exhibit.

RESEARCH PROJECTS

1. Dr. Aviva E. Gileadi and Angel Sánchez del Río, After-Shutdown Xenon Study. The purpose is to determine methods of minimizing the after-shutdown xenon peak and methods of avoiding instabilities due to xenon oscillations.

2. Dr. Willy Smith Pérez, Nuclear Mass Flow Meter. The objective is to design and construct a device to determine the mass flow rates in pipes by using the nuclear Doppler effect.

3. Dr. Phillip Osborne and Erick Méndez Veray, Steady State Fracture - Irradiation Effects. A steady-state fracture device has been built and is being used to determine the effects of irradiation on the fracture characteristics of Plexiglass.

4. Dr. Aviva E. Gileadi and Prof. Francisco Picó, L-77 Transfer Function. The transfer function of the L-77 reactor is being determined by use of a rotating reactivity oscillator.

5. Dr. Aviva E. Gileadi and Fernando Plá Barby, Burn-Up Determination. The variations of the nuclear characteristics of a BONUS-type reactor due to the change in isotopic composition of the core are being determined.

6. Dr. Donald S. Sasscer, Metal to Metal Diffusion Coefficients. The purpose is to devise an accurate method of determining metal to metal diffusion coefficients by use of radioactive tracers.

7. Dr. Kenneth Soderstrom, Emissivity of Graphite. A study is being made on the effect of nuclear irradiation on the emissivity of graphite.

8. Dr. Carlos Wheeler, Neutron Monochromatization. A device is being built and tested that monochromatizes reactor beam-port neutrons by multiple critical angle scattering. (See Figure 7.)

The following research projects have been completed.

1. Dr. Aviva E. Gileadi and A. Sánchez, Evaluation of the Doppler Effect in the Research Reactor of the Nuclear Center.

2. Rev. Dr. Ignacio Cantarell and Efraín Rosario García, Fatigue in Photomultiplier Tubes - Time-Dependent Field Emission.

3. Dr. Donald S. Sasscer and Arnoldo de Hoyos, Random Numbers From a Radioactive Source.

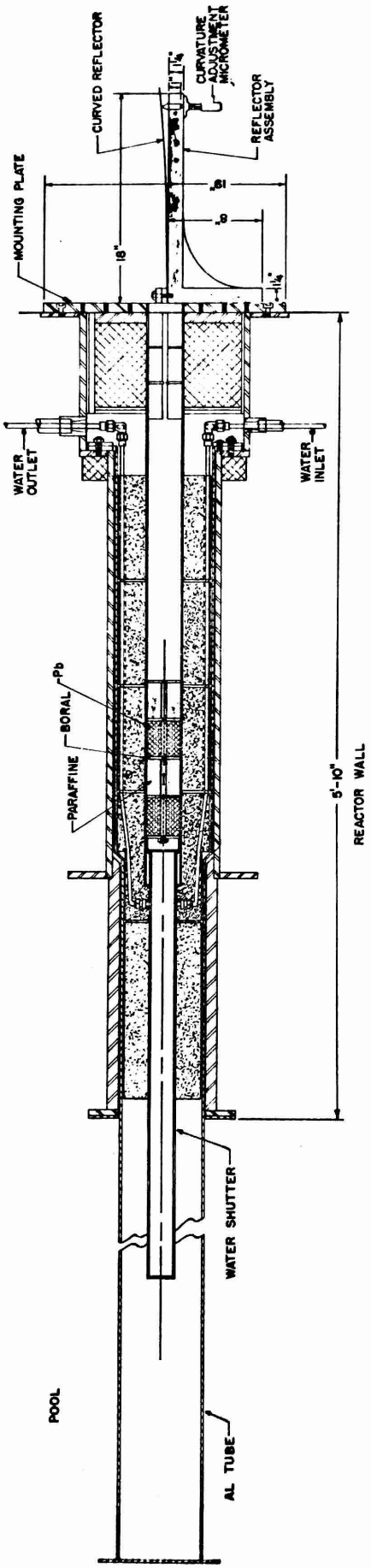


Figure 7. Water shutter and collimator for neutron reflection project.

RADIOISOTOPE APPLICATIONS DIVISION

Edwin Roig, Ph. D., Head

The Radioisotope Applications Division offers training and research opportunities in the application of radioisotopes and ionizing radiation to the physical sciences, to provide scientists with technical competence for their future work. Introductory training in radioisotope and ionizing radiation is offered to scientists and students, regardless of their fields of interest, as background or as complementary preparation for participation in other PRNC programs. In order to strengthen this program, the Radioisotope Applications Division works in close cooperation with the University of Puerto Rico Department of Chemistry. Staff members participate in teaching courses, especially at the graduate level, and research opportunities are provided, with emphasis on thesis research leading to an M.S. degree.

Courses taught by Division staff members include:

		Students
Radiochemistry	Dr. E. Roig	4
Chemical Analysis	Dr. E. Roig	17
Organic Chemistry	Dr. H. H. Szmant	25
Theory of Organic Chemistry	Dr. H. H. Szmant	20
Physico-Chemical Aspects of Biological Processes	Dr. H. H. Szmant	8

Dr. Edwin Roig collaborates with Dr. Robert A. Luse of the Agricultural Bio-Sciences Division in teaching the course on nuclear techniques in biological research.

During the year three students completed the requirements for an M.S. degree at the UPR Department of Chemistry, having done their thesis research under the guidance of Dr. H. H. Szmant. They are:

1. Mr. Juan J. Rigau, who is now pursuing studies toward a Ph.D. degree at Wayne State University,

2. Mr. Arnaldo Carrasquillo, now pursuing studies toward a Ph.D. degree at Ohio State University, and

3. Miss Mirta Román, who is presently on the teaching staff of the Physical Sciences Department of the UPR School of General Studies.

The basic course on radioisotope techniques continues to be offered mainly for the benefit of local institutions. A number of laboratories in Puerto Rico besides PRNC require their technicians to have this training; for example, the Radioisotopes Laboratory of the San Patricio Veterans Hospital and the Biochemistry Department of the UPR School of Medicine. The sugar industry, the Agricultural Experiment Station, and others are also interested in radioisotope techniques.

Mr. Santiago Ramírez, Professor of Physics at UPR, and Mr. Miguel A. Jiménez, Professor of Physics at the College of Agricultural and Mechanical Arts, took the basic course on radioisotope techniques in May and June 1964, under the auspices of the Puerto Rico civil defense program. They have since been teaching a course for radiological monitoring instructors, sponsored by the U.S. Department of Defense and the U.S. Office of Civil Defense and administered by the University of Puerto Rico. The persons taking this course are mainly public school teachers, civil defense officers, and other professionals with a background in physical sciences, such as engineers, or agronomists, who are interested in cooperating with the Puerto Rico civil defense program. During the year 1964-1965 eight sessions of this course were offered in different cities all over Puerto Rico, and a total of 116 persons completed it. These participants are at present teaching other members of the community at a more elementary level under the program of adult civil defense training sponsored by the Puerto Rico Department of Education.

Training equivalent to the basic course on radioisotope techniques is being offered by a number of Latin American countries such as Argentina, Brazil, and Chile. Latin Americans are encouraged, whenever possible, to take such a course at home before coming to PRNC for further training. However, medical doctors usually repeat this course here before continuing with further training in clinical applications. Experience has shown that the basic training here is more practical than the Latin American equivalents. For example, the three-month course offered by the Atomic Energy Commission of Argentina requires for admission a thorough knowledge

of nuclear physics and mathematics. Argentineans who have taken the basic training here consider the approach more in accord with the purpose of the training,which is to place emphasis on experimental work and to simplify theoretical discussions, thus eliminating rigorous mathematical treatment. This approach is more successful in giving the participants, most of whom have been out of college for several years, a clear understanding of the subject.

During 1965 there were 31 participants in the basic course on radioisotope techniques: 23 from Puerto Rico, two each from the Dominican Republic and Argentina, and one each from Colombia, Uruguay, Spain, and the Phillippines. (See Figure 1.) Their names and present positions are listed in Table 1.

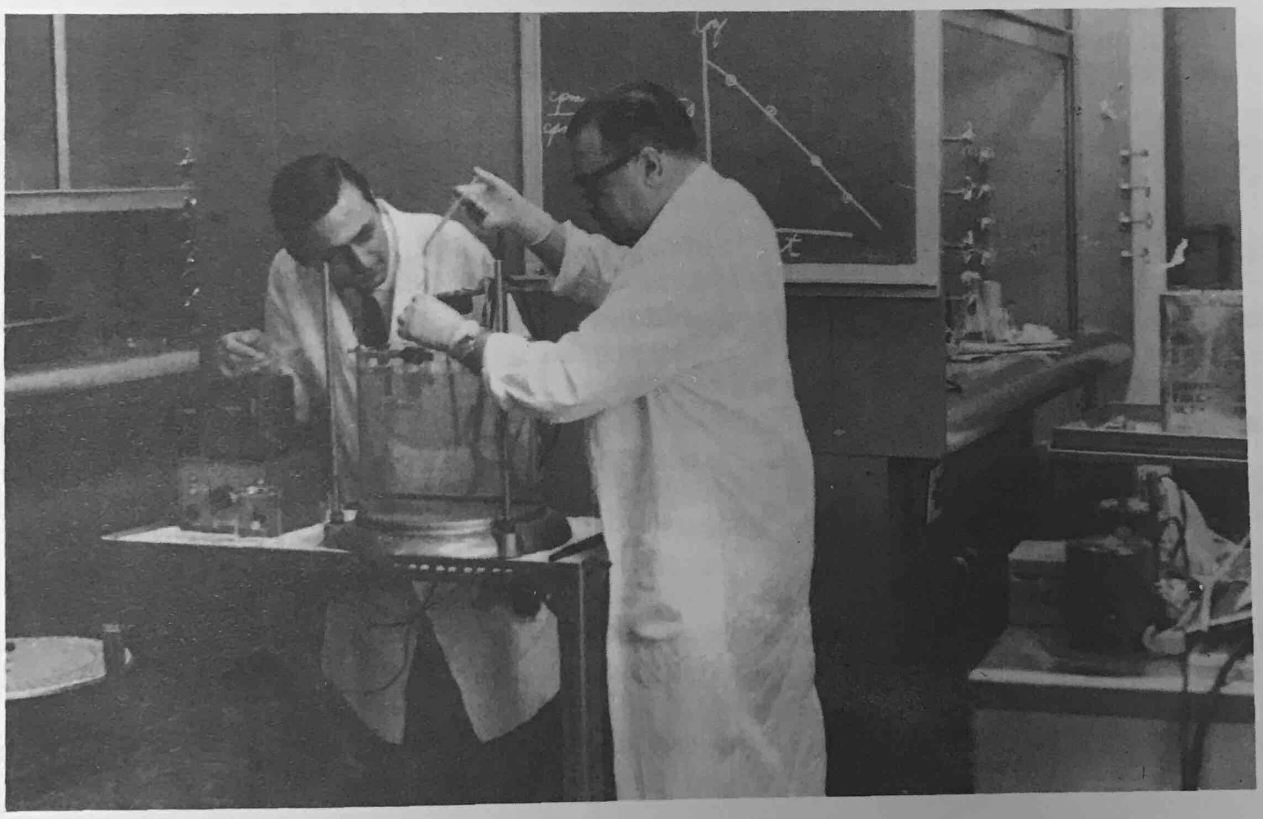


Figure 1. Dr. Hugo Gastón Fermepín and Mr. Randolfo E. Rapallini, both from Argentina, perform a kinetic study on an isotope exchange reaction as part of their training in isotope techniques.

TABLE 1

Participants in Basic Course on Radioisotope Techniques, 1965

Name	Present position
1. Leila Crespo Fernández	Research Technician, Clinical Applications Division, PRNC
2. Julián Roldán Regus	Research Associate, Agricultural Bio-Sciences Division, PRNC
3. Louise Valentín González	Research Assistant, Medical Sciences Division, PRNC
4. Adriana Rodríguez de Calderón	Technical Assistant, Clinical Applications Division, PRNC
5. Arturo Valencia Serna	Research Associate, Radiotherapy and Cancer Division, PRNC
6. Eduardo J. Brenes	Research Assistant, UPR Agricultural Experiment Station
7. Jorge Luis Camuñas	Premedical student, Georgetown University
8. Agnes Martínez-Lahoy	Graduate student in bacteriology, UPR School of Medicine
9. Luis Meyer	Chemist, Administración Nacional de Combustible, Alcohol y Portland, Montevideo, Uruguay (Had additional training at PRNC on clinical applications, agricultural applications, and health physics)
10. Norma Miranda de Zetterstrand	Pediatrician, UPR Hospital. (Had additional training in clinical applications at PRNC)
11. Marta Olivieri Malavé	Research Assistant, Department of Biochemistry, UPR School of Medicine
12. Freddy Sallent Jurgensen	Professor of Biochemistry, School of Medicine, Universidad Autónoma de Santo Domingo, Dominican Republic
13. Mirta Toro González	Graduate student in Bacteriology, UPR School of Medicine
14. Alberto Toro Nazario	Graduate student in Medical Technology, UPR School of Medicine
15. Modesto Capiel	Research Associate, Plant-Water-Climate Relationship, UPR Agricultural Experiment Station

TABLE 1 (continued)

	Name	Present position
16.	Jacinto Figarella	Research Associate, Agriculture Research Service, USDA
17.	Carlos López Domínguez	Professor of Veterinary Medicine, Universidad Autónoma de Santo Domingo, Dominican Republic
18.	Nancy Ortiz Torres	Research Technician, Clinical Applications Division, PRNC
19.	Hamilton Quiñones Rivera	Agronomist, South Puerto Rico Sugar Corp.
20.	Antonio Reyes Padilla	Teacher of industrial education, Puerto Rico Department of Education
21.	Awilda Román de Sandoval	Research Assistant, Radioisotope Applications Division, PRNC
22.	Adriam Romero	Public school teacher, Puerto Rico Department of Education
23.	Adria Suazo de Delgado	Instructor, School of Medicine, Universidad Autónoma de Santo Domingo, Dominican Republic
24.	Ederlyna V. Belardo	Research Assistant, Radioisotope Applications Division, PRNC
25.	Alexis M. Estevez	Engineer, Sugarcane Program, Puerto Rico Land Authority
26.	Hugo Gastón Fermepín	Doctor of Medicine, Central Military Hospital, Argentina Army (Had additional training on clinical applications at PRNC)
27.	Milton Matos Maldonado	Biochemist, San Patricio Veterans Hospital, San Juan
28.	Raúl Pérez Escolar	Associate Soil Scientist, UPR Agricultural Experiment Station
29.	Randolfo E. Rapallini	Chemist, Central Military Hospital, Argentine Army (Had additional training on clinical applications at PRNC)
30.	Saulo J. Rodríguez Ortiz	Associate Scientist in Horticulture, UPR Agricultural Experiment Station
31.	José Rodríguez Rivera	Medical technologist, UPR School of Medicine

Dr. Malcom Daniels, Associate Scientist, resigned his position at PRNC to accept a position as professor at Oregon State University.

Dr. Alec Grimison joined the staff in August 1965. He is in charge of developing a research program that provides training in advanced research techniques on the radiation chemistry and photochemistry of heterocyclic compounds of biochemical significance. Part of this work is purely experimental, and part involves training in quantum mechanical methods, especially as applied to heterocyclic systems. Two undergraduate students and one graduate student from the University of Puerto Rico are participating in this program. A brief account of their research activities follows:

1. Jhagadish S. Jhaveri (B.S., University of Bombay), research for an M.S. thesis: Radiation and Photochemical Studies on Heterocyclic Molecules in Rigid Matrices. This work is in its initial stages, such as construction of optical Dewars for low temperature irradiations and preliminary experiments on systems studied by other workers. In view of the probable importance of ionization processes, theoretical calculations of ionization potentials of the relevant molecules have been started, with the use of a simple molecular-orbital method. (See Figure 2.)

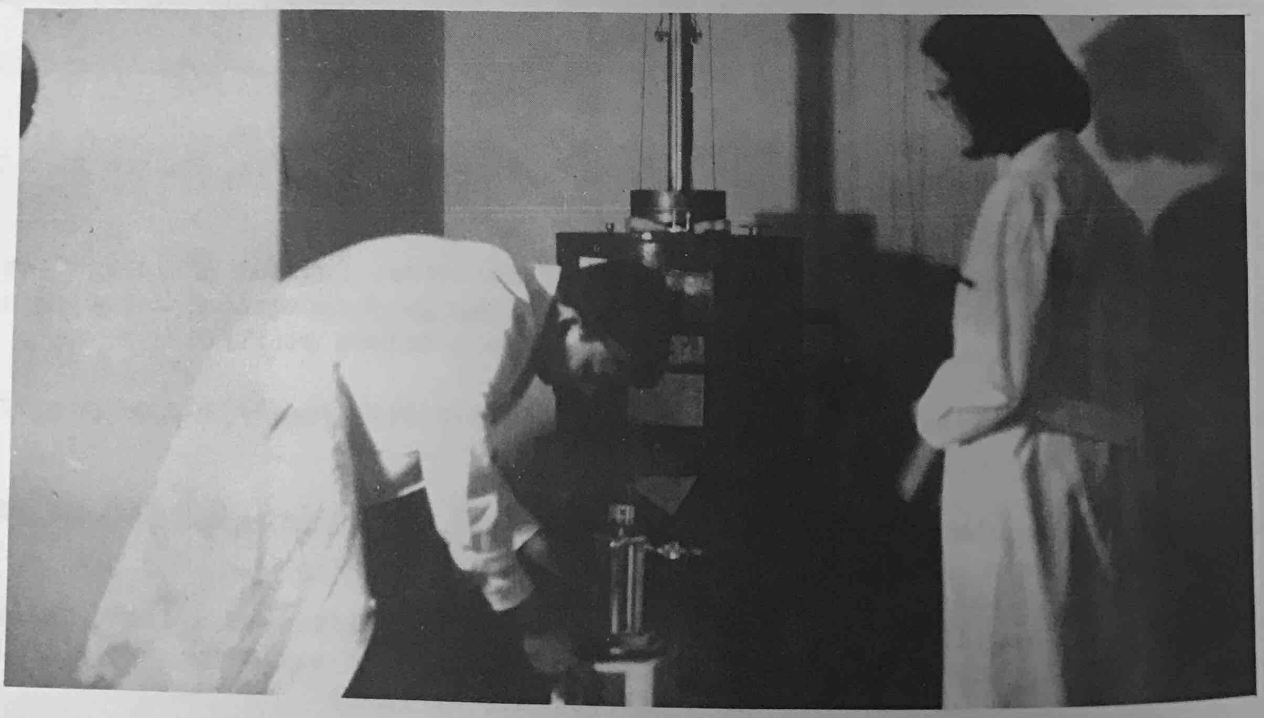


Figure 2. Mr. Jhagadish S. Jhaveri, from Bombay, India, a graduate student working on his thesis research, uses the 2700-curie, cobalt-60 source to irradiate a heterocyclic system a liquid nitrogen temperature. He is being supervised by a health physicist.

2. Magda Delpin, undergraduate research: Photochemistry of Pyrrole in Aqueous Solutions. Since the major reaction of pyrrole in the presence of oxygen is known to be photooxidation, work has been started on the purification of pyrrole and on the absorption spectra of aqueous pyrrole solutions in the presence and absence of oxygen.

3. Rodulfo Gauthier, research for undergraduate honors program thesis: Molecular Orbital Calculations on Heterocyclic Ring Systems. Calculations have been carried out on the simple pyrimidines by the omega-technique modification of the Huckel theory. Correlation with experimental parameters is being studied, particularly by detailed analysis of the nuclear magnetic resonance chemical shifts.

Dr. H. H. Szmant is continuing to develop the organic chemistry research program, with participation by Dr. J. P. A. Castrillón and collaboration by Dr. E. Roig in some of the projects. This year the use of radioisotopes as tracers was initiated, and preliminary steps were taken in the study of the effect of gamma radiation on dimethyl sulfoxide. Participating in thesis research were eight graduate students, of whom three completed their degree requirements during the year, and five advanced undergraduate students. Brief description of the research projects are given below.

1. Juan José Rigau (M.S. Chemistry, UPR, 1965): Stereochemistry of Substituted β-Hydroxy Sulfoxides. A series of β-hydroxy sulfoxides has been prepared for the purpose of investigating their radiation-protective activity. This series includes several sulfoxides derived from styrene by the addition of different thiols in the presence of oxygen, and also some derived from indene. Among the latter, all four isomers (two cis and two trans) of the 2-phenylsulfinyl-1-indanols were separated and their structures differentiated on the basis of their nuclear magnetic resonance spectra and the differences in their ability to produce intra- and intermolecular hydrogen bonding. In connection with the study of β-hydroxy sulfoxides, the ultraviolet spectra of sulfoxides were studied in the hope of being able to distinguish the different possible electronic excitations in aliphatic and aromatic sulfoxides. The classification of electronic transitions has been extended to other families of sulfur compounds as well. During the work with 2-phenylsulfinyl-1-indanols, a clear-cut case was found of intramolecular hydrogen bonding involving a sulfide

center in the cis isomer of 2-phenylmercapto-1-indanol. Interesting differences in the chemical properties of these cis and trans isomers are attributed to the intramolecular hydrogen bonding of the former.

2. Arnaldo Carrasquillo (M.S. Chemistry, UPR, 1965): Organic Boron Compounds. The chemistry of water-soluble and hydrolysis-resistant boron compounds for neutron activation therapy is being explored along two lines. First, different orthoborates have been prepared in which the boron atom is chelated by a suitably located electron-donor atom. Two of the alkoxy groups form a cyclic structure, which further increases the stability toward hydrolysis. Second, in the family of boron compounds derived from diboron, such as those containing a covalent boron-boron bond, a series of new cyclic derivatives of diboron has been prepared with different glycols used as the starting material.

3. Mirta Román (M.S. Chemistry, UPR, 1965) and Hipólito Poussin, Carmen Ana Rivera, and María de Lourdes Santiago (undergraduate research students): Solvent Effects in the Wolff-Kishner Reaction. The long-standing interest in the mechanism of the Wolff-Kishner reaction overlaps the interest in the properties of dimethyl sulfoxide, since the latter solvent is capable of reducing dramatically the high temperature requirement of this reaction. A detailed study of the effect of dimethyl sulfoxide on the kinetics of the Wolff-Kishner reaction reveals that the reaction requires the presence of a hydroxylic solvent; furthermore, it suggests the nature of the mechanism of the reaction and the specific role of dimethyl sulfoxide in that mechanism. This research is being continued in order to elucidate also the nonlinearity of the Hammett relationship for the Wolff-Kishner reaction of hydrazones, and the nature of the activated complex.

4. Raúl H. Figueroa (graduate student, UPR Department of Chemistry): Association of Sulfoxides. The nature of the association of sulfoxides is being studied. Self-association of dimethyl sulfoxide has been demonstrated by infrared spectroscopy, and it is concluded that up to a concentration of 0.3 M (in carbon tetrachloride), dimer formation predominates. Since the structure of the dimer is believed to be cyclic, this implies an association via dipole interactions involving the fractional positive charge at the sulfur atom. Confirmation of the existence of electrostatic attractive forces operating between the sulfur atom of sulfoxides and electron-donating centers is now being obtained. The

association of sulfoxides (dimethyl, diphenyl, di-p-bromophenyl, di-p-anisyl, di-p-tolyl, di-p-nitrophenyl) with phenol produces, in addition to a 1:1 complex, also a complex of one sulfoxide and two phenol molecules. The structure of the latter is believed to be cyclic, with the second phenol molecule hydrogen-bonded to the first, and also held in place through the above-mentioned dipole-dipole interaction.

5. Luis Bravo Navarrete (Chilean) and Luz Rodríguez (graduate students, UPR Department of Chemistry): Nucleophilic Substitution Reactions of Imidates. This project, supported by a National Institute of Health grant, has as its aim the development of a novel and versatile method for the replacement of one hydroxyl group in a polyfunctional alcohol. The synthetic scheme is to convert the polyfunctional alcohol into the monoimidate by a base-catalyzed reaction with a suitable nitrile. Subsequently, the imidate is treated with the conjugate acid of a nucleophile, and the substitution reaction produces the amide derived from the original nitrile as well as the desired product. The novelty of this process consists in the occurrence of the substitution reaction at the alkoxy carbon atom of the carboxylate system and the use of an amide as a "leaving group." The feasibility of the reaction was demonstrated with the formation of iodo, thiocyano, amino, and arylmercapto derivatives derived from ethylene glycol. The optimum conditions for the desired reactions are now being determined for the imidates derived from 2-cyanopyridine, from ethylene and tri- and tetramethylene glycols, and from glycerol. There is great interest in applying this reaction scheme to carbohydrates, but so far methyl glucopyranoside has failed to form an imidate under base-catalyzed conditions. This is attributed to the relative stability of a chelated hydroxy-substituted alkoxide ion, which also manifests itself in the relative reluctance of trimethylene glycol to give the imidate under base-catalyzed conditions. The structural factors affecting the stability of hydroxy-substituted alkoxide ions are being investigated because of the general importance of this phenomenon. (See Figure 3.)

6. Jaime L. Colón (part-time PRNC Research Assistant and graduate student, UPR Department of Chemistry): Mechanism of Chromic Acid Oxidation of 1,1-Diarylethanes. It was shown some time ago that 1,1-diarylethanes containing substituents known to stabilize radicals (nitro, iodo) give, in the course of oxidation by chromic acid, the normal degradation product, a substituted benzophenone, and an unexpected degradation product, the substituted benzoic

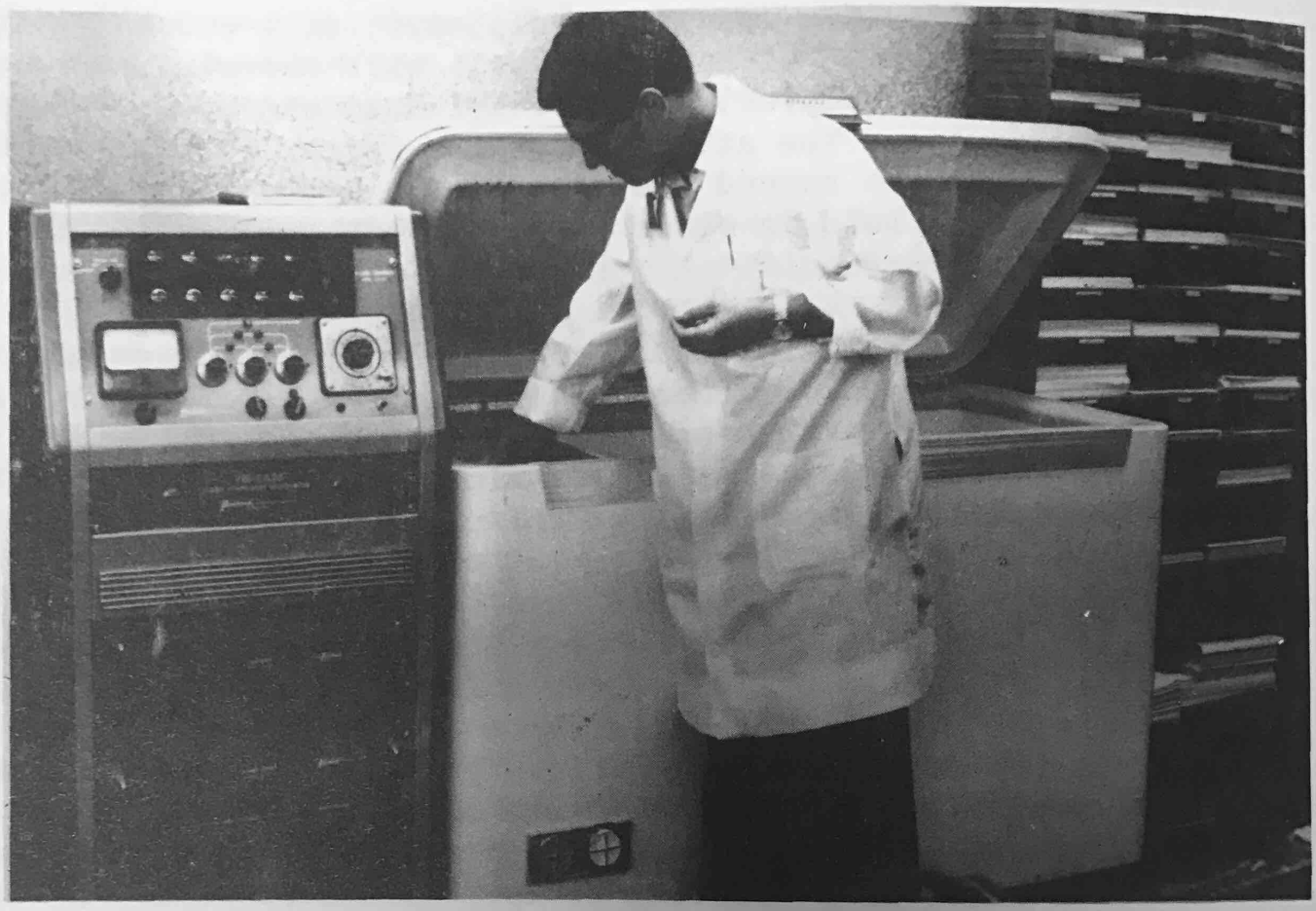


Figure 3. Mr. Luis Bravo Navarrete, a graduate student from Chile, places a ^{14}C sample in the freezer compartment of the liquid scintillation counter. The ^{14}C counting techniques are fully considered in the radiochemistry course.

acid. Evidence was accumulated to support the hypothesis that the abnormal degradation is obtained by way of a rearrangement of the less probable 2,2-diarylethyl radical to the corresponding 1,2-diarylethyl radical. An alternative explanation for the formation of the unexpected substituted benzoic acids involves degradation of one of the substituted benzene rings. In order to differentiate between these two mechanisms, and possibly to prove the above-mentioned rearrangement, 1,1-diarylethanes labeled with ^{14}C in the 2-position are being synthesized. These hydrocarbons are to be subjected to oxidation, and the formation of labeled benzoic acids will be a measure of the rearrangement.

7. Michael Dowman (UPR undergraduate honors program student): Enzyme Model. It has been found possible to convert a portion of the carboxylic acid groups in a commercial polymer to amino groups, and thus to prepare a series of macromolecules containing various ratios of amino to carboxylic acid functional groups. These macromolecules are being tested as catalysts for the hydrolysis of an ester, p-nitrophenyl acetate. It is hoped that this study will lead to the development of a macromolecular enzyme model.

8. Edgar Rodríguez Méndez (undergraduate student, UPR Department of Chemistry): The Sulfoxide of Thiaxanthone. It is of interest to investigate several physical and chemical properties of the sulfoxide of thiaxanthone, but this compound has not been described in the literature. The reaction of thiaxanthone with phenyliodoso acetate was recently shown to produce the desired sulfoxide, and its physical and chemical properties are being investigated.

9. Marilyn Pérez Arzola (graduate student in biochemistry, UPR School of Medicine): ^{35}S Exchange Studies. An exchange of sulfur takes place in triphenylphosphine sulfide at elevated temperatures. This exchange, as well as the exchange reaction in isothiocyanates, is being studied via ^{35}S labeling, and it is hoped that the mechanism of these reactions can be elucidated by using suitably substituted reagents.

10. Edgar Rodríguez Méndez (undergraduate student, UPR Department of Chemistry): Studies of the Mechanism of Sulfoxide Reduction by Triphenylphosphine - Carbon Tetrachloride. It has been shown that sulfoxide reduction by triphenylphosphine can occur by two distinctly different mechanisms. The first is an acid-catalyzed process in which the acid-complexed sulfoxide is believed to be subject to nucleophilic attachment by the phosphorus center. This

reaction follows the Hammett relationship with a negative value of ρ. The second process takes place in the presence of carbon tetrachloride and presumably involves an active intermediate (ylide) formed by the interaction of triphenylphosphine and carbon tetrachloride. The details of these mechanisms are being investigated by means of ^{36}Cl. The reduction of sulfoxides by phosphines is now being extended to the family of N-sulfinylanilines.

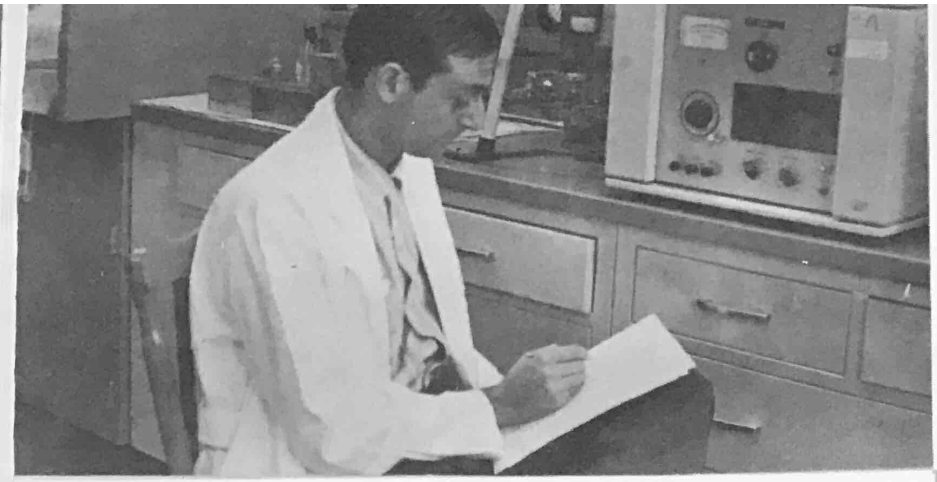


Figure 1. Mr. Randolfo E. Rapallini (Argentina) is conducting a test utilizing the well counter visible on the right.

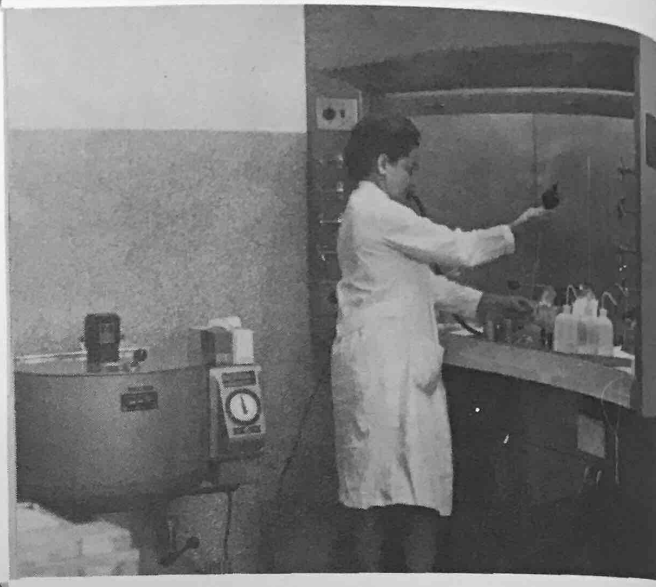


Figure 2. Miss Hilda Pérez Alvarez (Puerto Rico) working in the hood during a laboratory session.

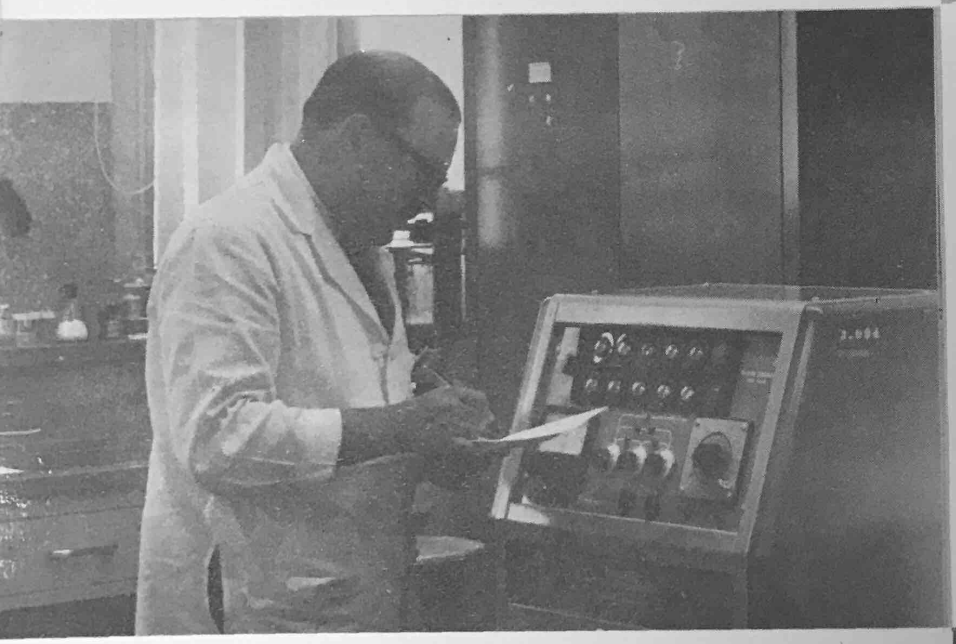


Figure 3. Dr. Gastón Hugo Fermepín (Argentina) using a liquid scintillation counter to gather data for a clinical test.

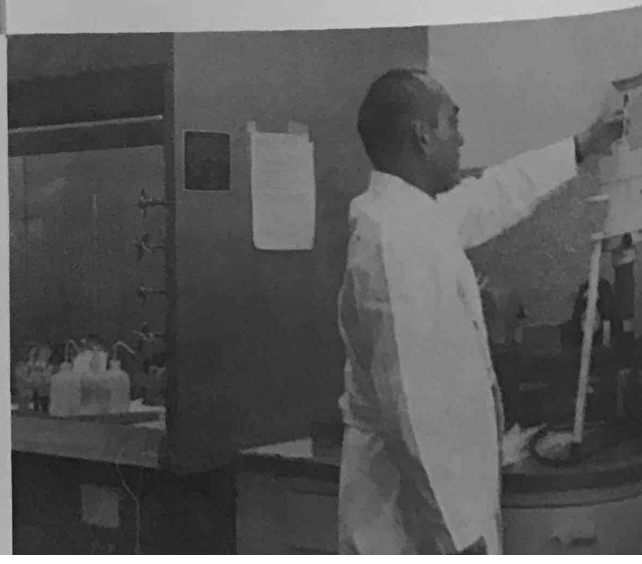


Figure 4. Dr. Leonardo Adachi Sasaki (Peru) placing a sample in the well counter during a laboratory exercise.

CLINICAL RADIOISOTOPE APPLICATIONS DIVISION

Sergio Irizarry, M. D., Head

TRAINING ACTIVITIES

The Clinical Radioisotope Applications Division offers several training programs for physicians and other types of medical personnel in the diagnostic and therapeutic uses of radioisotopes in humans. A course set up in 1958 on the basic clinical applications of radioisotopes has been developed into a two-month, full-time formal training program. A one-semester general orientation course on the medical applications of radioisotopes is offered every second year to the medical staff of the University Hospital. A special program, Advanced Course in Nuclear Medicine: Nephrology, based on the use of radioisotopes in the study of renal diseases was offered twice in 1965. A long-term course in clinical research is also offered for trainees desiring additional experience.

Training is done directly on clinical problems. The lectures, discussions, audiovisual presentations, laboratory practice, design of experiments, and examination of patients all form interrelated parts of the curriculum. To provide the necessary clinical material, an active training program requires constant access to patients on whom the various tests to be studied can be carried out. To satisfy this need, referral of diagnostic problems is welcomed, and all diagnoses worked up at this laboratory have a fundamental function in the teaching activity.

Some modifications in the training curriculum are required at times to best serve the needs of students with different individual backgrounds and interests. When a student desires a short period of additional experience in the laboratory in any specified field of application, this is permitted after a basic formal course is taken. Several students from various parts of Latin America have made such requests. The program is flexible enough to allow for extra work in different fields of interest such as renography, isotope localization, and hematology.

A brief description of the courses offered during 1965 follows.

1. Basic Course in Clinical Applications of Radioisotopes. Training

is given in the clinical uses of radioisotopes in diagnosis and therapy. This course consists of formal lectures, demonstrations, seminars, roundtable discussions, review of literature, and laboratory work. Two techniques are introduced each week, preceded by an explanation of the theory and medical aspects of the tests. (See Figures 1 to 4.) Participants perform approximately 80 tests during the eight-week period. Procedures include studies of thyroid function, blood volume and cardiac flow, erythrocyte survival, location of cancerous metastases, gastrointestinal absorption, and renal and hepatic function. Table 1 presents a breakdown of the units of study.

2. Orientation in the Clinical Uses of Radioisotopes. This is a one-semester course for medical residents consisting of 18 lecture hours and 12 hours of demonstration exercises. Essentially, the same theoretical aspects are covered as in the basic course but without the intensive training in laboratory procedures.

3. Advanced Course in Nuclear Medicine. This one-month course is offered in different medical specialties and is designed for physicians specializing in the field offered who may or may not be utilizing radioisotopes. The medical field covered during 1965 was nephrology.

TABLE 1

Two-Month Training Program on
Clinical Applications of Radioisotopes

Unit of Study	Average Number of procedures per trainee
Thyroid function	35
Routine uptake measurements	(15)
Assay of radioactive thyroid hormone levels in blood	(15)
Modified tests of thyroid function	(5)
Dynamic functions of the hepatic, renal and vascular systems	20
Hematologic applications of radioisotopes	5
Tumor localization studies	10
Gastrointestinal absorption	5
Electrolyte and fluid balance	2
Therapeutic procedures	3
Total	80

4. Informal Courses. These comprise tutorial arrangements made with participants in the regular courses to extend training in different areas of isotopic studies and clinical research.

In Table 2 the participants in the courses offered during 1965 are listed. A numerical tabulation of the professional backgrounds and countries of origin of the participants in the training program is presented in Table 3.

Prospective students from Latin America and Puerto Rico are encouraged to apply for financial support when needed and are directed to various known agencies for this purpose. Among 49 current applicants, 37 indicated a need for financial support to cover living expenses while training. This stems in large measure from unfavorable monetary exchange rates between Latin American currencies and United States currency.

The medical services routinely carried on ensure an adequate variety of clinical material for the training program. Table 4 presents a numerical analysis of the services rendered during 1965. The clinical research program is vital to good training - it stimulates new ideas and engenders an alert approach to the various problems posed by medical practice. It also serves to attract better teachers. The correlation of research activities with training is shown in Table 5. (See Figure 5).

RESEARCH ACTIVITIES

Experimental Demonstration of Exudative Loss of Serum Albumen in Gastritis. The purpose is to study the degree of albumen loss through the gastric mucosa after the induction of several types of experimental gastritis. Three groups of mongrel dogs, each dog weighing approximately 30 pounds and in good health, were subjected to three types of experimental gastritis induced by chemical means: (1) serous type of gastritis induced by exposure to creosote-diol solution, (2) erosive gastritis induced by Atophan, and (3) papillomatous gastritis induced by croton oil. Three dogs were studied before the experimental induction of gastritis by following the blood disappearance activity curve of ^{131}I-albumen (biologic half-life) and its appearance in the gastric juice collected for a specified period of time, 25 minutes after histamine stimulation on the fourth day of intravenous administration of labeled albumen. The same procedure was repeated on these three dogs and on seven others after the production of gastritis. Blood ^{131}I-albumen

TABLE 2

Participants in Courses, 1965

Name, country, and sponsor (if any)	Present position
1. BASIC COURSE IN CLINICAL APPLICATIONS OF RADIOISOTOPES	
Dec. 7, 1964 to Jan. 29, 1965	
1. Graciela Maytorena Serna, M.D., Mexico (PRNC)	Visiting Radiotherapist, PRNC
2. Evelyn Cintrón Ruiz, M.D., P. R. (Ponce District Hospital)	Organizing Radioisotope Lab., Ponce District Hospital
3. Norman I. Maldonado, M.D., P. R. (University Hospital)	Fellow in Hematology University Hospital
Feb. 11 to Nov. 1, 1965	
4. Frankie Alvarado Norat, M.D., P. R.	Internal Medicine, Radioisotopes, Cardiology Mimiya Hospital, San Juan
March 29 to May 21, 1965	
5. Lillian Conde Pérez, M.D., P. R. (San Juan City Hospital)	Internal Medicine, San Juan City Hospital
6. Arturo Valencia Serna, M.D., Colombia (PRNC)	Research Assistant, Radiotherapy and Cancer Division, PRNC
7. Adriana Rodríguez de Calderón, P. R. (PRNC)	Research Technician, PRNC
8. Leila Crespo, P. R. (PRNC)	Research Technician, PRNC
July 6 to Aug. 27, 1965	
9. Luis H. Meyer, Ph.D., (Chemist), Uruguay	Trainee, Agricultural Bio-Sciences Division, PRNC
10. Pedro Juan Santiago, M.D., P. R. (PRNC)	Research Assistant, Clinical Applications Division, PRNC
11. Norma Miranda de Zetestrand, M.D., P.R. (UPR School of Medicine)	Pediatrics and Endocrinology, University Hospital
12. Delia Beatriz Giudici, M.D., Argentina (PRNC)	Taking short-term Radiotherapy Course, PRNC

TABLE 2 (continued)

Name, country, and sponsor (if any)	Present position
Dec. 6, 1965 to Jan. 28, 1966	
13. Carlos López Domínguez, M.D., Spain	Chief, Dept. of Physiology, Universidad Autónoma de Santo Domingo
14. Hilda Pérez Alvarez (med. technologist), P. R. (UPR School of Medicine)	Medical Technologist, UPR School of Medicine
15. Gastón Hugo Fermepín, M.D., Argentina	Chief, Hemotherapy Service, Hospital Militar Central, Buenos Aires
16. Randolfo E. Rapallini, (chemist) Argentina	Biochemical Technician, Hospital Militar Central, Buenos Aires
17. Leonardo Adachi Sasaki, M.D., Peru	Assistant, Dept. of Internal Medicine, Hospital Central de Empleados, Lima
18. José J. Corcino, M.D., P. R. (UPR School of Medicine)	Fellow in Hematology, UPR School of Medicine

2. ORIENTATION IN THE CLINICAL USES OF RADIOISOTOPES

Jan. 13 to May 19, 1965 (all medical students from Puerto Rico)

1. Fernando L. Alvarez Malavé
2. José J. Corcino Blanco
3. Luis G. de Jesús Pérez
4. Enrique O. Horta Navarro
5. Acisclo M. Marxuach Cuétara
6. Agapito Miranda Rivera
7. Mario C. Miranda Torres
8. Francisco J. Muñiz Vázquez
9. Hernán F. Padilla Ramírez
10. Ibrahim Pérez Lloréns
11. Alan H. Rapoport
12. Pedro O. Santiago Correa
13. Juan Tomasini Flores
14. Francisco X. Veray

3. ADVANCED COURSE IN NUCLEAR MEDICINE: NEPHROLOGY

June 1 to 11, 1965	
1. Guillermo Castillo Castillo, M.D., Venezuela	Instituto Diagnóstico, Caracas, Venezuela
Sept. 13 to Oct. 8, 1965	
2. Rafael Baquero, M.D., Venezuela	Hospital Central de las Fuerzas Armadas, Venezuela
3. Alberto G. Bonfante, M.D., Argentina	Chief, Nephrology Institute, Modelo Clínica Médica, Hospital Rawson, Buenos Aires

TABLE 3

Number of Trainees

	1965	All previous years
TYPE OF STUDENT		
M.D.	15	19
Chemist	2	
Med. technician	1	
Ancillary medical		3
Total	18	22
ORIGIN		
Puerto Rico	9	5
Spain	1	17
Latin America	8	
Argentina (4)		(5)
Chile		(2)
Venezuela (2)		(3)
Mexico		(3)
Dom. Rep.		(2)
Colombia		(1)
Bolivia		(1)
Uruguay (1)		
Peru (1)		
Total	18	22

TABLE 4

Diagnostic and Therapeutic Procedures
Carried Out During 1965

Thyroid studies	3184
Liver studies	183
Heart studies	157
Kidney studies	255
Gastrointestinal studies	60
Blood studies	46
Tumor localization	104
Miscellaneous	66
Tritium	7
^{22}Na determinations	21
Total	4082

TABLE 5

Correlation Between Study Units in Training Program and Current Research Projects

Clinical Applications Study Unit	Research Project
1. Tests of thyroid function	Clinical and laboratory evaluation of thyroid disorders Evaluation of *in vitro* tests of thyroid function for use as diagnostic procedures Study of the effect of anticonceptive therapy on the 24-hour uptake of ^{131}I by thyroid
2. Cardiovascular	Cardiovascular studies in diabetics
3. Kidney function	Renogram followup study in cancer of the cervix uteri Combined clinical, renographic, and scintigraphic studies in kidney diseases Renogram studies in diabetics
4. Liver function	^{131}I-rose bengal localization and dynamic studies: scintigraphy, hepatogram
5. Gastrointestinal function	Effect of radiotherapy on intestinal absorption of ^{131}I-labeled fats and vitamin A in humans Thyroid gland as an indicator of intestinal absorption of ^{131}I-labeled fats
6. Hematology	
7. Tumor localization	Instrumentation improvement: combined x-ray photoscanning unit of gamma photoradiography Organ and tumor localization: brain scannings, others
8. Electrolyte balance and fluid compartments	Electrolyte and fluid balance in women under anticonceptive therapy
9. Therapeutic procedures	Review of patients treated with ^{131}I

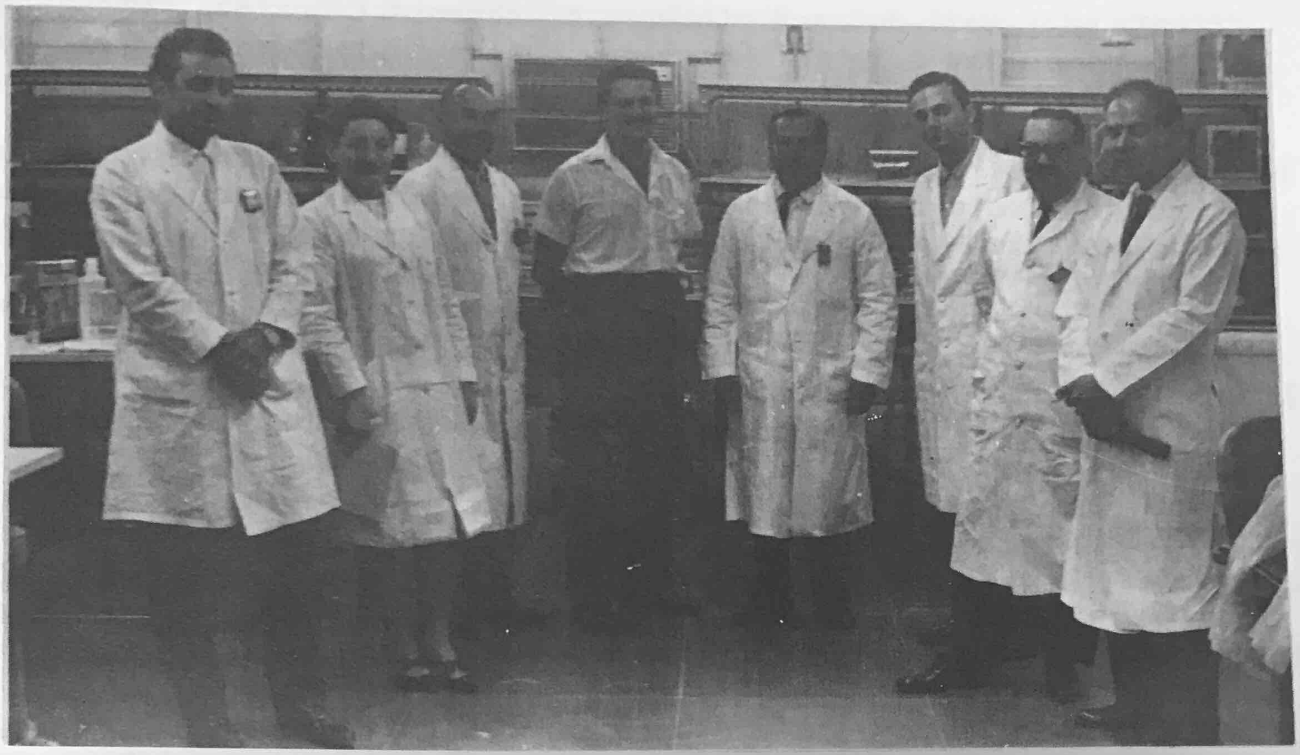


Figure 5. Faculty and students, basic course in clinical applications of radioisotopes. Left to right, Dr. Carlos López Domínguez (Spain), Miss Hilda Pérez Alvarez (Puerto Rico), Dr. Leonardo Adachi Sasaki (Peru), Dr. Aldo E. Lanaro, Dr. Sergio Irizarry, Mr. Randolfo E. Rapallini (Argentina), Dr. Gastón Hugo Fermepín (Argentina), and Dr. Oscar N. Vázquez.

disappearance curves were more rapid, and the detected level of labeled protein exuded into the gastric juice was higher, than in control animals. Protein loss in gastritis is one of the factors contributing to protein malnutrition often associated with the various types of gastritis observed in the clinic. This project has been completed, and a publication is in press.

Clinical Evaluation of 24- and 48-Hour Thyroid Iodine Accumulation and Protein-Bound Hormonal ^{131}I Levels. The purpose is to determine normal and abnormal values for the 24-hour and 48-hour thyroid ^{131}I uptake test, and the rate of thyroid hormone synthesis. Patients referred for routine tests of 24-hour uptake and tagged protein-bound hormone blood levels are being studied also at 48 hours. Records will be reviewed for correlation of clinical data with the laboratory values obtained to gain information necessary for defining the values for normal and abnormal function in Puerto Rican

patients with well-defined pictures of thyroid function. More than 285 patients have entered the study, but the data have not yet been analyzed.

The Evaluation of Thyroid Function in Sprue. Low thyroid function is suspected in sprue patients, but this problem has not been investigated. Patients with well-defined clinical pictures of sprue and with additional supporting clinical and laboratory data for intestinal malabsorption and megaloblastic anemia are being selected for study of thyroid function. First the usual procedure for 24-hour ^{131}I uptake will be used, with the ^{131}I given orally; then, regardless of the result, the test will be repeated with intravenous administration.

^{131}I Therapy of Carcinoma of the Thyroid. The purposes are to offer palliative therapy to patients with advanced thyroid carcinoma with pulmonary and skeletal metastasis; to ablate residual thyroid tissue following partial thyroidectomy for cancer of the thyroid; and to learn appropriate schedules for treatment and gain a better understanding of the management of the disease with the use of internal emitters. Patients with carcinoma of the thyroid, some with residual thyroid tissue in the neck after surgical intervention and the majority with evidence of far advanced disease in lungs and bones, are evaluated for this type of therapy. The prime requisite is the detection of foci of metastatic thyroid tumors with ability to concentrate ^{131}I. Seven patients have been treated. Four patients with far advanced disease, each of whom received a single dose of 25 millicuries ^{131}I died within a period of two years. Three patients were successfully treated as follows: (1) 13 millicuries were given for ablation of residual thyroid tissue. (2) 105 millicuries were given in five doses over two years, with ablation of neck metastasis and partial resolution of pulmonary lesions. (3) 125 millicuries were given in seven doses over one year, with successful remission of a bone fracture and other foci of functioning tumors. The series is too small to comment upon. However, relatively small amounts of ^{131}I were needed to produce good clinical and objective responses in the last three patients mentioned.

Tapazole Inhibition of Thyroid Function in Hyperthyroid Patients. The purposes are to study the degree of thyroid function inhibition by pharmacologic doses of tapazole in hyperthyroid patients; to determine how frequently the antithyroid effect of the medication is partial or unsuccessful; to learn whether so-called clinical resistance to antithyroid medication is due to lack of adequate pharmacologic drug action on the patient; and to gain personal

experience with the use of this radioisotopic technique to anticipate the clinical response of a patient to antithyroid medication as demonstrated by Stanley and Astwood in 1948.

Phase I. Patients with documented hyperthyroidism are being studied by the technique of using potassium thiocyanate to discharge from the thyroid gland trapped iodide not yet bound to thyroid hormone precursor because of the inhibitory effect of antithyroid medication. Enough patients are to be studied to determine the criteria of failure of the antithyroid drug successfully to inhibit hormone synthesis and the rate of incidence of failure in a group of hyperthyroid patients.

Phase II. A search will be made for hyperthyroid patients with "clinical resistance to antithyroid management" to test the hypothesis that the resistance is due to a pharmacologic failure of the drug in producing the necessary metabolic blockade to hormone synthesis, or to discover whether the resistance is due to other factors. A group of 21 hyperthyroid patients were initially studied by the potassium thiocyanate discharge test in which the patient is medicated with 40 milligrams tapazole simultaneously with the diagnostic ^{131}I tracer dose. A baseline uptake test is done three hours later, followed immediately by oral administration of 1 gram potassium thiocyanate. Uptake measurements are then done three times at 30-minute intervals, to follow the release of free iodide from the thyroid gland into the blood causing a sharp fall in the activity in the thyroid region. Comparison of the last uptake, one and a half hours after potassium thiocyanate administration, with the three-hour baseline uptake in the 21 patients yielded and average level of 15.9 percent, but three patients showed exceptionally high values (32.1 percent). These three patients may be considered as demonstrating failure of the antithyroid drug to supress thyroid hormone synthesis effectively. For the other 18 patients the average level was 12.9 percent. Of three other patients in whom refractoriness to antithyroid medication was clinically suspected, two gave values in the high range (34.8 percent). Additional observations will be made on patients in phase II of the study.

Determination of Thyroidal Plasma ^{131}I Clearance Rates. The purpose of this study is to test the results of this routine method for the determination of thyroid function (originally described by Berson and Yalow). Should it prove advantageous, it would be used at PRNC. ^{131}I is injected intravenously, and one-minute counts are recorded over the neck during 30 minutes. The ability of the thyroid gland to clear a volume of plasma of its iodine content per unit time,

as a measure of function, is calculated from the half-hour uptake data and the iodide space of ^{131}I dilution (25 percent of body weight). This determination is considered to offer the most sensitive index of the iodine accumulating capacity of the thyroid gland. Since other methods yield values showing considerable overlap, particularly in the hypothyroid-euthyroid range, it would be clearly advantageous to have an assay that would permit a better-defined delineation.

Application of Activation Analysis to Thyroid Disorders. The purpose is to develop a method of determining thyroid function by quantitative analysis of protein-bound iodine by neutron activation. Blood samples are obtained from patients coming to the laboratory for routine radioisotopic tests of thyroid function, which include thyroid uptake and radioactive blood hormone levels. Blood collected is passed through an ion-exchange resin column and then sent to Mayaguez for activation in the reactor. These samples are then analyzed for the presence of ^{131}I in the protein fraction. Protein-bound iodine as determined by activated iodine levels are then correlated with the clinical condition of the patients and with other radioisotopic measurements. This method is potentially advantageous, because its sensitivity is comparable to that of the chemical method for determining protein-bound iodine. This project is just being started.

The Renogram in Patients with Carcinoma of the Cervix Uteri. The purpose is to evaluate the functioning of the urinary tract in patients with carcinoma of the cervix uteri in the followup period after radiotherapy in order to detect early changes indicating dysfunction of urinary drainage before irreversible damage to the renal parenchyma, so that urogical treatment may be started early. Serial renograms using ^{131}I-oiodohippuric acid are done at intervals depending on the stage of the disease; stage I carcinoma is followed up once every six months, and stage IV every four weeks.

Instrumentation: Modified Scanner. The scanning equipment has been modified by the addition of an x-ray facility to permit collection of isotopic data on radiographic film in combination with radiographic examination of the region under analysis. Isotopic localization in organs and tumors can be done by double successive exposure of the same film without moving the patient or the film. With this adaptation it has been possible to obtain combined photo-scintigraphic and radiographic images. The study of an area by isotopic localization is enhanced when the final record of the data is presented with the anatomic background obtained by radiography. The method has been particularly useful in elucidating spatial relationships of clinically

palpable masses in the neck (in the thyroid region) and the thyroid gland, in the differentiation of masses of vascular and nonvascular origin in the mediastinum, in brain tumor localization, and so on. (See Figure 6.)

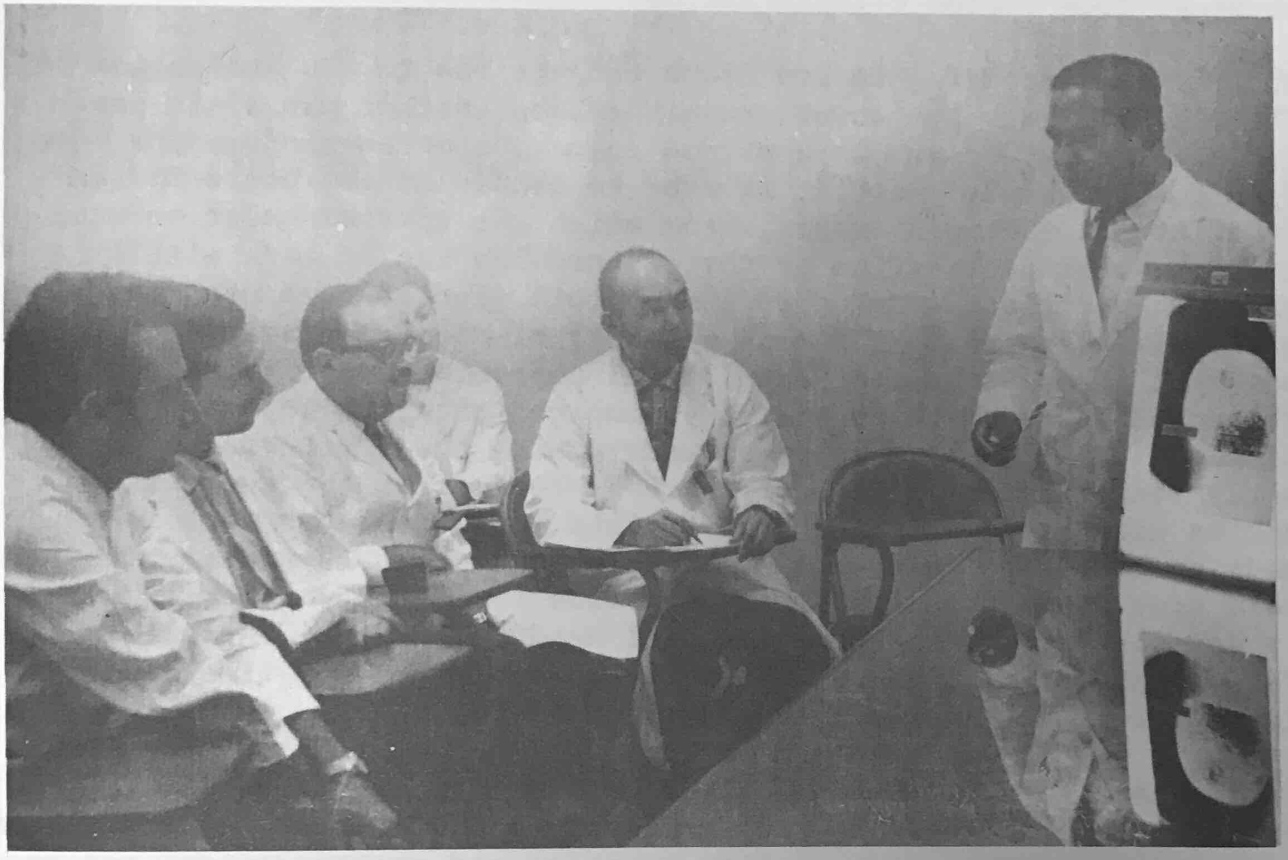


Figure 6. Dr. Sergio Irizarry (right) discussing the techniques utilized for tumor localization during a clinical session.

Organ and Tumor Localization. The purpose is to learn the normal and abnormal patterns of distribution of isotopically labeled substances, to correlate clinical findings with isotopic localization patterns, and to seek information applicable to clinical diagnosis and therapy. Isotopic localization is performed by an automatic isotopic scanner with a paper dot printout recorder and photoscanner. In some instances, a paper dot registration and simple photoscan image with radiography is obtained. The following organs can be examined: thyroid, heart, kidneys, liver, brain, pancreas, parathyroid, and spleen, with a variety of labeled substances including ^{131}I-albumen and ^{203}Hg-Chlormerodrin for brain neoplasms, ^{131}I for thyroid studies, ^{131}I-albumen for visualization of the cardiac blood

pool, ^{131}I-rose bengal for liver and gall bladder, ^{75}Se-methionine for pancreas and parathyroid, ^{203}Hg-Chlormerodrin for kidneys, and ^{51}Cr for the spleen. Enhanced contrast is obtained with photoscan records, and the advantage of radiography strengthens the image obtained from isotopic localization.

The Value of Scanning in Two Plane Projections in the Evaluation of Thyroid Nodules. The scintigraphic method, either the plain paper dot graphic method or the combined gamma photoscan-radiography (gamma radiography) method, is used to obtain antero-posterior and true lateral isotopic images, from which the spatial relation and isotopic characterization of thyroid nodules can be made with greater precision. More than 100 thyroid studies have been made with this technique. The vast majority of nodules examined by the combined antero-posterior and lateral approach appear to have decreased activity or no activity compared with the adjacent thyroid tissue. This has been well documented with the additional help of x-ray localization studies of the soft tissues of the neck in combination with isotopic mapping of thyroid lesions. An effort is being made to correlate this with findings at surgery. If present findings hold true, then the scintigraphic evaluation of thyroid enlargement by antero-posterior examination will need reappraisal. Preliminary data suggest that findings by antero-posterior examination alone are insufficient for isotopic localization of thyroid nodules.

Brain Tumor Localization. The purposes are to evaluate the efficacy of brain tumor localization by means of isotopic detection by the use of automatic gamma scintillation scanning and photoscanning, and to compare the usefulness of different radioactive labeled substances in detecting tumors. Patients are scanned after the injection of a suitable material, Neohydrin labeled with ^{203}Hg or ^{131}I-albumen. After injection, the patient is scanned for two to six hours the first day in three different positions, frontal and lateral. If the substance used is ^{131}I-albumen, scans are repeated at daily intervals for one, two, or three days after injection, if the previous tracings indicate further study. Whenever possible, the patient undergoes scans first with one substance and then with the other, and the findings are compared to assess the advantages of each substance as shown in the type of tracings obtained. The brain scanning findings will be correlated with the results of surgery and other neurosurgical and neurologic techniques of evaluation. Seven intracranial intracerebral tumors documented by surgery were detected by brain scanning prior to operation. One out of two intracranial extracerebral tumors (pituitary chromophobe adenomas) was detected prior to operation. One extracranial tumor (pharyngeal rhabdomyosarcoma) was not detected

prior to surgery. This is a painless method of brain tumor localization which may provide useful data before surgery. It may also be of value in guiding radiotherapy treatment when indicated. It may be the only *in vivo* method of documenting the disappearance or recurrence of the lesion after therapy.

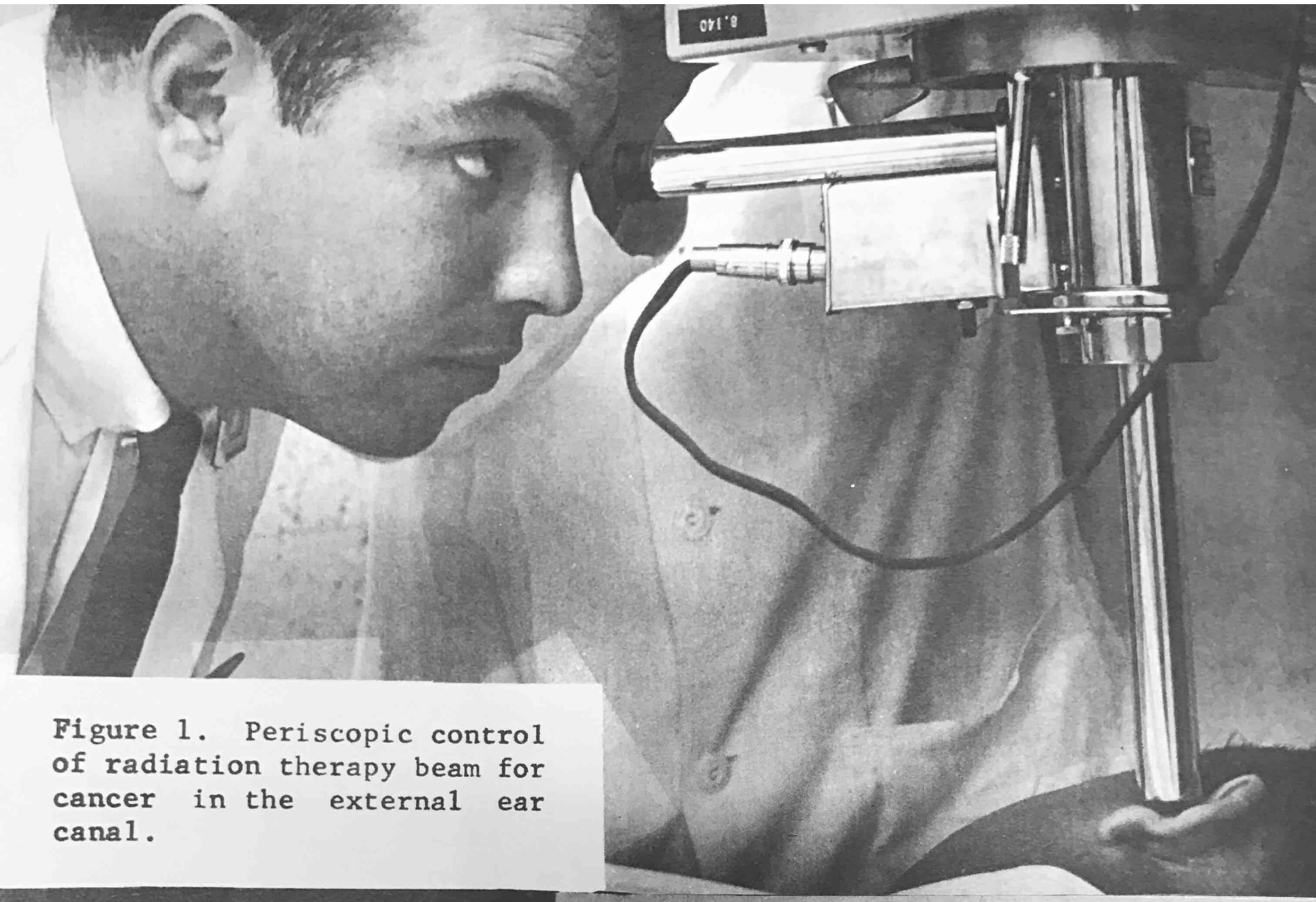
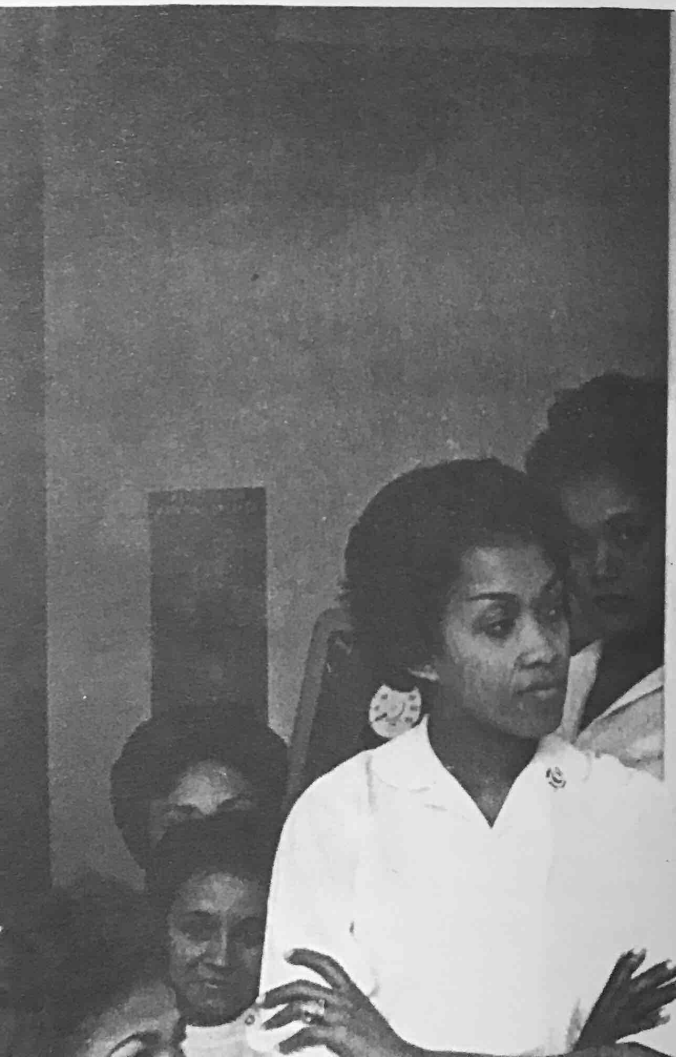
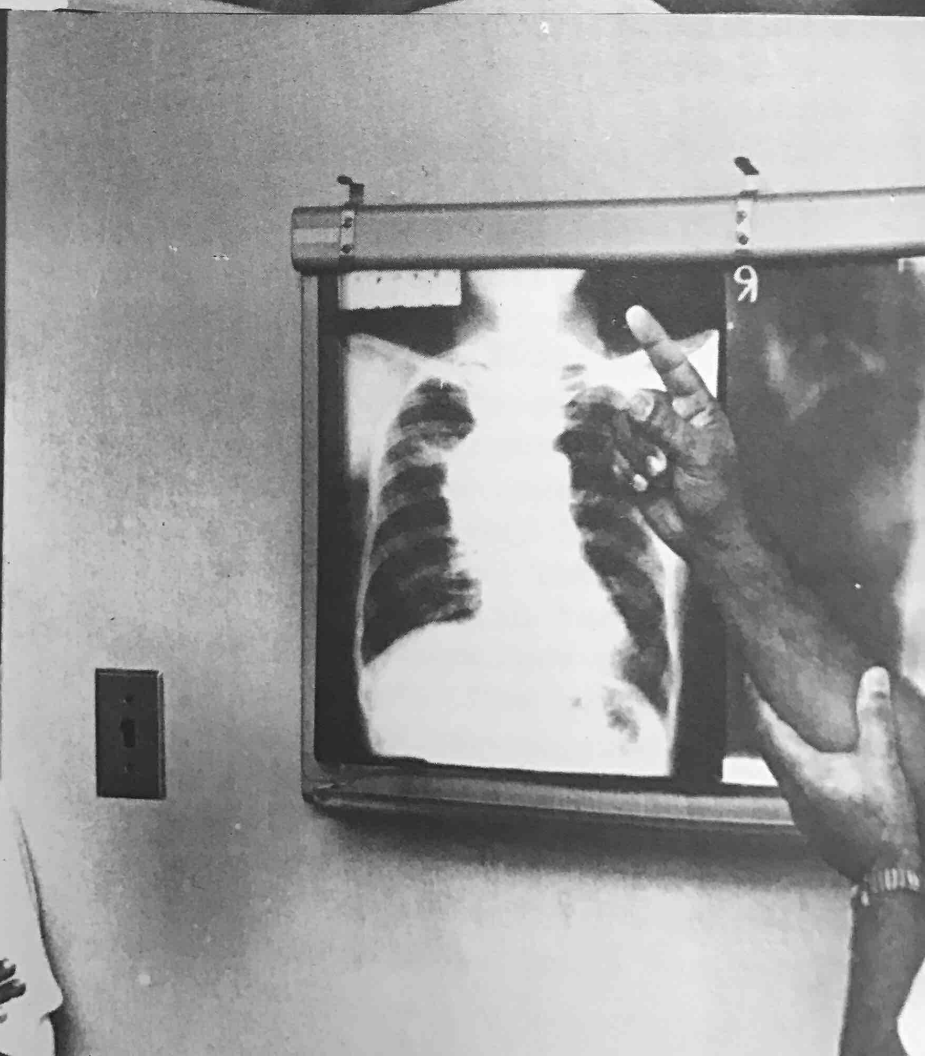


Figure 1. Periscopic control of radiation therapy beam for cancer in the external ear canal.





RADIOTHERAPY AND CANCER DIVISION

Víctor A. Marcial, M. D., Head

During the year 1965 the Radiotherapy and Cancer Division continued its main activities - education, research, and service in the areas of radiation therapy and cancer. Education is carried out through formal programs and courses offered regularly to physicians and other medical personnel, as described briefly below.

The Radiotherapy Residency Program is designed to prepare qualified radiation therapists and meets the requirements of the American Board of Radiology. The trainees are physicians with a year of internship or equivalent clinical experience. The training period is three years, but trainees are required to take an additional fourth year of supervised practice (preceptorship) before admission to the specialty examinations. Diagnosis of cancer, determination of extent and radiosensitivity of tumors, selection of appropriate treatment, and the planning and conducting of radiological therapy are included in the curriculum. Background in clinical oncology is imparted to residents through supervised work with new, followup, and hospitalized cancer patients. Radiation therapy experience is acquired by working with roentgentherapy machines of various voltages, cobalt teletherapy units, cesium units, and application of radioactive material such as radium, strontium, cobalt, and iridium.

The special short-term radiotherapy training course is prepared according to the needs of the individual desiring training. Participants may engage in research and may participate in all training activities of the Division, but they are not given responsibility for patients.

The cancer course for medical students is designed to acquaint future physicians with clinical problems in cancer and radiation therapy and with current research in these fields.

The Radiotherapy and Cancer Division continues its collaboration with the Puerto Rican League Against Cancer by serving as the Radiotherapy Department of the Dr. I. González Martínez Oncologic Hospital, which is adjacent to the Puerto Rico Nuclear Center Bio-Medical Building in the Puerto Rico Medical Center. At the academic level the Division functions as the radiotherapy section

of the UPR School of Medicine. It also works in close association with the cancer control program of the Commonwealth of Puerto Rico Department of Health.

The Radiotherapy Residency Program continued to be the principal training activity. Residents learned about clinical cancer and radiotherapy by rotation through the various sections of this Division: the PRNC treatment area, Oncologic Hospital treatment area, radium and in-patient section, and the followup section. They also rotated through the radiological physics section and the Department of Pathology of the Oncologic Hospital. In addition to direct patient contact under supervision, residents were given demonstrations and lectures on cancer and radiotherapy and participated in seminars.

The regular academic staff of the Radiotherapy and Cancer Division during 1965 was composed of five fully certified radiotherapists, a visiting radiotherapist who received certification during the year, one physicist, an assistant physicist, and a bio-statistician. The training program was enhanced by the visits of consultants from other institutions, each of whom spent several days here. They are listed below.

Maurice Lenz, M.D.
Professor Emeritus of Radiation Therapy, Francis Delafield Hospital, Columbia University School of Medicine, New York

Gilbert Fletcher, M.D.
Chief, Radiotherapy Department, University of Texas, and M.D. Anderson Hospital and Tumor Institute, Houston

Henry S. Kaplan, M.D.
Chairman, Radiology Department, Stanford University School of Medicine, Palo Alto

Michel Ter-Pogossian, Ph.D.
Professor of Radiation Physics, Washington University School of Medicine, St. Louis

Frank Kelly, M.D.
Radiotherapist, Christie Hospital and Holt Radium Institute, Manchester, England

John E. Ultman, M.D.
Assistant Professor of Medicine, Institute of Cancer Research, College of Physicians and Surgeons, Columbia University, New York

Additional support for the program was obtained from a National Cancer Institute training grant through the UPR School of Medicine. The Residency Review Committee for Radiology, representing the American Board of Radiology and the Council on Medical Education, continued approval of the radiology residency program at the University of Puerto Rico affiliated hospitals, including the Dr. I. González Martínez Oncologic Hospital, the University Hospital, and the Veterans Administration Hospital. The radiotherapy part of this training program is offered at the Radiotherapy Department of the Oncologic Hospital and the PRNC Radiotherapy and Cancer Division.

The persons who received training in the programs and courses offered by this Division are listed in Table 1.

In addition to the regular training program offered, the staff participated in the teaching programs of other PRNC divisions. A series of lectures on radiotherapy and cancer was offered to the third-year class at the UPR School of Medicine. Dr. Antonio Bosch is directing a special training program for radiotherapy technicians, which is being offered under the auspices of the Dr. I. González Martínez Oncologic Hospital with the help of the staff of this Division. Medical services are listed in Table 2.

Dr. Jeanne Ubiñas and Dr. Graciela Serna Maytorena passed the examination for certification in radiotherapy and nuclear medicine given by the American Board of Radiology in San Francisco in June.

Dr. Jeanne Ubiñas was appointed Director of the cancer control program of the Puerto Rico Department of Health starting July 1, 1965, replacing Dr. Víctor A. Marcial, who resigned as Director but remains a consultant. She had been Assistant Director the previous year. Dr. Graciela Serna, from Guadalajara, returned to Mexico after spending one year here as Visiting Radiotherapist. Dr. Víctor A. Marcial continued as one of the ten members of the Committee for Radiation Therapy Studies sponsored by the National Cancer Institute; has been named chairman of the Subcommittee for the Study of Time-Dose-Fractionation in Radiation Therapy; was named Counsellor for Puerto Rico to the Radiological Society of

TABLE 1

Radiotherapy and Cancer Division Trainees, 1965

RADIOTHERAPY RESIDENCY PROGRAM

Arturo Valencia Serna, M.D., Colombia
January 1, 1963 - December 31, 1965
(Now Radiotherapy Resident, Buffalo General Hospital)

Felipe N. de Jesús, M.D., P.R.
July 1, 1964 - June 30, 1965
(Now Radiology Resident, University Hospital, San Juan)

Restituto Alvarez, M.D., P.R.
July 1, 1965 -

Juan A. Castro Barnés, M.D., P.R.
July 1, 1965 -

Sylvio Antonio Ariztizábal, M.D., Colombia
August 2, 1965 -

SPECIAL SHORT-TERM RADIOTHERAPY TRAINING

Delia B. Giudici, M.D., Argentina
September 1, 1965 -

CANCER COURSE FOR MEDICAL STUDENTS

Carlos R. Baeza Muñiz, P.R.
February 1-28, 1965

Rafael A. Burgos Calderón, P.R.
March 1-31, 1965

José M. Marina Cortés, P.R.
June 1-30, 1965

Gilberto E. Rodríguez Vélez, P.R.
July 1-31, 1965

Luis A. Marrero Torres, P.R.
September 1-30, 1965

Angel Luis Rivera Ortiz, P.R.
October 1-31, 1965

Héctor M. Hernández Alvarez, P.R.
Jan. 2 - Feb. 1; June 1-30, 19

Fermín C. Miranda Hernández, P.R.
August 1-31, 1965

Domingo Cordero, P.R.
May 3-31; June 1-30, 1965

Francisco M. Dubocq Ventura, P.R.
May 3-31, 1965

TABLE 2

Medical Services

	Number of Cases
1. Distribution, by Site, of Cancer Patients Treated With Radiation, January to December 1965 (New Teletherapy Cases)	
Cervix Uteri	161
Breast	68
Ovary	10
Endometrium	16
Female genital, other	3
Pharynx	48
Tongue	29
Floor of mouth	17
Palate	14
Oral cavity, other	17
Lung, bronchus, trachea	17
Larynx	17
Respiratory, other	13
Esophagus	77
Gastrointestinal, other	8
Hodgkin's disease	13
Lymphomas, other	22
Bladder	9
Urinary, other	7
Male genital	6
Brain and nervous system	4
Soft-tissue sarcomas	5
Bone and connective tissue	8
Skin	57
Other	44
Total	690
2. Teletherapy Applications (^{60}Co - x-ray)	19016
3. Curietherapy (^{60}Co, radium, iridium)	230
4. Followup	5402
5. Medical Records Handled	3656
6. Clinical Records Coded	366

North America; and was a member of the Subcommittee for Clinical Services of the Puerto Rico Medical Center, and Counsellor for Puerto Rico to the Inter-American College of Radiology. Dr. José M. Tomé served as a member of the State Examining Board for X-Ray Technicians and as a member of the Education Commission of the Inter-American College of Radiology. Dr. José N. Correa assumed direction of the radiobiological research in the Division on July 1, 1965.

The members of this Division presented scientific papers at medical meetings in Puerto Rico and at national and international meetings. These, as well as papers published, are listed in the Appendix.

The research effort was more intense this past year with 14 projects under study, of which five were completed. In May a mouse chondrosarcoma was brought from the National Cancer Institute for use in in vivo and in vitro radiobiological studies under the direction of Dr. José N. Correa. With the new animal house becoming operative, an increase in radiobiological research was possible.

RESEARCH PROJECTS

1. Evaluation of Radiation Response by Means of Exfoliative Cytology in Cases With Cancer of the Cervix Treated with Radiation. The objective of this study, in operation since fiscal 1961, is to evaluate exfoliative cytology as a tool for determining the prognosis in cases with carcinoma of the cervix treated with radiation. The laboratory part of this project has been discontinued in this Division, but the study has continued in collaboration with the Cytology Laboratory of the Puerto Rico Department of Health. Results of a two-year followup on 244 cases, correlating the presence of tumor cells in the vaginal smear at the end of irradiation and at one, two, four, six, and twelve months after therapy, were presented in the Annual Report 1964, page 47. Next to be analyzed will be the correlation with the prognosis of the percentage of cells with radiation response in the normal vaginal epithelium during radiotherapy. The energy and dose of radiation, age and menopausal status of the patient, and stage of the disease will be related to three- and five-year survival.

2. Incidence of Leukemia in Patients With Cervical Cancer Treated With Radiation. This is an international study conducted in collaboration with the Gynecology Department of the Oncologic

Hospital and the Department of Pathology of the UPR School of Medicine. The objective is to determine the risk of developing leukemia in patients irradiated for cancer of the uterine cervix. A review of the international data early in the fiscal year showed that 57,000 person years have been considered and that three cases have developed leukemia. The incidence corresponds to that expected in a normal population. Data on a total of 931 patients have been contributed to this study by PRNC as of December 1965.

3. Fractionation of Weekly Doses in Cancer Patients Subjected to Irradiation. The objective of this clinical study is to determine optimal fractionation of weekly tumor doses in patients being irradiated for cancer. Half the patients are receiving the weekly dose in three applications and the other half in five. Effect on the tumor, on survival, and on normal tissue reactions are being observed. So far, 1033 patients have entered the study, and a clinical review of the cases with a minimum of one year followup has shown that three applications per week are as well tolerated as five. Better tumor response has been observed with three applications per week when treating oropharyngeal tumors and carcinoma of the cervix, stage III.

4. Control Study of the Split-Dose Technique in Radiotherapy of Cancer. The purpose of this study is to compare the results obtained by the usual uninterrupted treatment (6000 R in six weeks) with the results obtained by a similar dose given in two separate periods (3000 R in two weeks plus two to three weeks' rest plus 3000 R in two weeks). Tumors measuring 5 cm or more, excluding those in the pelvis and esophagus, are included. Half the cases are being treated by each technique. Results will be evaluated in terms of tumor regression, normal tissue reactions, and curability. From January 1964 to December 1965, 75 patients have been included in this study.

5. Study of the Optimal Dose to the Tumor in Radiation Therapy for Cancer of the Esophagus. This clinical study to determine the optimal radiation dose to the tumor in the treatment of cancer of the esophagus began in July 1963. In terms of disappearance of dysphagia and twelve-month survival, it appears that 5000 R given in four weeks gives better results than 6000 R in six weeks. As of December 1965, 127 patients have been included in this project.

6. Lithium Fluoride Dosimetry in Radiotherapy. The objective of this study is to test the usefulness of lithium fluoride dosimeters

in radiation therapy. Measurements in cavities such as the vagina and in the Rando phantom have been conducted to compare the Victoreen R-Chamber model 131 and lithium fluoride dosimeters. The following radiological physics projects have been completed: (a) studies of the penumbra of the cobalt-60 El Dorado 8000-curie therapy unit at PRNC, and of the cobalt-60 Junior Theratron 3000-curie unit source and the cesium-137 2200-curie unit source at the Oncologic Hospital (these included studies of the penumbra extension at the level of the skin and at depths of 2.5, 5, 7.5, and 10 cm); (b) study of the radiation field homogeneity of the cobalt-60 El Dorado unit; (c) comparative study of two rotational therapy techniques practiced with the cobalt-60 Junior Theratron unit at the Oncologic Hospital; (d) study of the dose distribution in pelvic treatment fields of the 300-kv Maxitron therapy unit at PRNC.

7. Adjuvants to Surgical Treatment of Breast Cancer. This is a national project being conducted in collaboration with the Surgical and Pathology Departments of the Oncologic Hospital, and is described in the Annual Report 1964, page 47. Data are to be accumulated for at least five years before final analysis. A total of 47 cases have been contributed to this project so far.

8. Carcinoma of the Cervix Uteri in Sterilized Women. The aim of this study is to analyze the possible relationship between carcinoma of the cervix uteri and previous surgical sterilization. It has been observed that in patients under 50 years of age with carcinoma of the cervix uteri, 27 percent have been surgically sterilized. The significance of this finding is being evaluated by comparing data regarding sterilization taken from a hospital cancer population with data from a sample of the normal population. The latter data will be obtained from the Master Health Sample Survey of the Puerto Rico Department of Health.

9. Relative Biological Effect (rbe) of Irradiation With X-Rays, Cobalt-60, and Cesium-137 in Mice. The results of several experiments in which newborn mice were irradiated with cobalt-60 or with 300-kv x rays suggest a greater rbe for the latter, the LD_{50} with x rays being approximately half that with cobalt-60. Preliminary experiments with young adult mice have also been done with 120-kv x rays and cobalt-60, the results of which are as yet incomplete. In a recent experiment newborn mice were irradiated with ^{137}Cs to establish the LD_{50} with this type of beam. It would be of interest to repeat the experiments with 300-kv x rays to confirm the results

and at the same time to obtain lithium fluoride dosimetry as verification. Young adult mice will also be irradiated with the ^{137}Cs unit and the 300-kv x-ray unit when this can be arranged at the Oncologic Hospital.

The following projects have been completed.

1. Adenocarcinoma of the Cervix Uteri. This retrospective clinical study was made to determine whether adenocarcinoma of the cervix uteri is more radioresistant than epidermoid carcinoma of this structure. Analysis of data from 76 patients showed that the five-year survival in this group was no different from that encountered in cases of epidermoid carcinoma. It is noteworthy that in all stage I cases treated from October 1956 to the end of 1960, the disease has been controlled with irradiation.

2. Lymphangiography in Cancer Patients. Early in fiscal 1965 lymphangiography was introduced as a method of helping the radiotherapist localize malignant lesions prior to irradiation, as described in the Annual Report 1964, page 50. So far, 18 lymphangiographic studies have been made, and the technique has proved of great value in cases with lymphona or carcinoma of the uterine cervix.

3. Cancer of the Breast and the Role of Radiation Therapy in its Management. This retrospective clinical study was made to determine the value of radiation therapy in the management of breast cancer. Data were analyzed on patients from the Radiotherapy Department of the Oncologic Hospital with a minimum followup period of five years. The results were presented at a symposium of the Puerto Rican Chapter of the American College of Surgeons in February 1965.

4. Orthovoltage Versus Supervoltage in the Treatment of Cancer of the Uterine Cervix. Carcinoma of the uterine cervix is the most frequent neoplasm encountered in the Latin American woman. Its incidence in Puerto Rico has fluctuated between 37.2 and 35.0 per 100,000 women during the past three years. The Oncologic Hospital in San Juan, which serves approximately two thirds of the indigent cancer patients in Puerto Rico, managed 334 cases with invasive cervical cancer from 1958 to 1960; radiotherapy was the treatment of choice. One group was treated with orthovoltage and another with cobalt-60 supervoltage preceding curietherapy. Results obtained with these two modalities of treatment have been analyzed. The group treated with cobalt-60 supervoltage in general fared

better than the group treated with orthovoltage, particularly the stage III and IV cases. In early stage I and II cases the results were similar in the two groups.

5. Carcinoma of the Floor of the Mouth: Review of Clinical Factors and Results of Treatment. Carcinoma of the floor of the mouth is the second most frequently encountered cancer of the oral cavity in Puerto Rico (after carcinoma of the tongue). Experience with cancer of the floor of the mouth (145 cases) at the Oncologic Hospital during the 25-year period 1940 through 1964 has been reviewed. An analysis of the incidence and etiologic factors was included. Results of three- and five-year clinical control were evaluated according to the stage of the disease and the different modalities of treatment, including external irradiation alone or with interstitial curietherapy, curietherapy alone, and surgery with or without irradiation. The highest control rate was obtained with external radiotherapy combined with interstitial curietherapy. Cases treated with interstitial iridium-192 were also included. The complications resulting from treatment were also analyzed, including their management and probable causative factors. The final results will be presented at a meeting of the American Radium Society in Tucson, Arizona, in April 1966.

6. Osteonecrosis. The problem of radionecrosis has been reviewed by Dr. Graciela Serna, visiting radiotherapist from Mexico. She has reviewed cases with cancer of the head and neck, breast, and pelvis who have received irradiation and has noted the cases of resulting radionecrosis. This complication was encountered in 7.5 percent of 131 cases with lesions of the floor of the mouth, in three out of 147 patients with breast cancer, and in one out of 2063 cases with carcinoma of the cervix.

7. Carcinoma of the Cervix Uteri in Pregnancy. The purpose of this retrospective study was to determine the incidence of carcinoma of the cervix associated with pregnancy and its optimal management. In a group of 2736 cases of uterine cancer treated at the Oncologic Hospital, 66 cases were associated with pregnancy. The optimal treatment has been determined by reviewing the cases, and the results were presented at a meeting of the American Radium Society in New Orleans in April 1965.

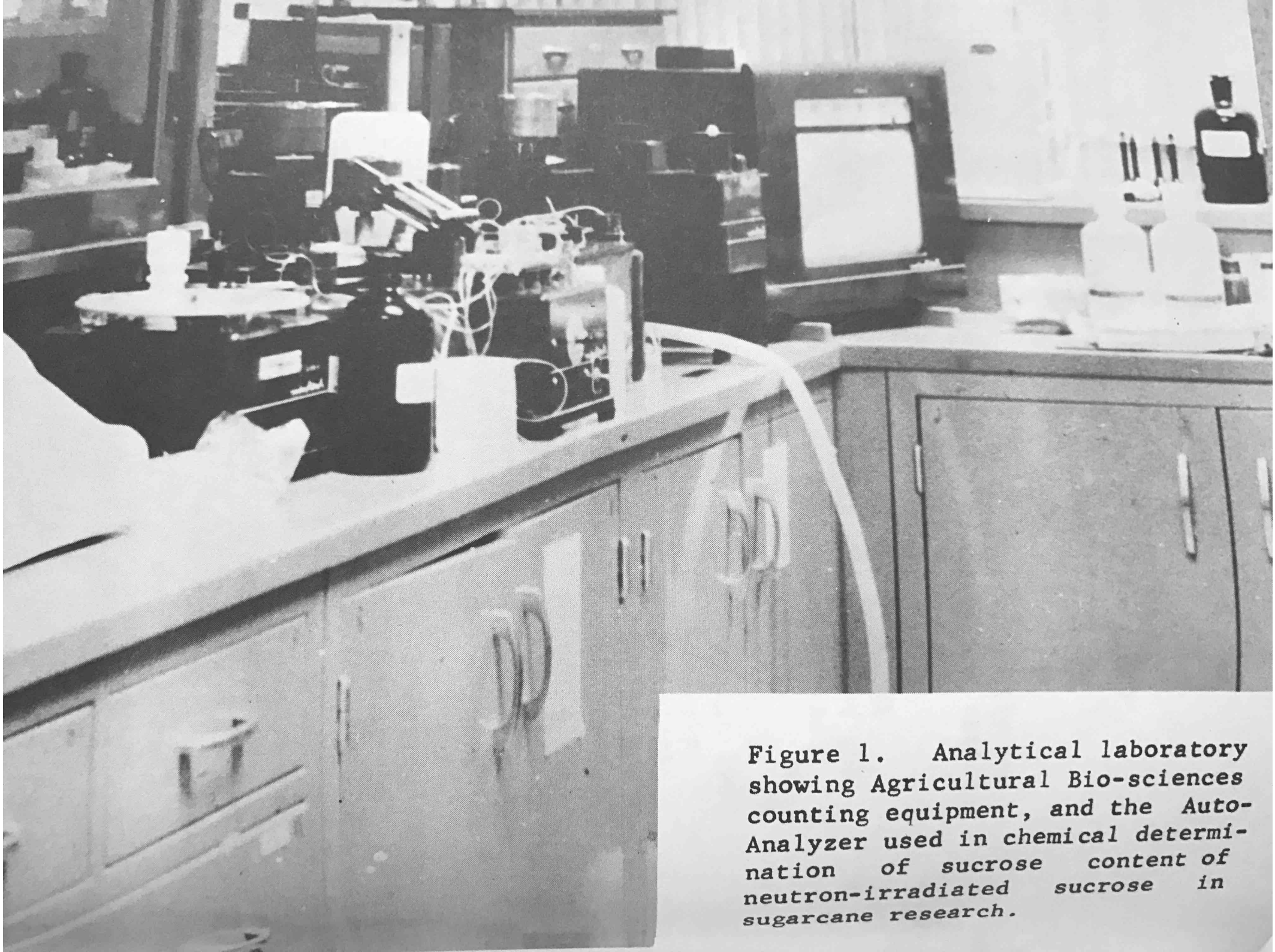


Figure 1. Analytical laboratory showing Agricultural Bio-sciences counting equipment, and the Auto-Analyzer used in chemical determination of sucrose content of neutron-irradiated sucrose in sugarcane research.

AGRICULTURAL BIO-SCIENCES DIVISION

Robert A. Luse, Ph. D., Head

EDUCATION AND TRAINING ACTIVITIES

In order to further the application of nuclear technology in the agricultural and biological sciences, the Agricultural Bio-Sciences Division has as one of its functions the training of students in agricultural research in its broadest sense with emphasis on nuclear techniques. Students are accepted for training at the undergraduate, graduate, and postgraduate levels. Division staff hold ad honorum University appointments.

At the undergraduate level, staff members offer certain general courses that are necessary for advanced work. In 1965 the following courses were offered:

Biology 253, Biochemistry of the Cell, Dr. A. Maretzki.

Biology 372, Nuclear Techniques in Biological Research, Dr. R. A. Luse. (Also may be taken for credit toward an M.S. degree.)

In addition, the staff contributed lectures and laboratory sessions in radioisotope techniques and radiobiology to the Nuclear Center basic course in radioisotope techniques, to the UPR radiochemistry course, and to the UPR School of Medicine courses in biochemistry.

At the graduate level, advanced courses are offered, often closely related to the student's research thesis. Courses given this year were the following:

Biology 379, Advanced Radiobiology, Dr. R. A. Luse.

Biology 618, Cytogenetics, Dr. F. K. S. Koo.

Biology 699, Thesis Research in Nuclear Biology, Staff.

Five students currently are working toward M.S. degrees in biology from UPR. Their research topics reflect the broad interests of the Division:

Radiopasteurization of Mangoes (Mr. J. Cuevas, Puerto Rico).

Synergistic Effects of Chemicals and Gamma Radiation in Producing Chromosome Breaks (Mrs. E. Robles de Irizarry, Puerto Rico).

Radiation Inactivation of the Enzyme Polyphenol Oxidase (Mrs. A. García de Fournier, Puerto Rico).

Influence of Ionizing Radiation on Methionine Utilization by E. coli (Mr. F. E. Rushford, Puerto Rico).

Uptake and Retention of Zinc-65 in Penicillus capitatus and Udotea flauellum (Mr. Ramos, Puerto Rico; under Dr. Frank Lowman, Head of the Marine Biology Program).

Four students who completed M.S. degrees under the auspices of the Agricultural Bio-Sciences Division are now working toward Ph.D. degree studies in the United States:

Vicente Julio Medina (Uruguay) at University of Georgia, Athens.

Vicente Rodríguez (El Salvador) at Iowa State University, Ames.

Flavio Padovani (Puerto Rico; M.S., May 1965) at Louisiana State University, Baton Rouge.

Ariel Lugo (Puerto Rico; M.S. thesis done under Dr. H. T. Odum, Head of the Rain Forest Project) at University of North Carolina, Chapel Hill.

It is expected that the flow of students taking M.S. degrees under the direction of the staff will increase, since M.S. degree programs have now been established in the Departments of Biology in Río Piedras and in Mayaguez.

At the postgraduate level, research projects designed specifically to meet the students' needs are offered. During the past year, four persons have carried out postgraduate (i.e., beyond the M.S. degree) research with Division staff. In all cases, financial support for these students was derived from sources other than PRNC.

Mr. Loh Kong, IAEA Fellow from Taiwan, started twelve months' training in April 1965 in radioisotope techniques useful in sugarcane research. In particular, he has carried out field and pot tests designed to show the nature and extent of nutrient uptake by the sugarcane plant and

how soil factors (moisture, pH) affect such uptake and distribution. These experiments have used the radioisotopes ^{32}P, ^{35}S, and ^{65}Zn. Mr. Kong will return to continue research work at the Taiwan Sugar Experiment Station.

Dr. R. A. Luse has served on the thesis committee for Mr. Robert F. Smith, ORINS Graduate Fellow, since September 1964. Mr. Smith is completing a Ph.D. thesis to be submitted to the University of Georgia, covering research which he has done in conjunction with the Rain Forest Project.

Dr. Shreekant N. Deshpande, of the Department of Isotope Technology, Tuskegee Institute, was an ORINS Summer Research Participant in the Division from June to September, engaged in biochemical studies of the softening processes in mangoes following gamma irradiation.

Dr. Luis H. Meyer, a chemical engineer from Uruguay, is spending a four-month period in this Division starting in November 1965, studying radioisotope applications in tropical agriculture. This study involves an introduction to agricultural practices in Puerto Rico, followed by an intensive research problem, which deals with the effect of various wetting agents on the foliar uptake by sugarcane of ^{32}P-labeled phosphate fertilizers. Foliar application of fertilizers to sugarcane by aerial spraying is becoming increasingly common in Puerto Rico and could be of considerable importance to agronomic practice in Dr. Meyer's home country. Support for this training was through an OAS fellowship.

A further contribution to the Center's training in biology at the graduate level has been provided by the Rain Forest Project. Under the direction of Dr. H. T. Odum, several students have carried out experiments which are being used to fulfill degree requirements at universities in the United States: (See Figure 2.)

James T. Holler, for Ph.D., University of North Carolina.

Barbara Bannister, for Ph.D., University of North Carolina.

Robert F. Smith, for Ph. D., University of Georgia.

Peter Murphy, for M.S., Syracuse University.

As a part of the PRNC participation in the US AEC International Exhibits Program, four Division staff members served as scientific advisors with the Atoms in Action Exhibit in El Salvador in March

Figure 2. Edith Irizarry is examining changes in the volume of the nuclei of plant cells following gamma irradiation, as part of the Terrestrial Ecology Project.

and April and in Guatemala in August and September, as follows:

Name	Place	Period	Topic
Dr. D. B. Linden	El Salvador	2 weeks	Food irradiation
Dr. H. D. Graham	Guatemala	2 weeks	Food irradiation
Dr. R. A. Luse	Guatemala	2 weeks	Radioisotope applications
	El Salvador	4 days	Radioisotope applications
	Costa Rica	3 days	Radioisotope applications
Dr. D. W. Walker	El Salvador	3 weeks	Insect sterilization
	Guatemala	2 weeks	Insect sterilization

This opportunity for contact and cooperation with Central American scientists will assuredly increase the use of nuclear techniques in Central American agriculture.

RESEARCH ACTIVITIES

The second function of the Agricultural Bio-Sciences Division is to carry on basic research on problems in tropical agriculture that can uniquely be studied by nuclear techniques. Division research falls into four main categories:

1. Radiobotany of Sugarcane. To increase the economic return from sugarcane (Puerto Rico's most important crop), the induction of plant mutants with high sucrose content is being done by Dr. R. A. Luse. Initial experiments to determine the radiosensitivity of seeds and buds to thermal neutrons produced in the PRNC megawatt reactor were completed in 1964. Subsequently, thousands of seeds and vegetative buds have been irradiated, germinated, and planted in the field. Mass chemical screening for sugar content in the individual plants produced is being carried out via automated analytical techniques. Visible mutations such as wider, stiffer leaves indicate that other favorable characteristics may be induced. Superior mutants will be propagated and evaluated in the program of the University Agricultural Experiment Station for crop breeding and improvement. Further details may be found in the Annual Report 1964. (See Figures 3 and 4.)

A similar program concerned with the induction of resistance in sugarcane to the mosaic virus disease was started this year by Dr. F. K. S. Koo. Nearly a thousand plants have been grown from irradiated seed, and these will be mass screened by artificial infection with the virus. (See Figures 3 and 4.)

2. Radioisotope Studies in Sugarcane. Important studies of both immediate and long-range application have been made on sugarcane through the use of radioisotopes. Several field and greenhouse experiments concerned with agronomic practice are in progress. For example, the effect of soil factors (pH, density, moisture content) on the nutrient uptake and utilization of phosphates, sulfates, and trace elements is being determined. In a second project the enhancement of foliar absorption of phosphates by wetting agents is being measured by Mr. J. Roldán and Dr. L. H. Meyer. The extent of ^{32}P uptake by sugarcane leaves has been determined in a series of tests having the experimental variables (a) type of wetting agent (anionic, nonionic, cationic), (b) concentration of wetting agent, (c) pH of applied solution, (d) cation associated with the phosphate, and (e) time after application. In all cases, there was a considerable enhancement of foliar absorption in the presence of the wetting agent - a fact that has an important bearing on the agronomic practice of aerial spray application of fertilizers.

Studies of mineral cycling in tropical crops are under way. With use of ^{65}Zn, the extent of the following cycle in sugarcane is being measured:

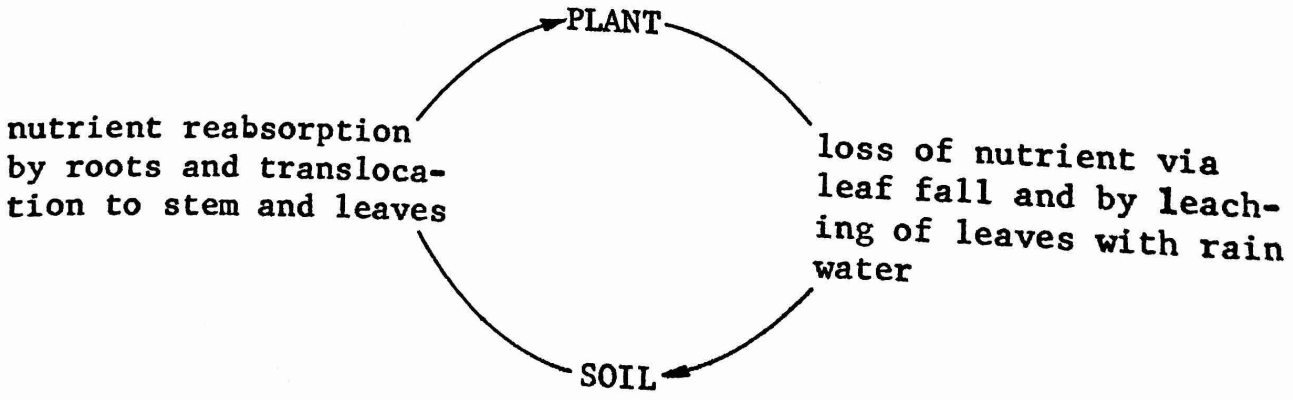


Figure 3. Field workers are cultivating sugarcane that has been neutron irradiated for selecting high sucrose strains.

Figure 4. Field workers are cultivating gamma irradiated sugarcane in the mosaic virus program.

The enzymatic degradation of sucrose in the sugarcane plant by invertase was the subject of biochemical investigation by Dr. A. Maretzki. Factors that control invertase formation have been determined by measuring the incorporation of added ^{14}C-labeled amino acids into the protein fraction of sugarcane meristem tissue. Cofactors such as magnesium ion have been found essential for this incorporation; protein formation is considerably reduced by the presence of sulfhydryl compounds. To supplement this work, identification of nucleotides found in such tissue was carried out by chromatographic techniques.

In another project, in cooperation with Dr. A. Alexander of the University Agricultural Experiment Station, Dr. Maretzki has employed techniques of salt fractionation, dialysis, and gel filtration to distinguish a number of invertases in extracts of sugarcane meristem. Molecular sieving experiments revealed three different weight fractions having invertase activity of both glucosidase and fructosidase type. Separation of the enzymes required low ionic strength eluent; aggregation occurred when ionic strength was increased. Enzymatic activity was maximal in acid medium. Dialysis treatment revealed that low molecular weight activators or cofactors in the tissue extracts are essential for maximum activity of all invertase molecules. The gel filtration studies indicated the presence of inhibitors complexed with the enzyme molecules.

3. Radiation Sterilization of Sugarcane Borer. Division activity in this research area is carried out by Dr. D. W. Walker, with primary financial support provided by the US AEC Division of Biology and Medicine. This research is described elsewhere in this Annual Report.

4. Radiation Preservation of Mangoes. Several exotic tropical fruits would have considerable market potential if their ripening could be delayed to permit shipment. To evaluate the process of radiation preservation, a series of experiments was conducted by Dr. D. B. Linden and Mr. J. Cuevas involving ten varieties of mangoes irradiated at different doses at three different stages of ripening and stored at post-irradiation temperatures of 50° and 70°F. From these studies it was found that 250-kilorad doses of gamma radiation extend the shelf-life at 70°F by approximately twenty days for certain varieties of mangoes. Such results hold promise for the radiation preservation of this fruit. (See Figure 5.)

Biochemical studies of the softening of mangoes during and following irradiation were conducted by Dr. S. N. Deshpande, who measured the

Figure 5. José López is testing for quantity of sugar content in irradiated mangoes.

extent of depolymerization of the pectic constituents in irradiated fruit. Softening was found due both to radiation-induced depolymerization of pectic acids and to the considerable polygalacturanase activity in the mango.

Other research, with the purpose of evaluating the feasibility of radiation preservation of bananas and mangoes, is being carried on as a project supported by the US AEC Division of Isotope Development and is described elsewhere in this Annual Report.

Agricultural and Bio-sciences Division staff continue their cooperation with Puerto Rican scientists in the field of radiobiology. Indeed, the University Agricultural Experiment Station has set up a project on crop improvement by irradiation, which permits its staff members to explore more fully the potential of ionizing radiation in producing beneficial plant mutants. The Division has been freed of the responsibility of operating the pool-type cobalt-60 gamma irradiator in Mayaguez, now operated by Reactor Division personnel. In Río Piedras, the gamma room housing the 2000-curie cobalt source is being used increasingly for irradiation of plant seed material and is proving a very adaptable facility. Whenever size of plant material permits ease in handling, the megawatt reactor is utilized as a source of thermal neutrons.

Cooperative projects in progress in 1965 include the following:

Dr. F. Mariota Trias, UPR School of Agronomy, Mayaguez, Induction of Spine-Free Pineapple Mutants.

Dr. C. Briscoe, USDA Department of Forestry, Río Piedras, Effect of Mycorrhiza on Pine Root Radiosensitivity.

Mr. H. Irizarry, UPR Agricultural Experiment Station, Río Piedras, Induction of High Sugar Pineapple Mutants.

Mr. A. Sotomayor Ríos, UPR Agricultural Experiment Station, Río Piedras, Induction of High Yield Mutant of a Tropical Legume (L. leucocephalla).

An additional cooperative project between staff and other investigators has been the biochemical characterization of the proteolytic enzyme penguinain by Dr. Maretzki and Dr. E. Toro-Goyco of the University School of Medicine.

This was a year of change for the Division staff. In June, Dr. D.

B. Linden left to accept the position of Associate Professor at Newark State College, Union, New Jersey. The Paramutation Project headed by Dr. Linden was terminated at that time. In December, Dr. A. Maretzki moved to Honolulu to join the Experiment Station of the Hawaiian Sugar Planters' Association. In October, Dr. F. K. S. Koo went on a leave of absence for six months as National Visiting Professor at the National Taiwan University, Taipei, where he has offered courses in advanced cytogenetics, radiation genetics, and radiobiology, and initiated research in these fields. Dr. Koo will return to the Division in March 1966.

Expansion of the research program was made possible by two developments in 1965. The first was the acquiring of nearly three acres of experimental land at the Gurabo Substation of the University Agricultural Experiment Station, through contract agreement. This excellent land has permitted growth of large numbers of sugarcane plants from neutron-irradiated seed materials. It also has permitted establishment of an enclosed half-acre field plot for radioisotope experiments. The second development was the receipt of additional financial support for studies in food preservation by gamma irradiation. Some of the activities in this area are now funded through a US AEC Division of Isotope Development contract and are described elsewhere in this Annual Report.

Scientific papers published or presented at professional meetings by Division staff are listed in the Appendix.

Figure 1. Unique application of a Whitfield bench for transfer of trypsinized BHK cells to T-60 flask for subculturing.

Figure 2. HeLa cells previously treated with ^{10}B and irradiated with neutrons are examined under the inverted microscope.

Figure 3. HeLa cell colonies previously treated with ^{10}B and irradiated with neutrons are being counted.

MEDICAL SCIENCES AND RADIOBIOLOGY DIVISION

M. Paul Weinbren, M. D., Head

The primary objectives of the Medical Sciences and Radiobiology Division have been (1) to establish a tissue culture facility to serve as a medium for training and research, (2) to develop a series of research projects based on the tissue culture unit, (3) to establish the program which is now separately financed as the Terrestrial Ecology Program, Part II, and (4) to establish projects which have a bearing on the problems of tropical medicine and which utilize the facilities of the Puerto Rico Nuclear Center for studying radiation, such as the now separately financed Schistosomiasis Project.

The tissue culture unit has been established and, after a number of delays due to bacterial or fungal contamination, a system of clean tissue culture methods has been developed for use in the tropics or any heavily contaminated area. This works so well that on a test basis it has been possible to carry cell lines safely in the animal quarters. The system utilizes a Whitfield ultraclean workbench, a semi-nontouch working technique, and scrupulous attention to "hygiene." (See Figure 1.) All conventional tissue culture procedures are carried out in this section.

Probably the most important of the research projects using the tissue culture unit is the one designed to study at the cellular level the effects of neutron capture by boron-10. With use of HeLa cells, a 10-curie PuBe neutron source (with 10-cm paraffin moderator), and triethanolamine borate as a tagging compound, a system has been evolved in which, with cells growing and dividing in synchrony, the conditions have been established that are necessary to reduce the plating efficiency of the tagged and irradiated cells to half that of the controls. (See Figures 2 and 3.)

A cooperative study of human chromosomes in normal individuals and those receiving radiation therapy was set up with the U.S. Army Tropical Research Medical Laboratory and the Division of Radiotherapy, but with the reorientation of the Army program this support was lost and the program has been greatly curtailed. Dr. Barbara Weinbren assumed the responsibility for the chromosome projects which continue: (a) collection of specimens from PRNC

staff to establish a reference collection, (b) study of the karyotypes of individuals of two distinct asthma patterns with specimens provided by Dr. J. A. de Jesús, (c) study of chromosome patterns in "normal" HeLa cell cultures for comparison with those affected by ^{10}B neutron capture (see Figure 4), and (d) occasional clinical studies which derive from associated programs or anomalies found in volunteers.

The DC2 chondrosarcoma brought from the National Cancer Institute by Dr. J. N. Correa has been adapted to our CF1 mice (see Figure 5) and from them has been established in tissue culture where it has yielded three distinct morphological cell types that appear to be stable.

The series of attempts to adapt the dengue viruses isolated during the 1963-1964 epidemic to tissue cultures has been dropped because Dr. Wissman's group in Baltimore has achieved an adaptation to chilled baby mice.

Three mosquito species have been colonized and are being tagged with strontium-89 for release and recapture to study flight pattern and range.

Groups of young and adult snails have been set up (with controls) in water containing 1 nCi strontium-89 per milliliter. These are being watched for variation in egg production, and periodically snails are to be sectioned and studied by autoradiography and straight histology for accumulations of strontium-89 and possible damage caused by the beta radiation.

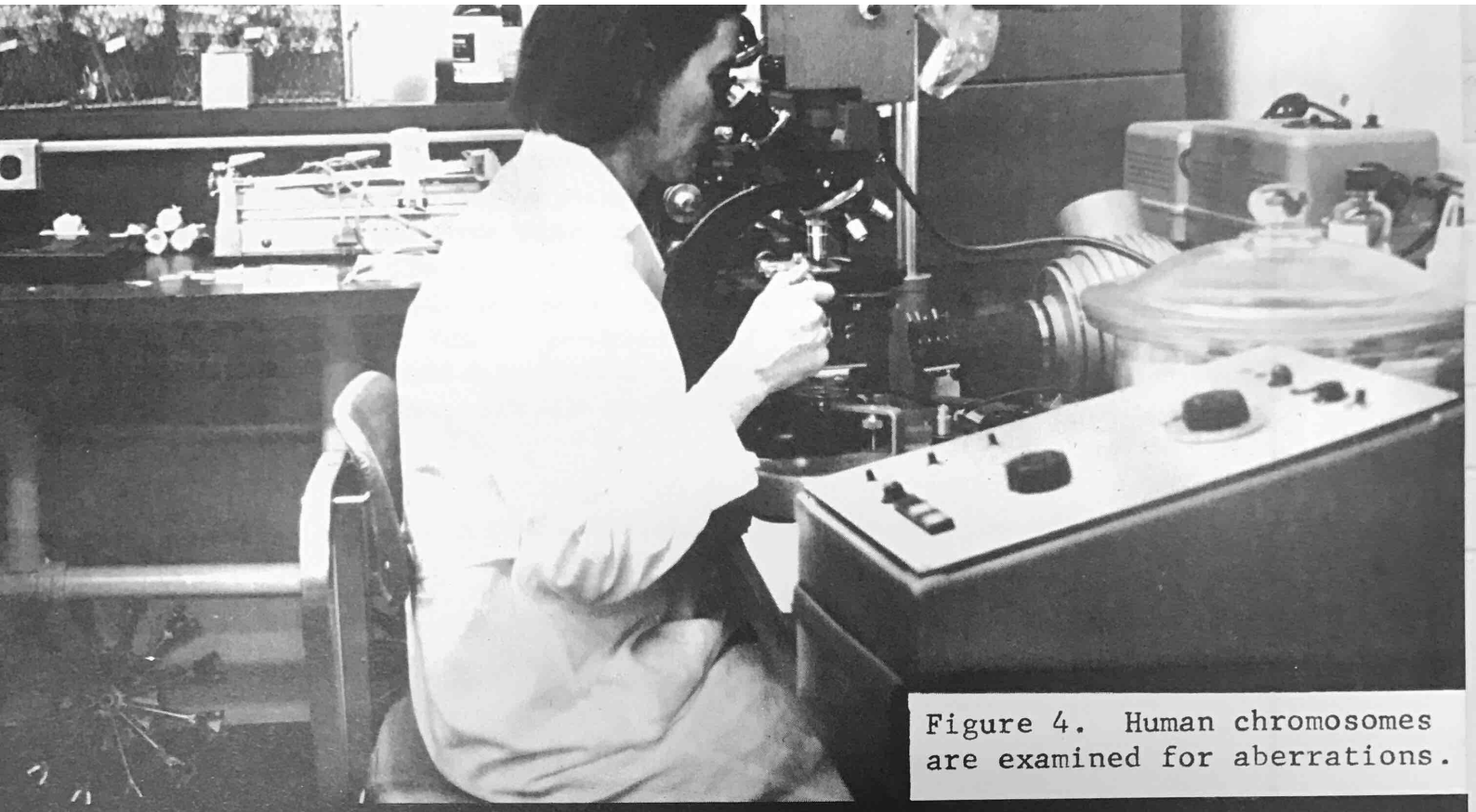


Figure 4. Human chromosomes are examined for aberrations.

Figure 5. Mouse breeding cage.

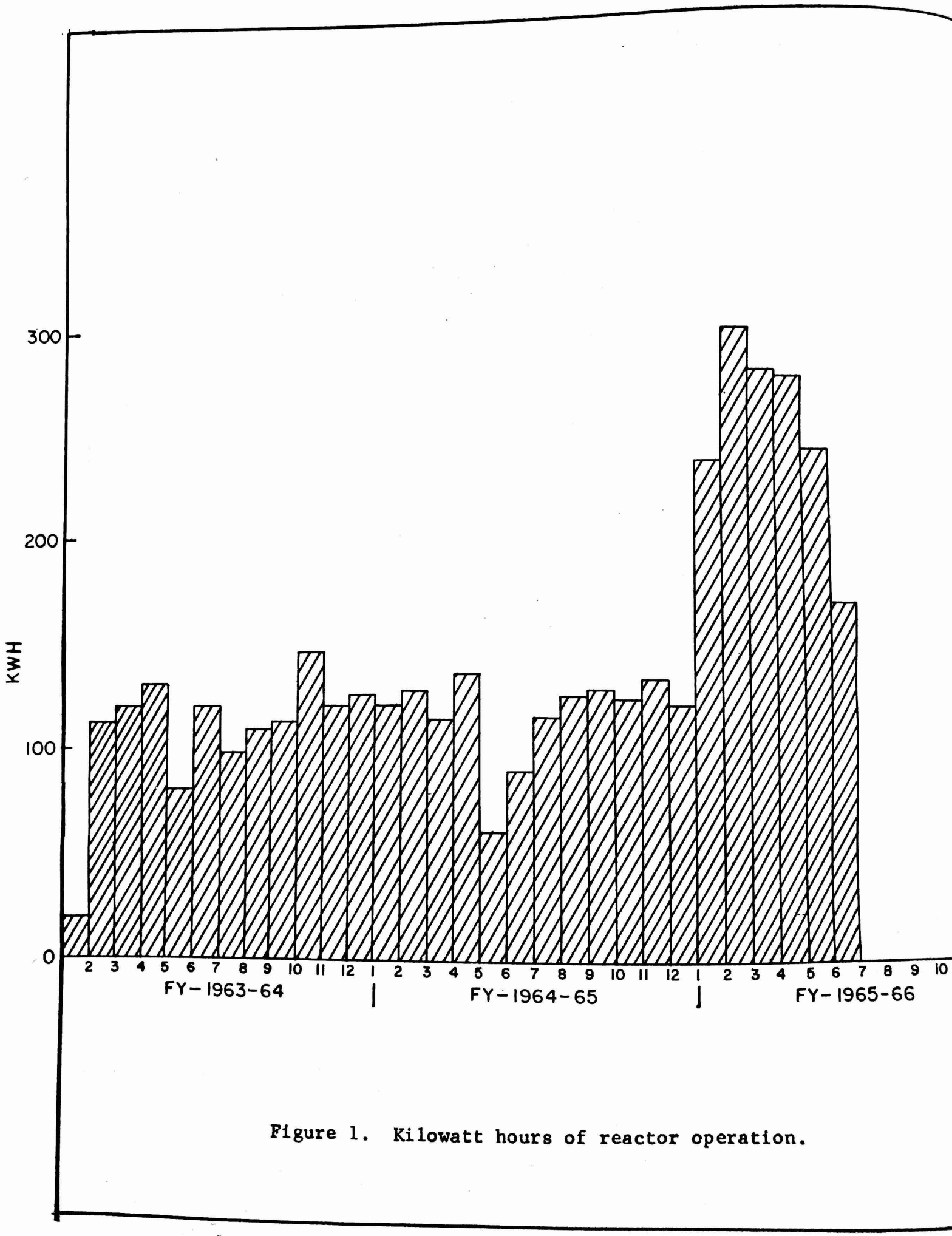


Figure 1. Kilowatt hours of reactor operation.

REACTOR DIVISION

Héctor Barceló, M.S., Head

The main responsibility of the Reactor Division is to operate, maintain, and protect the two reactors, an L-77 homogeneous reactor and an AMF pool-type research reactor currently operating at a one-Megawatt power level. The Division is also responsible for the pneumatic tubes, hot cells, gamma irradiation room, fuel element irradiators, and all equipment necessary for the operation of these facilities, and participates actively in the training of reactor operators and supervisors. (Refer to Table 1).

TABLE 1

Trainees

Name and dates of training	Present position
REACTOR OPERATOR TRAINING	
Juan Jesús Pérez 5/17/65 to 11/17/65	Reactor Operator PRNC, Mayaguez
Sigfredo Torres 2/15/65 to 8/15/65	Reactor Operator PRNC, Mayaguez
Lorenzo Rosa Graniel 2/15/65 to 8/15/65	Reactor Operator PRNC, Mayaguez
REACTOR SUPERVISOR TRAINING	
Melvyn Cotto Serrano, B.S. 1/1/65 to 1/1/66	Working for M.S. PRNC, Mayaguez

In the pool-type research reactor, two 6-inch beam tubes are being used in the neutron diffraction programs for two neutron spectrometers. A shielded room has been built around another 6-inch beam tube for future experiments in biology and medicine. A borated water shutter has been built for this beam tube. A neutron monochromator, designed on the basis of critical angle reflection techniques, is being built to be installed in a fourth beam tube. The fifth beam tube is scheduled for experiments on fission product radiolysis of hydrogen halides.

Since July 1965, the 1-Megawatt research reactor has been operated on a 16-hour per day basis at a continuous power of 1 Megawatt. Figure 1 shows the reactor kilowatt hours per month for the last three years of operation.

The L-77 reactor is being used for teaching and experiments suitable for a water boiler homogeneous type of source. An oscillator for dynamic experiments is being built.

Two different modes of operation of the pool-type reactor are in demand: (1) steady state, full power operation for research and (2) intermittent, variable flux operation with changes in core configuration required for any training program. Because of this, the Reactor Division presented a proposal for the construction of another reactor to be installed at the other end of the pool. This would be a low-power reactor, built and put into operation by members of the Division. It would be operated on an on-off basis with the primary purpose of providing a flexible facility for graduate students in nuclear engineering and other fields to perform laboratory experiments and research projects related to reactor physics.

Dr. Amador Cobas, Associate Director of PRNC, and Mr. Barceló, Head of the Reactor Division, attended the inauguration ceremonies of the first pool-type research reactor of the Instituto de Asuntos Nucleares (Atomic Energy Commission) of Colombia on February 20, 1965. Mr. Guillermo León Valencia, President of the Republic of Colombia, presided at the ceremonies. It is of interest that both reactor supervisors were trained at PRNC, and suggestions made regarding reactor modifications by PRNC staff were accepted. Members of the Division have maintained close contact with the staff at the Colombia reactor. (See Figure 2.)

The Division Head is a member of the BONUS Safety Committee, and last year he participated in an IAEA study group meeting in Caracas. (See Figure 3.)

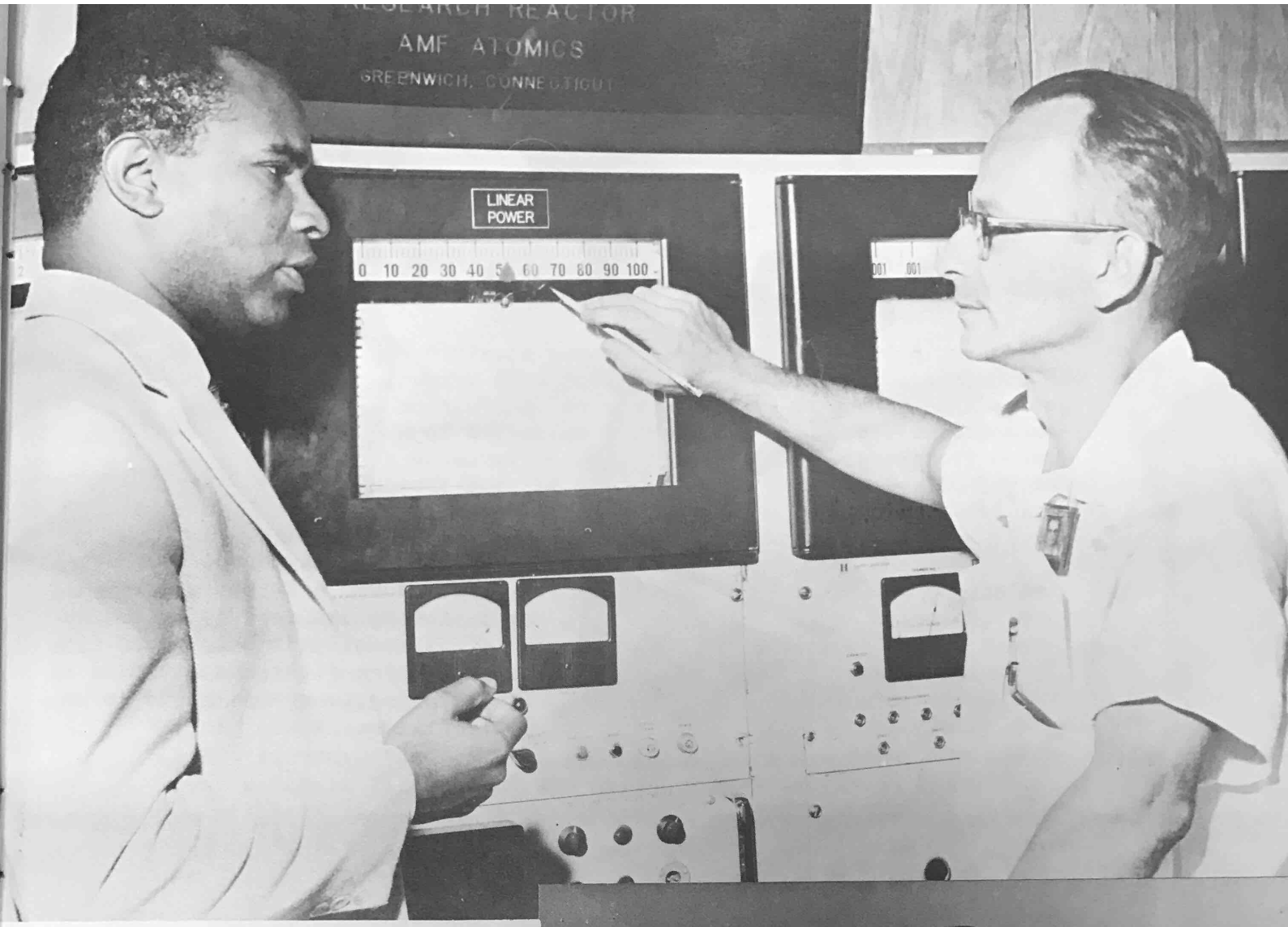


Figure 2. Dr. Gustavo Rada, Chief of the RV-1 Reactor Department of the Venezuelan Institute of Scientific Research (left), with Mr. Barceló during a tour of the PRNC reactor control room.

Figure 3. Dr. Julio A. Marulanda, Executive Director of the Atomic Energy Commission of Colombia (seated), with Mr. Héctor Barceló, Head of the PRNC reactor Division, at the operating console of the PRNC researh reactor.

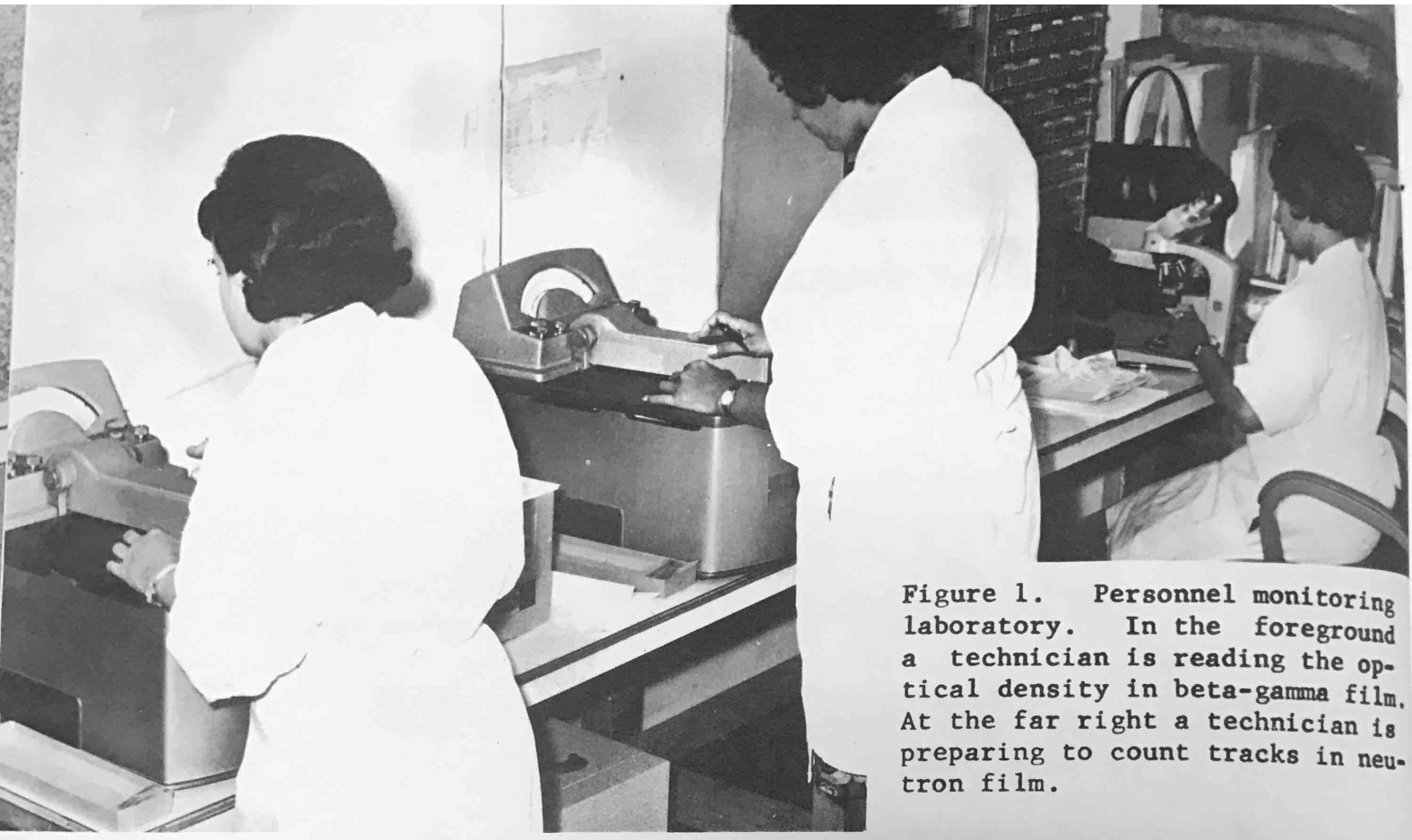


Figure 1. Personnel monitoring laboratory. In the foreground a technician is reading the optical density in beta-gamma film. At the far right a technician is preparing to count tracks in neutron film.

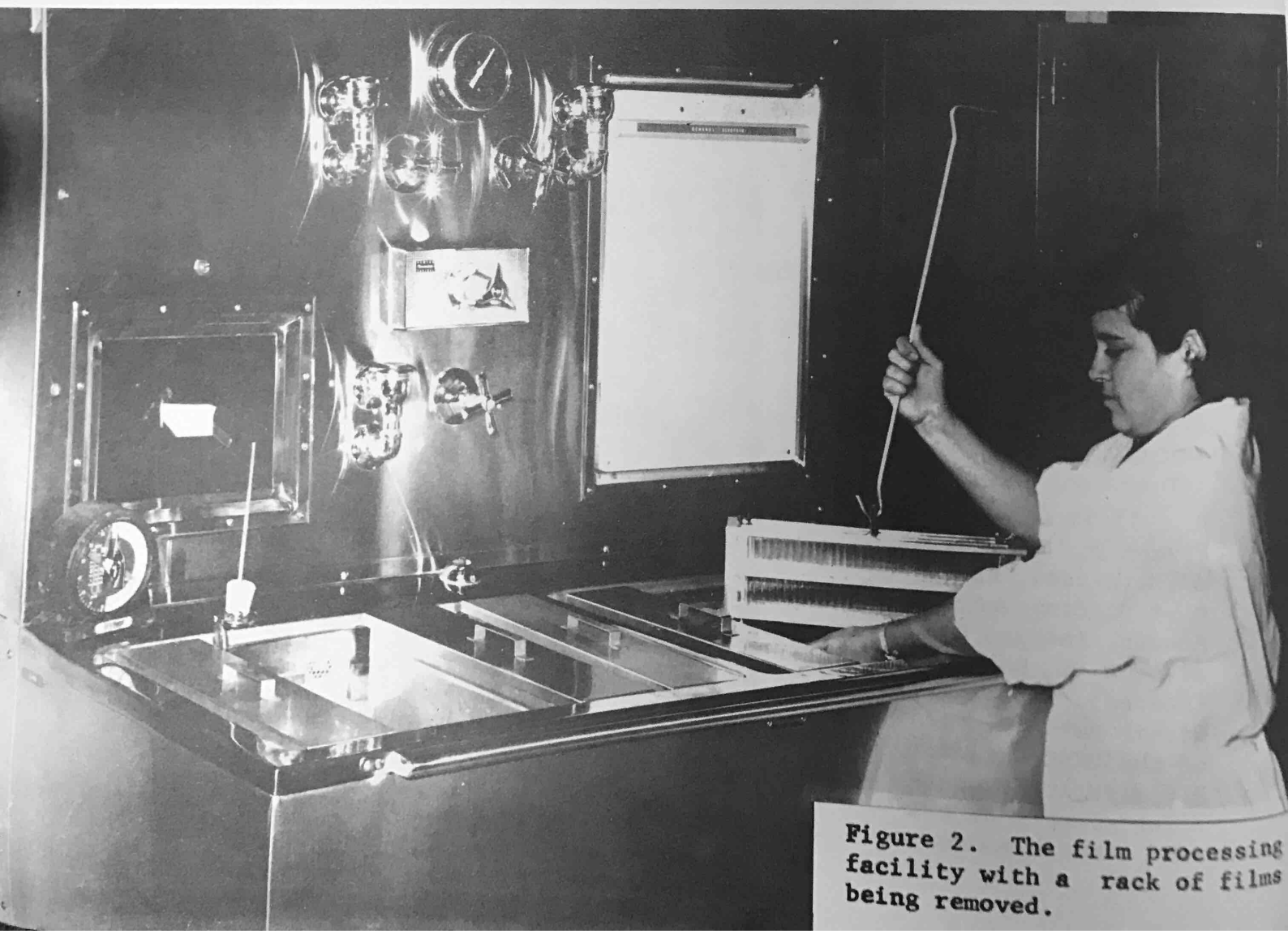


Figure 2. The film processing facility with a rack of films being removed.

HEALTH PHYSICS DIVISION

José A. Ferrer Monge, Ph. D., Head

The Health Physics Division provides the services needed for safe operation of the Puerto Rico Nuclear Center. These include personnel monitoring, area monitoring, environmental surveillance, waste disposal, calibration of radiation monitoring equipment, decontamination, radioactive materials handling, and general laboratory safety instruction. Support for the M.S. degree program in Health Physics of the University of Puerto Rico in Mayaguez is given by providing both teaching personnel and research opportunities.

The Division has had a very active year, with increased provision of services in personnel and area monitoring, waste disposal, health physics instrument calibration, environmental surveillance, decontamination, handling of radioactive material, and consultation. Film services for personnel monitoring are now being provided to the Dr. I. González Martínez Oncological Hospital, the University Hospital in Río Piedras, the UPR School of Medicine in San Juan, the BONUS Power Plant in Rincón, and the Military Hospital in El Salvador, Central America. (See Figures 1 and 2.) Environmental surveillance service comprising soil, water, and vegetation sample analysis are also provided for the BONUS reactor. (See Table 1.)

The Nuclear Accident Dosimetry (NAD) System that is being used in Puerto Rico was developed at Oak Ridge National Laboratory. PRNC maintains two complete NAD counting systems in the basement of the Monzón building Mayaguez campus, UPR, and offers its services to the staff of the BONUS power reactor, as well. The system is designed for a quick determination of radiation dose as accurately as feasible in case of a nuclear accident. A complete report on the design and the principles of operation can be found in Radiation Accidents: Dosimetric Aspects of Neutron and Gamma Ray Exposures, ORNL-2748A, 1959. The method of calibration of the threshold detectors has been published by D. R. Johnson et al., Health Physics, 11, p. 759 (1961).

The fission foil counting system utilizes NaI(Tl) crystals as detectors at an almost 4- π geometry, linear amplification, integral counting, and discrimination below 1.2 Mev. Standardization of the counters is done with a ^{137}Cs standard source. The efficiency of the fission counters was determined by measuring the natural gamma

TABLE 1

Health Physics Services, 1965

1. Film badges processed: 12000

PRNC	6380
BONUS	5620

2. Radiation survey meters calibrated: 245

3. Area monitoring samples analyzed: 681

Water	36
Smears	615
Air	30

4. Environmental surveillance samples analyzed: 269

   PRNC: 165

Water	75
Air	74
Soil	8
Vegetation	8

   BONUS: 104

5. Medical Dispensary - Number of cases seen: 54

6. Review of questionnaires for reactor experiments: 25

7. Review of requests for use of irradiation facilities other than reactor: 15

activity of a Pu foil at both the PRNC and the standard ORNL fission counters. The gold foil counting system also utilizes a NaI(Tl) crystal, but at 2- π geometry and discrimination below 0.35 Mev. Its efficiency was also determined by measuring the gamma activity of an activated gold foil in both the PRNC and the standard ORNL gold counters. The sulfur pellet counting system utilizes a plastic scintillator at 2- π geometry and a low discrimination level. Its efficiency was determined by measuring the beta activity of an activated sulfur pellet in both the PRNC and the standard ORNL sulfur counters.

The fission counters are also used at a discrimination level below 2 Mev to count the ^{24}Na activity of blood samples obtained from persons exposed to neutron radiation. A centrifuge is now available for the separation of blood serum.

Fission foils, gold foils, and sulfur pellets have been exposed many times to neutron radiations from the reactor in order to simulate an accident, to test the equipment, and to train personnel. The NAD counting system is continuously functional, and trained personnel are available at all times. This Division is responsible for operation of the NAD and provides the materials and personnel to meet this requirement. Dr. Peter Paraskevoudakis is in charge of this facility. (See Figure 3.)

The services of a health physicist are available at Mayaguez for two-shift operation of the pool reactor.

During the year, several trips were made to the United States by Division personnel. In June, Dr. José A. Ferrer Monge attended the Tenth Annual Meeting of the Health Physics Society in Los Angeles. On the return trip he made a visit to ORO, ORTEC, and ORNL at Oak Ridge, as a result of which new procedures have been adopted in personnel monitoring and a new approach to the problem of reactor beam dosimetry is being developed. In September, he attended the course on radiological emergency operations, designed to train personnel of radiological emergency teams, offered by the Reynolds Electric Company at the Nevada Test Site.

Dr. Peter Paraskevoudakis presented papers at the Radiation Research Society Meeting in Philadelphia in May and at the Calorimetry Conference in Ames in August.

Two new instruments have become available. The first, a low level, alpha-beta counting system, capable of handling up to 100 samples,

Figure 3. A view of the nuclear accident center installed on the Mayaguez campus of the University. The NAD readout system (left) is being calibrated, while a sample is being added to a centrifuge tube (right).

is expected to speed up the analysis of area and environmental samples. The other, a multichannel analyzer on loan from the Nuclear Science and Technology Division, will permit the identification of radionuclides in samples, as well as the measurement of their activities.

Developments in the research and training programs have significantly increased the demands for services of the Division - in addition, new responsibilities have been assigned.

EDUCATION AND TRAINING

Minor changes have been made in the curriculum leading to the M.S. degree in Health Physics to bring it in line with the revised criteria advocated by the US AEC Fellowship Program in Health Physics. The laboratory exercises in the Health Physics I and II courses are being revised. Experiments that are similar to those in other courses have been deleted and new ones are being prepared.

During the year, seven students enrolled in Health Physics I and three in Health Physics II. (See Table 2.)

Dr. Luis Meyer, an OAS Fellow from the National Committee on Radiation Protection of Uruguay, received three months of special training in health physics techniques and procedures. Since he was considered a regular staff member, he acquired experience by actually performing routine tasks such as film calibration and processing and dose conversion; collecting, processing, and reporting of samples used in area monitoring and environmental surveillance; calibration of instruments, and reactor surveys. This training was augmented by formal lectures and periodic discussions with senior staff members on problems encountered, approach used, alternatives, and so on. The results of this training regime were so satisfactory that it will be used with future trainees.

Five students are doing thesis work under the supervision of Dr. Paraskevoudakis. The problems under investigation are as follows:

1. Ferdinand Rosa, Total Absorption X-Ray Calorimeter. Improvements are being made on a calorimeter whose basic design was worked out by Dr. Paraskevoudakis at the University of Michigan. A new type of polyester film has been successfully used as the x-ray window, and an improved vacuum system has been tested. The results obtained are promising. The calorimeter will be used to determine the energy

TABLE 2

Students

HEALTH PHYSICS I

1. José Aguiar Aramburu
2. Mario Beauchamp
3. Raúl Colón Santiago
4. Melvyn Cotto Serrano
5. Erick Méndez Veray
6. Néstor Rubén Ortiz
7. Eduardo Sagredo Robles

HEALTH PHYSICS II

1. María Luisa Cruz
2. Vivian Torres
3. Gilberto Vélez

content or power of monochromatic x rays.

2. Francisco Jiménez, Determination of the G-Value of the Fricke Dosimeter for Monochromatic X Rays in the 5- to 15-kev Range. G-Values of the Fricke dosimeter are fairly well known for high energy gamma and x rays, but data are lacking for the low energy ranges. This work is designed to provide data on the energy absorbed, as measured by calorimetry.

3. José Aguiar, Improvements on an X-Ray Calorimeter. A desirable improvement in many types of calorimeters would be a reduction in interference from noise. The approach in this study involves a multiple-bridge redesign of the Wheatstone bridge, use of a low thermal-emf flux and special soldering to minimize the emf from Cu-Cu plus soldering, and a special low gain preamplifier to match the high impedance of the bridge with the low impedance of the meter. These improvements, if successful, are expected to increase the sensitivity of the calorimeter by a factor of at least ten.

4. Heriberto Cuebas, Gamma-Ray Spectra Around the PRNC Pool Reactor. The purpose of this study is to determine the energy spectra of gamma rays around the reactor and correlate them with the exposure rates measured at selected points. A single-channel analyzer was used calibrated with ^{60}Co, ^{137}Cs, and ^{198}Au. The results indicate that the predominant gammas have an average energy of 0.1 Mev. Exposure rates averaged generally from 2 to 20 mR per hour, but at some particular points 100 mR per hour could be detected, due to changes in experimental arrangements of other investigators in the area.

5. Angel Escalona, Neutron Dosimetry. The objective of this study, which is just being started, is to determine neutron dose rates by foil activation. The foils are calibrated by exposure to a neutron source of known emission. The flux is determined from known cross sections whenever applicable, and comparisons are made.

Research work is in progress on the development of a calorimeter for measuring the absorbed dose from low energy x rays and on the design and dosimetry of a neutron beam (from the pool reactor) for the irradiation of experimental animals and other material. Such a facility would make possible critical evaluation and studies of neutron effects in these materials.

The NAD system was used to determine the intensity of the neutron beam at beam tube No. 1. The collimator opening is 2 inches in diameter and the beam about 2.5 inches in diameter at the exit of the beam tube. The beam consists of mixed neutron and gamma radiation in about equal proportions. Since the beam will be used for radiation biology experiments with fast neutrons, it is desirable to reduce the gamma dose as much as possible. Lead filters of different thicknesses were used to determine an optimum thickness which will reduce the gamma dose without appreciable attenuation of the fast neutrons. The optimum thickness was found to be 6 inches of lead. The filter was placed 32 inches deep into the tube to reduce the scattered radiation.

The Hurst threshold detector system and the calibrated NAD system have been used for the determination of fast neutron fluences. The total fast neutron flux density above 0.001 Mev was 2×10^7 n/cm^2-sec in the center of the beam at the exit of the tube. The spectral distribution showed that the majority of the neutrons (> 50 percent) had an energy between 0.5 and 1.5 Mev. From these data, the first collision dose rate was estimated to be 120 rads per hour. The gamma ray dose rate was measured by a thimble ionization chamber calibrated with a ^{60}Co source, and was found to be about 56 R/hr.

Gold foils, bare and cadmium covered, were used to determine the thermal flux at the exit of the beam tube. Flux mapping of the cross section of the beam at the exit was performed. The results indicated a flux density of about 2×10^7 n/cm^2-sec at the center and within a few inches of the beam. The beam was not uniform, and only a small area of the total cross section could be used for irradiations with satisfactory dosimetry. Therefore, it was concluded that the present plugs and shutter-filter system should be replaced. It is proposed that a 4-inch-diameter opening be used together with an 8-inch-thick lead filter and 1-millimeter-thick cadmium. The cadmium eliminates the thermal neutrons, and the additional lead further reduces the gamma dose. The fast flux density remains at the same level.

The aim of the neutron dosimetry program is to determine neutron flux densities and energy spectra at points of interest at the PRNC reactor. Some experiments were carried out in the pool. The Hurst threshold detector system together with bare and cadmium-covered gold foils were placed into an aluminum tube three feet long and three inches in diameter. The aluminum tube was placed

vertically about two inches from the face of the reactor core. The detector system was approximately at the center of the face. The measurements indicated flux densities of about 3×10^{12} n/cm^2-sec for both thermal and fast neutrons. The reproducibility of the position with this setup is difficult, and a better method should be established. The future aim of this program includes the utilization of a surface barrier (silicon diodes) neutron spectrometer, which will have a higher energy resolution than that obtainable with threshold detectors.

Figure 1. A view of the conference table during the Inter-American Conference on Economic and Technical Aspects of Nuclear Power Generation in Latin America.

Figure 2. The Honorable Chet Holifield, Representative from California, Chairman of the Joint Committee on Atomic Energy with Dr. John C. Bugher, Director of PRNC, at the opening session of the conference.

OFFICE OF THE DIRECTOR

John C. Bugher, M. D., Director

The Office of the Director operates at both Río Piedras and Mayaguez. Its basic function is the planning and supervision of Puerto Rico Nuclear Center activities to achieve the objective of providing graduate level training and research in the tropics in the application of nuclear energy to the fields of agricultural science, marine biology, medicine, nuclear engineering, physics, and chemistry. The staff of this Office, in addition to its administrative duties, participates in the teaching and research of several divisions, and organizes and directs several special conferences and courses as needed. This Office is responsible for the production of special reports and papers concerning the activities of PRNC and generally serves as the focus of internal and external communication.

MEETINGS

During the past year, PRNC has been host to several scientific groups which chose to meet in Puerto Rico because of interest in the programs of the Nuclear Center. A brief résumé of these meetings follows.

On January 25, the Radiation Study Section Meeting of the National Institutes of Health, U.S. Department of Health, Education and Welfare, was conducted in the Bio-Medical Building. A review of the PRNC program in biology, medicine, and the physical sciences was included in the meeting.

On February 4 and 5, the Eleventh Meeting of the PRNC Bio-Medical Advisory Committee was conducted at the Mayaguez facilities. The significant developments toward a graduate program in agriculture at the University of Puerto Rico College of Agriculture and Mechanical Arts and the possible development of an international agricultural headquarters were presented to the Committee. Progress reports on research in marine biology, paramutation, sugarcane borer control, and resonance in radiation effects were presented by staff members. The proposed research program for the PRNC portion of the US AEC Atoms in Action Exhibit in El Salvador was presented, as well as a review of the physical science program.

On February 8 and 9, the US AEC Division of Biology and Medicine Bio-Medical Program Directors' Meeting was held in the Bio-Medical Building. The subjects included a review of the PRNC program, as well as the nuclear power program in Puerto Rico and civil defense in Puerto Rico.

On February 22 to 26, the Inter-American Conference on Economic and Technical Aspects of Nuclear Power Generation in Latin America, sponsored by the Inter-American Nuclear Energy Commission of the Organization of American States with the collaboration of the US AEC and PRNC, was held in Mayaguez in the Library of the UPR College of Agriculture and Mechanical Arts. (See Figures 1 to 5.) The Conference was organized to implement Resolution III adopted at the Fifth IANEC Meeting held in Valparaíso, Chile, in March 1964. The purpose of the Conference was to examine the technical and economic aspects which would be taken into consideration in planning, constructing, and operating nuclear power plants in Latin America. A summary of the results of the Conference by Dr. John C. Bugher, Director of PRNC, follows.

"While all the significant developments of this conference cannot be discussed in summary, certain of them emerge as having special merit.

"1. Many papers have reflected the dramatic acceleration in the

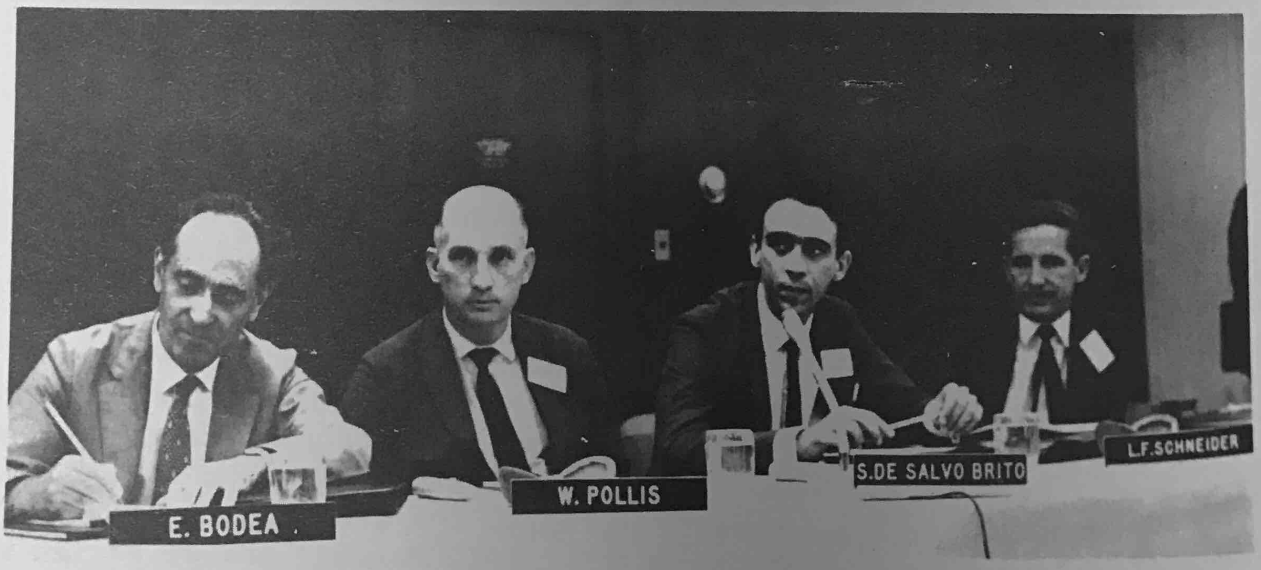


Figure 3. The delegation from Brazil during a working session of the conference.

Figure 4. Delegates from Mexico, Perú, and the Dominican Republic.

Figure 5. Seated (left to right), US AEC Commissioner James T. Ramey at the Inter-American Conference; Congressman Chet Holifield, Chairman of the Joint Committee on Atomic Energy; Dr. John C. Bugher, Director of PRNC, Dr. Jesse D. Perkinson, Executive Secretary of the Inter-American Nuclear Energy Commission and Director, Department of Scientific Affairs, Pan American Union, Dr. Miguel Wiewall, Jr., Dean of Studies, College of Agriculture and Mechanical Arts, University of Puerto Rico; and Dr. Henry J. Gomberg, Deputy Director. PRNC.

development of power reactors so that in high power cost areas electricity produced by nuclear power plants is already competitive with that from fossil fuel. The next generation of power reactors should substantially increase the economic attractiveness of nuclear power through better neutron economy, lower fuel cycle costs, and lower initial capital investment.

"2. At present, reactors moderated and cooled by light water and the large gas-cooled types have a leading position with a fully developed technology and a high order of reliability and safety. Over the next few years, we may see other systems coming to maturity. Among these are the high temperature gas-cooled reactor and the heavy-water-moderated organic-liquid-cooled type. Eventually, breeding systems utilizing both uranium and thorium must be developed.

"3. Recognition has been given to the importance of the availability of foreign exchange and the balance of payments of a country as factors in the choice of a power reactor system. This has been emphasized in papers from Argentina, Chile, and Brazil.

"4. A long-term policy has been enunciated by the United States by which a country may have its own uranium processed to the desired degree of enrichment in ^{235}U. This assurance should assist power systems in utilizing reactors requiring enriched uranium by providing a dependable supply of fuel.

"5. Extensive studies in Argentina, Chile, Brazil, and Puerto Rico have examined the problems of extending the capacity of hydroelectric and thermoelectric power systems by the addition of nuclear units to secure the most economic balance. The proportions of hydroelectric, thermoelectric, and nuclear power generation vary with the national circumstances.

"6. Great interest has been expressed in dual purpose plants for both electrical power production and the desalting of seawater. Countries such as Chile and Peru, with a deficit of fresh water, see a potential solution of at least part of the problem created by the Andes Mountains.

"7. Pumped hydroelectric storage systems have been mentioned in various relationships to nuclear power systems in order to provide a good plant loading factor. With this may be included the possibility of pumping water over mountain ranges by nuclear power and

recovering the power hydroelectrically on the downward side. This could be considered an extension of the concept illustrated by the diversion of water from the Amazonian watershed to the Pacific slope of Peru which is now under development.

"8. The uses of nuclear explosives in large-scale excavation and similar engineering projects were developed by the delegate from Colombia and led to expressions of lively interest in this matter. It appeared to be the consensus that this subject might be pursued to advantage in a future conference devoted to this subject alone.

"More important than the specific details has been the stimulus of bringing a variety of points of view and practical considerations to a critical discussion. This has given us all a clearer understanding of our problems and has strengthened our confidence that the near future will see a great expansion in electric power generated by nuclear energy at costs substantially less than those considered in the generally conservative analyses.

"There has been general recognition that in order to advance power development from nuclear energy, we must give strong support to the fundamentals of education in science and engineering in all countries. The establishment of research and training centers such as those in Argentina, Brazil, Venezuela, and Colombia is of vital importance to the future of the effective use of nuclear energy in national development."

On May 17 to 19, a visiting committee of outside scientists appointed by the Environmental Sciences Branch of the US AEC Division of Biology and Medicine reviewed the Terrestrial Ecology Program I: Rain Forest Project. The committee went to Roosevelt Roads Naval Station to inspect a coral reef site suitable for a future irradiation study utilizing the cesium-137 source constructed for the Rain Forest Project and at present installed there.

On November 4 and 5, the Twelfth Meeting of the PRNC Bio-Medical Advisory Committee was held at the Bio-Medical Building. The Terrestrial Ecology Program and the Río Piedras divisions were reviewed. In addition, reports on scientific needs in Latin America, the international aspects of radiological health and safety, and the international exhibit program were presented. At this meeting, Dr. Shields Warren, Chairman of the Committee, announced his resignation effective January 1, 1966.

On November 17 to 19, the University Relations Group, which represents major US AEC contractor laboratories throughout the United States, met with PRNC serving as the host institution. Tours of PRNC facilities in Río Piedras and in Mayaguez with an orientation on the PRNC program by Dr. John C. Bugher, Director, were included in the meeting agenda.

ADDITIONS TO THE STAFF

The staff of the Director's Office has been increased for the purpose of improving the operation of the Nuclear Center in relation to the needs of Latin American countries and especially those of their universities.

On March 1, Dr. Jorge Chiriboga, former Dean of the School of Medicine at the University of Arequipa in Peru and more recently a research scientist at the University of Tennessee - US AEC Agricultural Experiment Farm in Oak Ridge, was appointed Assistant Director for Scientific Programs. The principal responsibilities of this position include (a) expanding the utilization of the PRNC reactor for biological and medical research, (b) organizing a laboratory for biochemical research, and (c) coordinating the development of relationships between Latin American universities and PRNC. A summary of Dr. Chiriboga's activities since his arrival follows.

With the cooperation of Dr. Frank Lowman, Head of the Marine Biology Program, and Dr. J. R. Kline of the Terrestrial Ecology Program, activation analyses of tissues from mice are being carried out, especially analysis of hair.

Samples were taken from animals inoculated with tumors and from controls by Dr. J. N. Correa of the Radiotherapy and Cancer Division in order to obtain information about the movement of cations in different tissues after tumor transplantation. With the cooperation of Dr. R. A. Marcial Rojas, Head of the Department of Pathology of the UPR School of Medicine, collection was started of tissue samples from cadavers with various causes of death - accidents or different diseases - in order to study levels of trace elements, especially rare earths, by activation analysis. The results will be correlated with those of the ecological studies being done in Mayaguez and San Juan.

Chromatographic methods for thyroid hormone are being developed for the Clinical Radioisotope Applications Division.

The laboratory for biochemical research was finished in September and is now being equipped. The changes in surface ektopolysaccharides in different cell lines are being studied in relation to radiation, differentiation, aging, and tumorogenesis. In a preliminary study, HeLa cells are being incubated in uniformly labeled glucose in order to obtain information about their coatings. So far, after purification some components of the surface mucopolysaccharides appear to be labeled. Spectrophotometric, thin-layer, and column chromatography methods have been developed to aid in the study of this problem.

Dr. Chiriboga made extensive trips to North and South America during the year. He visited several laboratories at Oak Ridge National Laboratory; the Cancer Research Institute in Boston; the Medical Department of Brookhaven National Laboratory; and the Medical Department of Columbia University. At Columbia he saw Dr. Karl Meyer, an authority in the field of mucopolysaccharides. At Brookhaven he explored the possibility of cooperation in the medical area.

In Latin America various scientific institutions were visited in Buenos Aires, Argentina; Mendoza, Argentina; Santiago, Chile; Lima, Peru; and Quito, Ecuador. The purpose was to explain the objectives of PRNC and to explore the possibilities of cooperation, particularly the use of PRNC facilities in the training of young scientists from Latin American countries. Many of these countries now offer similar basic courses; therefore, in order to continue to attract Latin American students, PRNC must strengthen its research and graduate training capabilities, and must find a way of using federal money to support the training of Latin American students in Puerto Rico.

With the cooperation of Dr. Conrado Asenjo, Assistant Dean of the UPR School of Medicine and Head of the Department of Biochemistry, a Biochemical Club has been organized for interested persons in the whole area. Regular meetings are held at the UPR School of Medicine, at PRNC, and at the Clinical Research Center of the Puerto Rico Medical Center.

On September 1, 1965, Dr. Howard L. Andrews, who had been radiation safety officer of the National Institutes of Health and Chief of the NIH Clinical Center's Department of Radiation Safety until his retirement, was appointed Assistant Director for Health and Safety. At PRNC Dr. Andrews is available for consultation and advice on matters concerned with health physics, industrial safety, instrumentation for experiments, dosimetry, radiological physics, and other related matters.

The following biographical sketch presented by Representative Fogarty of Rhode Island (Congressional Record - House, August 18, 1965, p. 20223) indicates the depth of scientific capability which Dr. Andrews brings to PRNC.

"I wish to call to the attention of the House the outstanding record of a distinguished Rhode Islander, Dr. Howard L. Andrews, radiation safety officer of the National Institutes of Health, and Chief of the NIH Clinical Center's Department of Radiation Safety.

"Dr. Andrews will retire from the Public Health Service commissioned corps on August 31, 1965, to become Assistant Director of Health and Safety at the Puerto Rico Nuclear Center, a part of the University of Puerto Rico.

"I take a special interest and personal pride in pointing to Dr. Andrews' many achievements because once again a Rhode Islander has made solid contributions to the vital field of health. He received his B.S., M.S., and Ph.D. degrees from Brown University in Providence, R.I., and he served as instructor in physics there from 1930 to 1934. He also carried out some of the pioneer investigations in the field of electroencephalography at Emma Pendleton Bradley Hospital in East Providence, R.I.

"While his career was rooted in Rhode Island soil, his accomplishments embrace a much larger area. Dr. Andrews has been contributing his remarkable talents to the Public Health Service since 1937, when he joined the staff of the Public Health Service Hospital in Lexington, Ky. While there, he conducted research on the biophysical aspects of drug addiction, and was the first to demonstrate that opiates tend to control the subjective reaction to pain rather than to suppress the sensation of it.

"At the start of World War II, Dr. Andrews joined the staff of the National Institutes of Health. As our nuclear testing program developed, Dr. Andrews became involved in radiation work as a member of advisory panels formed to consider the safety aspects of test detonations.

"At that time also, he became a PHS commissioned officer and began a 14-year term as head of the radiobiology section of the National Institute of Arthritis and Metabolic Diseases. From 1959 to 1963, he served as chief of the radiation physics section in the National Cancer Institute.

"Dr. Andrews, because of his vast knowledge and experience in the field of radiation, was selected radiation safety officer of the National Institutes of Health in 1958 and was then appointed chief of the Clinical Center's Department of Radiation Safety when it was established in 1963, holding these two positions concurrently.

"The development of instruments for measuring radiation is just one of many research contributions Dr. Andrews has made. Among his others are studies of the biological effects of high doses of radiation, and the application of human whole-body counter techniques to clinical medicine.

"Serving as a member of the radiation study section at NIH, Dr. Andrews has influenced the growth and importance of the field of radiation biology. He has also served as a member of the National Academy of Sciences Biological Effects of Atomic Radiation Committee and was its executive secretary from 1959 to 1964. In addition, Dr. Andrews is a fellow of the American Physical Society, and is currently president of the Health Physics Society.

"Dr. Andrews is an author as well as a researcher and teacher. In addition to many articles on radiation physics and biology, he coauthored with Dr. R. E. Lapp, Nuclear Radiation Physics, which has been a standard college text since 1948.

"Dr. Andrews' impressive list of accomplishments will not be forgotten by those of us who are concerned with every facet of health research. His outstanding achievements in the broad field of physical biology as investigator, teacher, and leader were recognized when he was awarded the Public Health Service Medal for Meritorious Service in February of this year.

"Fortunately, Dr. Andrews is not retiring from active service. He is only moving from Bethesda, Md., to Puerto Rico. His long career of solid achievements and numerous contributions to the advancement of public health and welfare will stand as a tribute to Dr. Andrews, and I am sure he will continue to add to them in his new position at the Puerto Rico Nuclear Center."

PUERTO RICO NUCLEAR CENTER PARTICIPATION IN US AEC ATOMS IN ACTION EXHIBIT IN LATIN AMERICA

The Puerto Rico Nuclear Center has been assigned the responsibility for conducting a program of scientific investigations in biology, chemistry, and physics as a part of the United States Atomic Energy Commission Atoms in Action Exhibit in Latin America. During 1965 the Exhibit was taken to El Salvador and Guatemala under the auspices of the US AEC Division of Special Projects.

Figure 1. From left to right: Eng. Fausto Muñoz Ribadeneira, PRNC Representative; an Officer, Ministry of Foreign Affairs, El Salvador; U. S. Ambassador, Dr. Raúl H. Castro; and President of El Salvador, Crnel. Julio A. Rivera, at the gamma irradiation facility, Atoms in Action Exhibit, El Salvador.

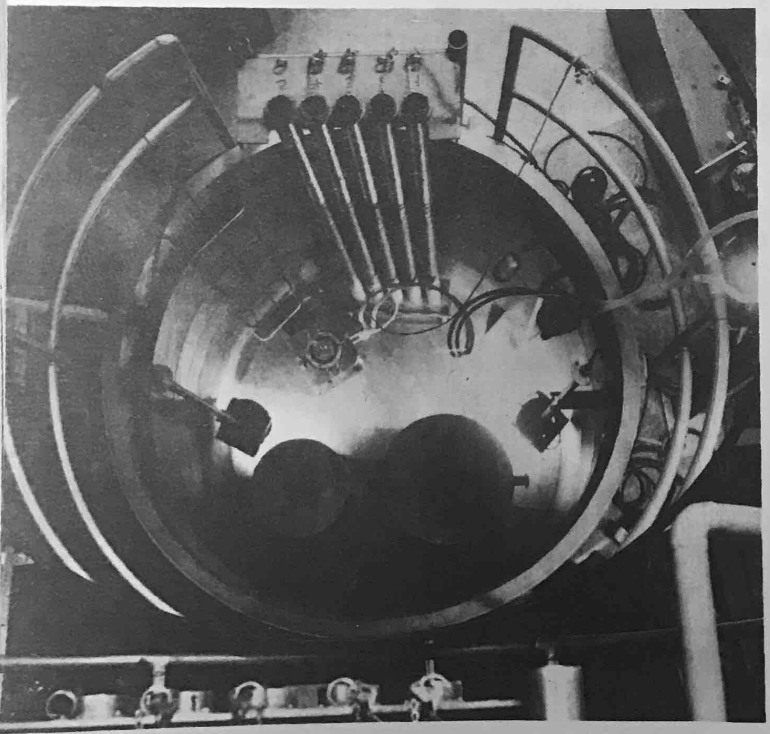


Figure 2. Gamma irradiation facility at the exhibit in Guatemala showing shielding case at the lower (part) and the first irradiator for power temperatures at upper left.

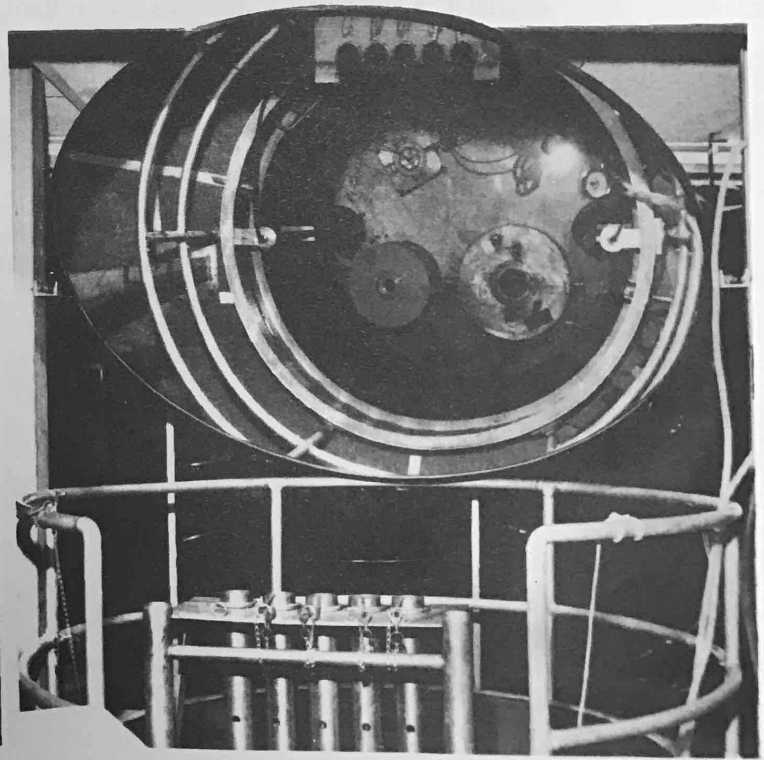


Figure 3. Front view of the five irradiations tubes and sight of the inside of the tank reflected on a mirror

PRNC PARTICIPATION IN THE US AEC ATOMS IN ACTION EXHIBIT IN LATIN AMERICA

Fausto J. Muñoz Ribadeneira, Scientific Coordinator

During 1965 the Puerto Rico Nuclear Center assumed responsibility for the research activities conducted in conjunction with the US AEC Atoms in Action Exhibit, which visited San Salvador, El Salvador, in February and March and Guatemala City, Guatemala, in August and September. The Oak Ridge Institute of Nuclear Studies assumed responsibility for the academic courses and special displays offered during the Exhibit. The Exhibit program was organized to provide useful information to persons of varying backgrounds: general public education through guided tours among special displays; demonstration lecture courses for students, scientists, and physicians; and supervised participation in research involving applications of radiation to problems of regional origin and interest, with emphasis on the utilization of gamma and neutron sources available at the Exhibit. An account of the research activities in El Salvador and in Guatemala follows. (Figures 1 to 3.)

RESEARCH ACTIVITIES: EL SALVADOR

A preliminary visit to El Salvador indicated that the research emphasis should be toward agriculture. Projects were selected on the basis of need to the local economy, similarity to current research at PRNC, and availability of PRNC personnel in the fields of entomology, genetics, and food preservation. The 2000-curie, cobalt-60 gamma irradiation facility was the principal research tool, with a total of 968 irradiations carried out during the Exhibit - the greatest number at any single international exhibit so far. A 6-curie Plutonium-Beryllium neutron source was utilized primarily for work in radiochemistry. Activities utilizing gamma radiation included study of radiation effects on coffee flavor, taste, and seed viability; genetic studies on rice, beans, and coffee; entomological studies on Leucoptera coffeela and Heliothis zea, insect pests attacking coffee and cotton crops, respectively; food preservation studies on shrimp and melons; and student thesis research project irradiations. (See Figures 4 and 5.) Projects on coffee seed viability; genetic studies of rice, beans, and

Figure 4. Mr. Fausto Muñoz Ribadeneira, Scientific Coordinator, is placing a Fricke dosimeter into a melon to measure the internal radiation dose given in the food irradiator.

Figure 5. Specimens of shrimp being examined following gamma irradiation.

coffee; and entomological studies of Heliothis zea are being continued by resident scientists in El Salvador with periodic review by PRNC scientists.

The following 18 scientific lectures were offered by PRNC personnel during their visits to El Salvador.

Prof. Fausto J. Muñoz Ribadeneira, Scientific Coordinator, Atoms in Action Exhibit

1. Nuclear Science and the Liberal Professions
2. Chemical Dosimetry of Gamma Radiation
3. Use of Tracers in Unit Operations of Chemical Engineering
4. Science in a Modern Society

Dr. David W. Walker, Entomologist, Agricultural Bio-Sciences Division, PRNC

1. Applications of Radiation Effects in Entomological Studies
2. Studies of Entomological Problems in Sugarcane in Puerto Rico
3. Procedures for Rearing and Handling Insects in the Laboratory
4. Artificial Diets for Insects
5. Effects of Gamma Radiation on Biological System
6. Mass Rearing and Mass Release of Sterile Insects

Dr. Duane B. Linden, Geneticist, Agricultural Bio-Sciences Division, PRNC

1. Radiation Effects on Genetics
2. Preservation of Tropical Fruit by Gamma Radiation at PRNC

Dr. Juan F. Facetti, Radiochemist, Nuclear Science and Technology Division, PRNC

1. Activation Analysis and Its Uses
2. Szilard-Chalmers Reactions

Dr. Eddie Ortiz, Physicist, Nuclear Science and Technology Division, PRNC

1. Geometrical Meaning of Covariance and Contravariance
2. Vectors Using Tensor Notation
3. One-Sided Green's Functions
4. Green's Functions and Boundary Value Problems
5. Simple Experiments That can be Done With a Neutron Source

In addition to those members of the PRNC staff mentioned above, Mr. Henry Besselievre, Electronics Technician, and Mr. Pedro P. Ossorio, Research Technician, participated in the Exhibit program.

An important contribution of the research program was to provide opportunities for students from the University of El Salvador to perform thesis research utilizing the scientific facilities of the Exhibit. Research on coffee seed viability and genetic studies on beans and rice were carried out by university students. Additional thesis research topics included effect of formic acid in the Fricke dosimetry system, effects of formic acid on ferrous sulfate solutions, effects of gamma pretreatment on arsenic compounds irradiated with neutrons, and determination of the solubility of $MgNH_4As \cdot 6H_2O$ using ^{74}As. The early graduation, with honors, of Mr. Cáceres, who had worked on the Fricke dosimetry system, attracted the attention of University authorities because students usually need from one to two years to complete a degree. The PRNC scientists were often asked for advice regarding the curricula of some of the University colleges; Mr. Muñoz discussed in detail a program for the future Department of Chemical Engineering, which was being set up at the time of the Exhibit.

The PRNC program had a great impact on El Salvador, particularly in the field of agricultural research. Extensive programs in entomology and in genetics were adopted by the research institutions at Santa Tecla. PRNC lecturing scientists gave the Salvadorean scientists detailed plans for six months. PRNC personnel engaged in these and other programs important to El Salvador, complying with a request from the United States Embassy and the US AEC Division of Technical Information, will return to San Salvador at the time of exhibits in other Central American countries. The Salvadorean researchers are maintaining contact with PRNC personnel who participated in the Exhibit research programs.

The President of the Republic, Colonel Julio A. Rivera, expressed gratitude for the work accomplished and during his last visit to the Exhibit on March 21, 1965, recommended that the Minister of Economy, Dr. Abelardo Torres, reorganize the National Commission for Atomic Energy. It is hoped that when this is done the Puerto Rico Nuclear Center will play a decisive role in planning the programs to be undertaken, as well as in training the needed personnel with the help of the University of Puerto Rico.

The Atoms in Action Exhibit in El Salvador was visited by 94,000 persons. It helped to acquaint the people with the needs of the

country in the general field of science, and it created goodwill for the cooperative programs currently being developed by the United States. The most important accomplishment of the Exhibit was to acquaint the government with the need for postgraduate education for its research workers in agriculture and its university professors.

RESEARCH ACTIVITIES: GUATEMALA

The same procedures used for the PRNC program in El Salvador were followed for the program in Guatemala, but with account taken of the fact that Guatemala is a well established country, receiving cooperation from international regional organizations. INCAP (Nutritional Institute for Central America and Panama) and ICAITI (Central American Institute for Industrial Technology Investigations) have introduced the use of nuclear energy into their current research programs, and with the cooperation of ROCAP (Regional Office for Central America and Panama Affairs) and US AID (U. S. Agency for International Development) accelerated development of nuclear energy is expected in Central America.

During the Atoms in Action Exhibit in Guatemala, educational programs designed for undergraduate university students were presented for the first time. These were well received by both students and faculty. There was more emphasis placed on having students conduct thesis work as part of the research projects, and on specially selected topics. Research included work on genetics, agriculture, pineapple sterilization, degradation of Incaparina, entomology, thesis research by students from the University of San Carlos, and other subjects. Researchers from El Salvador came to Guatemala to continue their projects with the gamma irradiation facility.

Genetic studies on beans and rice started while the Exhibit was in El Salvador were continued in Guatemala. Preliminary studies on corn, to establish maximum survival doses, were undertaken by geneticists of the General Directorate of Agricultural Research, Ministry of Agriculture, Guatemala.

Special research was conducted on several agricultural products. Radiation effects on coffee flavor and taste were determined on 74 samples, each containing 200 grams, supplied by the National Coffee Association of Guatemala. Radiation effects on beer were studied on 54 samples at different stages of maturity supplied by the National Brewery of Guatemala. Radiation effects on samples of lemon grass oil

and citronella oil irradiated with gamma doses up to 10^6 rads were studied. The analyses were made by gas chromatography techniques at the PRNC laboratories. These preliminary experiments showed no effects.

Experiments started while the Exhibit was in El Salvador showed that pineapple packed in plastic bags or in cans spoiled easily after receiving doses up to 10^6 rads. ICAITI researchers repeated the experiments using a low temperature irradiation facility and doses up to 2×10^6 rads. A special fruit irradiator designed at ICAITI and built at the PRNC laboratories was used. The post-irradiation treatment consisted of storage at different ambient and refrigeration temperatures. Irradiated and control samples were analyzed for ascorbic acid, sugar, pH, and total bacterial count. Tests for physical appearance, odor, and pressure in the can were also performed. A report is being prepared.

Incaparina is an enriched protein-vitamin-mineral mixture developed at INCAP to help increase protein content of the daily staple diet of the Central American population. INCAP researchers used Incaparina to study the degradation of vegetable protein under gamma irradiation effects. A total of 97 samples, each containing 200 grams, were irradiated with doses from 5000 up to 3×10^6 rads. Chemical tests were done for gossypol, glycine, free acid in fats, and vitamins B_1 and B_2. Bacteriological studies and biological tests with rats were also carried out. A report is being prepared by Dr. Ricardo Bressani of the INCAP staff.

Research studies have been conducted on radiation effects on Heliothis zea (bellotero); in Guatemala, a new insect, Tomaspinas postica, was given gamma radiation. The first studies were on sex differentiation, and preliminary results indicated that this insect is very resistant to gamma radiation. With a cobalt source now available in Guatemala, this investigation could be continued by staff members and senior students at the College of Agronomy, University of San Carlos.

Students from the University of San Carlos (all of whom are expected to graduate in June 1966) participated in the research projects and topics listed below.

1. The Possible Use of Peroxytitanic Acid as a Chemical Dosimeter (experimental work finished during the Exhibit).

2. Kinetic Interchange Between Cyclo Alkene Chloride and Radioactive Chlorine.

3. Radiation Effects on Pineapple Juice.

4. Effects of Formic Acid in the Fricke Dosimetry System (experimental work finished during the Exhibit).

5. Degradation of Incaparina by Gamma Radiation.

6. The Search for an Empirical Equation to Correlate Sedimentation of Particles in Media of Different Viscosities.

Dr. Owen H. Wheeler and Dr. Robert A. Luse of PRNC, visiting scientists at the Exhibit, set up three other programs:

1. Labeling of Gossypol. Study of the metabolism of gossypol, a toxic component in cotton seeds, which are used as animal feed, is important to INCAP. Metabolism studies through chemical analysis have yielded very erratic results. Appropriate labeling of gossypol would make such studies easier and possibly more successful. In labeling, diphenylformadine is used to convert apogossypol to gossypol. At the PRNC laboratories, this compound has already been tagged with ^{14}C, and preliminary data on the ^{14}C labeling of gossypol are expected by the end of December 1965.

2. Studies of Phosphorus-32 Absorption in Corn and Beans. Since ^{32}P absorption studies have regional importance in Central America, support by some international organization may become available after preliminary data have been obtained. In view of this possibility, with authorization from Dr. Burrell L. Wood, Manager of the Exhibit in Guatemala, Mr. Muñoz arranged through PRNC for a Geiger detection system to be used in the preliminary experiments by Eng. Mario Breeuner, University of San Carlos, and Lcdo. Oscar Ortiz M., Ministry of Agriculture. The National Commission of Nuclear Energy of Guatemala (CONEN) is expected to provide in its new budget for supplying the necessary tracers and detection equipment for this program.

3. Tracer Studies in Coffee Plants. Dra. Flora Espinosa from the Salvadorean Coffee Research Institute (ISIC), Santa Tecla, El Salvador, came to Guatemala three times to study the absorption of ^{32}P and ^{35}S in coffee plants with use of the electronic equipment at the Exhibit.

The following 19 lectures were presented by PRNC staff members.

Prof. Fausto Muñoz Ribadeneira, Scientific Coordinator, Atoms in Action Exhibit

1. Uses of Tracers in Engineering
2. Industrial Uses of Gamma Systems
3. The Fricke Dosimetry System
4. The Ceric Dosimeter

Dr. Donald Sasscer, Head, Nuclear Engineering Division, PRNC

1. Cross Section and Its Significance
2. Neutron Diffusion Theory I
3. Neutron Diffusion Theory II

Dr. David Walker, Entomologist, Agricultural Bio-Sciences Division, PRNC

1. Radiation Effects in Genetics
2. Application of Radiation Effects in Entomological Studies
3. Studies of Entomological Problems in Sugarcane in Puerto Rico
4. Entomological Problems in the Export Products of Guatemala

Dr. Horace Graham, Associate Scientist (ad honorem), Agriculture Bio-Sciences Division, PRNC

1. Food Preservation by Radiation
2. Deinfestation of Grains by Radiation

Dr. Owen H. Wheeler, Head, Nuclear Science and Technology Division, PRNC

1. Uses of Radioactive Tracers in Chemical Kinetics
2. Radiation Chemistry of Steroids in Amino Acids
3. Labeling of Organic Compounds With Tracers

Dr. Robert A. Luse, Head, Agricultural Bio-Sciences Division, PRNC

1. Tracer Applications in Plant Physiology
2. Tracer Applications in Plant Biochemistry
3. Activation Analysis

In addition to the PRNC staff participants listed above, Mr. Henry Besselievre, Electronics Technician, and Mr. Pedro P. Ossorio,

Research Technician, participated in the Exhibit.

A program for university undergraduates was offered, which consisted of a one-hour lecture by Mr. Muñoz and a three-hour lecture demonstration by the Salvadorean high school teachers who had participated in the Exhibit in El Salvador. Five groups of undergraduates from the University of San Carlos and one group from the Rafael Landivar Catholic University attended separate presentations of this special program on a voluntary basis. The large attendance (1200 total) indicates the success of the program.

Col. Rolando Ureta, CONEN President, requested a series of lectures on differential equations for CONEN staff members. This program was offered by Eng. Mario Batres Castillo, Professor at the College of Arts and Sciences and a graduate of the University of Puerto Rico.

The neutron source was used by ORINS personnel to demonstrate the physical meaning of half-life to senior students in the high school program of the Exhibit. It was also used in a demonstration of activation analysis in the course on basic research techniques. In the PRNC program, the neutron source was used in (1) student method for determining the binding energy of the deuteron, (2) an inelastic neutron scattering experiment, and (3) a versatile experiment with a neutron source and a tank of water. These experiments were based on PRNC publications and were performed by professors from the Department of Physics, College of Arts and Sciences, University of San Carlos.

The PRNC personnel working with ICAITI developed that institution's interest in applying nuclear science in its current investigations. ROCAP and US AID purchased the Exhibit gamma facility and donated it to ICAITI, which will be in charge of developing programs in nuclear energy in Guatemala. ROCAP is interested in having PRNC cooperate with ICAITI in its new responsibilities and is also requesting a US AEC representative for Central America.

With the availability of a gamma facility in Guatemala, continuation of the programs in genetics, food preservation, and entomology appears very promising, not only in Guatemala but also in El Salvador and Nicaragua. PRNC personnel hope to aid in the development of these programs, as well as new ones, after the Exhibit leaves Central America.

The Exhibit aroused the interest of the local government and international organizations. Mr. Muñoz discussed the possibility of

graduate study at UPR starting in July 1966 with several candidates.

Mr. Muñoz was granted a Diploma of Recognition for his services in the development of the sciences in Guatemala.

The PRNC program at the Exhibit in San Salvador was essentially educational; it was even more so in Guatemala, where more students participated in the research programs, activities, and lectures. These young people should be given the opportunity to continue graduate studies in Puerto Rico or the United States, and when they bring the benefits of applications of nuclear energy in the fields of agriculture, industry, and public health to their countries, the time and effort spent on the International Exhibits Program will be rewarded. (See Figure 6.)

Figure 6. Left to right: Dr. Burrell Wood, Exhibit Manager; Mr. Sam Bevins, Assistant Exhibit Manager; and Mr. Fausto Muñoz, Scientific Coordinator.

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Figure 6. Left to right: Dr. Burrell Wood, Exhibit Manager; Mr. Sam Bevins, Assistant Exhibit Manager; and Mr. Fausto Muñoz, Scientific Coordinator.

BIOLOGICAL AND MEDICAL RESEARCH PROGRAMS

The research activities in biology and medicine (also called the 06 Program) are sponsored by the US AEC Division of Biology and Medicine and comprise approximately one-third of the total PRNC program.

Figure 1. Mr. Raúl McClin and Mrs Iraida Oliver de Padovani working with a multichannel analyzer for the determination of scandium-46 from neutron activation *analysis for trace elements.*

MARINE BIOLOGY PROGRAM

Frank G. Lowman, Ph. D., Head

The research program in marine biology at PRNC is a continuation of studies started in January 1962. Although the program is composed of six major projects, its functions are integrated. The six original research projects were designed to provide measurements of the distribution and movement of selected trace elements in a restricted, but complete, ecological and biogeochemical system. The work included limited investigations of the lithosphere as well as detailed studies of the marine biosphere.

In order to obtain information on the interactions between the marine biosphere and hydrosphere, measurements are being made of (1) biological productivity, (2) the distribution patterns of selected trace elements throughout the system, (3) concentration factors of selected organisms for given radioisotopes, (4) distribution patterns of worldwide fallout in the marine organisms and sediments, and (5) physical and chemical oceanography. In addition to these investigations, work in marine ecology is under way with special emphasis on food web relationships.

The research program was designed to measure the distribution and the movements of selected trace elements from a land mass into the sea, the marine organisms, and the marine sediments, and to relate measurements of biological productivity and movements of organic components through food webs and chains with the incorporation and transfer of trace elements through the trophic levels. The geographical area of the studies is on the west coast of Puerto Rico and includes the watersheds and offshore marine areas of three rivers, one of which drains a watershed predominantly comprised of limestone, another of volcanic origin, and a third with extensive outcroppings of serpentine. The three rivers empty into the sea within a 17-mile stretch of coast, and the marine organisms which inhabit the estuarine areas of this area have been found to contain amounts of trace elements and fallout radioisotopes, which reflect the influences of the neighboring watersheds.

The measurements of distribution patterns of trace elements in the lithosphere, hydrosphere, and biosphere and the studies of the interactions of the biosphere and hydrosphere upon the distribution patterns of the elements has required the development of techniques

with sufficient accuracy, reproducibility, sensitivity, and simlicity to achieve the measurements in a large number of samples. This has included not only the development of methods for trace element analysis in the microgram and submicrogram range, but the adaptation of ecological field procedures to quantitative measurements in which correlations of observations with large numbers of biological and environmental variables may be made by sorting the data with machine methods.

Until recently, the amounts of trace elements in the organisms have been related to ash and to dry and wet weights. In the ecological studies, and especially in the food-web work, the elements are now also related to carbon and nitrogen content for comparison of "trace element to protein ratios" in trophic levels and to caloric content for comparison of "trace element to potential energy" between trophic levels. In addition, a cooperative plankton program has been initiated between the Marine Biology Program, Dr. Bernard Patten of the Oak Ridge National Laboratory, and Dr. Perry Jeffries of the Narragansett Marine Laboratory. This work is designed to interrelate species diversity with biological productivity; depth of sampling; geographical location; total carbon, nitrogen and caloric value in the phyto- and zooplankton; lipid and amino acid patterns in the phyto- and zooplankton; and macro- and trace element contents of the two trophic levels. The investigations will also be related to background observations on trace element content of the sea water, physical oceanographic measurements, and sedimentation studies, which are now in progress.

Investigations of marine sediments of the west coast of Puerto Rico include studies of trace element and macroelement distribution with depth in the core, analysis of grain size, determination of the mineral composition, and measurements of organic material. The physical studies on the sediments have been expanded to include x-ray diffraction analysis with a machine sorting program. The distribution patterns of calcite, aragonite, and α-quartz are being determined in all sediment samples by this method.

An initial investigation of the partitioning of the stable elements Fe, Sc, Zn, and Sm in the infaunal benthic organisms has been completed. Of particular interest was the discovery of two distinct groups of polychaetes, one of which concentrates iron and the other concentrates zinc to many times the levels of those found in the sediments. The division of elements between the two groups follows a distinct pattern; those that concentrate iron feed at the sediment interface, while those that concentrate zinc feed actively below the sediment-water interface.

Analyses of the qualitative and quantitative distributions of infaunal invertebrates continue to indicate a direct relationship between animal distribution and the fine sediments introduced from the on-shore watershed. Off the outflow from one river (Añasco) the select deposit feeders are most abundant in the immediate area of river outflow. Some species are limited in distribution to this area of rapid sedimentation, but, as distance from the river increases, suspension feeding crustacea, pelecypoda, and polychaeta increase in relative abundance. Non-select deposit feeding polychaetes, although present in the immediate vicinity of the mouth of the river, increase in relative abundance as distance increases, until the sand fraction of the sediment becomes dominant, and then they decrease.

Taxonomic work, limited to the most abundant polychaetes and a linguloid branchiopod has yielded six new species out of eight positive identifications. One family, Capitellidae, has posed a taxonomic problem. If the currently accepted characteristics for distinguishing between genera within this family are applied to specimens collected from Añasco Bay, 23 new genera would result, 14 of which have been collected in one sample.

Variability of trace element content in individuals of a given species has made difficult the analysis of differences in trace element content between populations of a species collected at different sites in the geographical area of investigation. In order to determine the patterns of variability, large numbers of individuals of apparently homogeneous populations of given species were collected. Thus, entire schools of small fish of one species were captured by fine mesh nets; large numbers of littoral snails of approximately the same size were taken from an area one meter square on a rocky coast, or a given species of alga was collected in large numbers from a restricted area. In all instances the organisms showed trace element (and macroelement) frequency distributions that are log-normal in pattern. A normal distribution occurs only for atom ratios of biologically similar elements such as calcium and strontium.

Rapid methods have been developed for the determination of lithium, zinc, and bismuth in sea water. In addition, a method utilizing neutron activation has been developed for biological samples in which six rare earths may be measured in 0.5 grams of biological ash.

A nondestructive activation analysis method for the quantitative determination of manganese, scandium, and iron has been developed for use with soils, sediments, rocks, and minerals. The samples and

comparator standards are irradiated in a neutron flux for an optimum time for each element, then held until the interfering radioisotopes decay out of the samples. The radioisotopes ^{56}Mn, ^{46}Sc, and ^{59}Fe are counted by gamma spectrometry.

The amounts of data, which may be collected by the several methods of trace and macroelement analysis, have increased to a degree that manual methods of tabulation and analysis are no longer feasible. Recently, a machine method of data storage and retrieval has been adapted to the marine biology program. With this method an opportunity for quick comparisons and rapid printout of all data is provided. Gross correlations between amounts of stable elements contained in organisms in relation to gradients in temperature, sediments, or salinity may be quickly ascertained, as well as differences in stable element content between geographic locations, between organisms within one animal, or between species or phyla. The system also provides a means for entering data directly into a computer for whatever program may be desired.

Figure 1. Aerial view of El Verde forest area with walkup tower and ring of giant cylinder towers on the left, radiation center to the right, and weather tower to the upper right.

TERRESTRIAL ECOLOGY PROGRAM I:

THE RAIN FOREST PROJECT

Howard T. Odum, Ph. D., Head

The rain forest project comprises studies on one small area of montane rain forest 1500 feet up the side of El Yunque in eastern Puerto Rico. It has three objectives: (1) study of the effects of radiation on the rain forest ecological system, one of the most complex of all natural systems; (2) study of the mineral cycling in tropical vegetation with emphasis on those elements often involved in processes of interest to the Atomic Energy Commission in a tropical environment, such as fallout, earth moving, and waste disposal; (3) study of the basic functional features of the rain forest system such as metabolism, transpiration, and biological circuits as necessary to understand the phenomena related to the first two objectives. The project is in its third year. A rain forest field station is in operation, the forest has been irradiated, the basic annual cycle of biotic events has been established, basic dimensions of the metabolism have been measured, gamma spectral studies are in progress, and chemical tracer experimentation has begun. Figure 1 is an aerial view of the forest, and Figure 2A is an aerial view of the El Verde field station.

The visiting program continued last year with new phases by additional participants, especially from the University of North Carolina and from the Institute of Radiation Ecology of the University of Georgia. To gather the results from the many different investigators into an organized unit, the decision was made to publish the results up to June 1966 in a book entitled A Tropical Rain Forest.

IRRADIATION

On January 19, 1965, after two years of preparation and measurements on the ecological systems of the rain forest at El Verde, Puerto Rico, the 10,000-curie cesium source was elevated for a 92-day irradiation providing a dosage of 1,000,000 roentgens to the nearest vegetation. By the end of radiation, leaves were yellowing and falling; the area of observable damage, at first only about 15 meters in radius, gradually increased to 25 meters by the end of

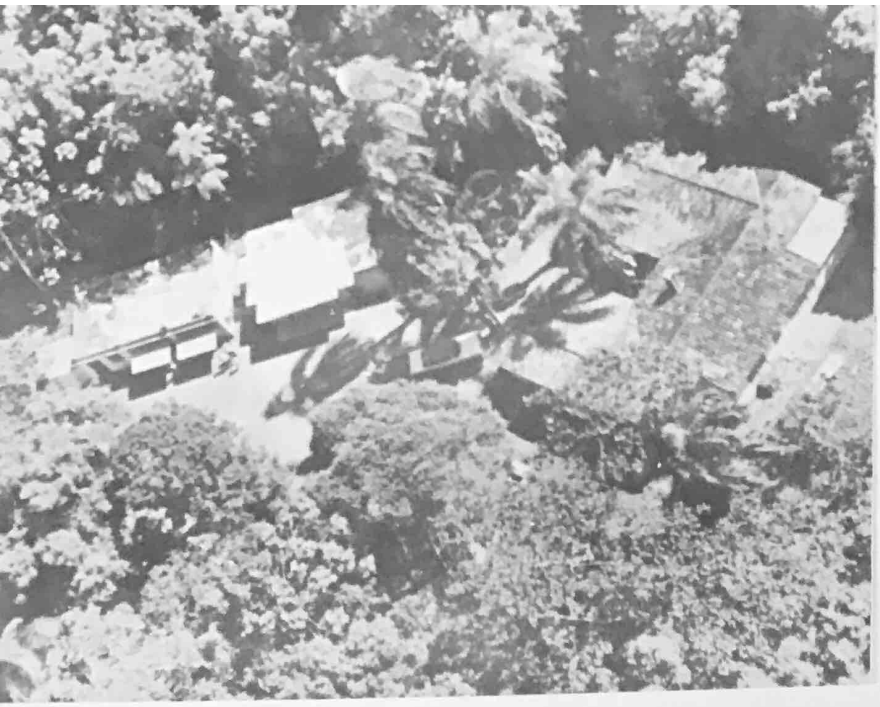


Figure 2. (A) New laboratory building at El Verde station. (B) One of 1500 lithium fluoride dosimeters in the forest. (C) Comparative study being made in virgin forest of Dominica. (D) Microcosms and Fiberglas litter bags for decomposition studies.

the summer. The extent of the sun's penetration due to loss of leaves from the canopy is recorded by optical density measurements for the three centers in Figure 3. Studies of various indices and properties were made afterward, as they had been during the year before treatment. The value of the two control centers now became evident. The untreated south center continued unchanged with only a slight seasonal variation in biological populations. The north cut center, which had been pruned by machete to resemble the post-irradiation state of gaunt bare stems, burst into regenerative budding with green shoots and hundreds of seedlings, while the irradiated center showed only a few green shoots from behind rocks. Data on numbers of shoots, seedlings, and fallen leaves are given for each center in Figures 4 and 5.

The 1500 lithium fluoride dosimeters of two kinds (one type is shown in Figure 2B) were read by four different laboratories, and the results were collated by Dr. J. F. McCormick of the University of North Carolina into a dosimetry map to be related to the field of biological measurements. Figure 3D summarized the radiation field. At 10 meters the accumulated dosage was 50,000 roentgens and at 30 meters, 5000 roentgens. By the end of the year the irradiated area was beginning to be recognizably different from the air.

CYTOLOGY

Having determined the nuclear volumes of all the species, Dr. Francis Koo, Mr. Charles Venator, and Mrs. Edith Irizarry made post-irradiation surveys of cytological effect by collecting meristems at various distances from the source, by studying abnormal division figures in Palicouria flowers in the irradiated field, and by measuring growth rates and pigment in the bromeliads, which had been placed in the environmental gradient. Dr. Veikko Sorsa was brought back from Finland to do a post-irradiation survey of fern cytology. Dr. Niilo Virkki prepared slides of gonads of the walking stick insects in the radiation field.

RADIATION EFFECTS ON POPULATIONS AND INSTRUMENTAL INDICES

Population studies verified the extent of radiation effects. Dr. Frederick Turner and Mr. Clayton Gist from UCLA found lizard and frog populations decimated to 10 meters. Dr. Harry Recher found

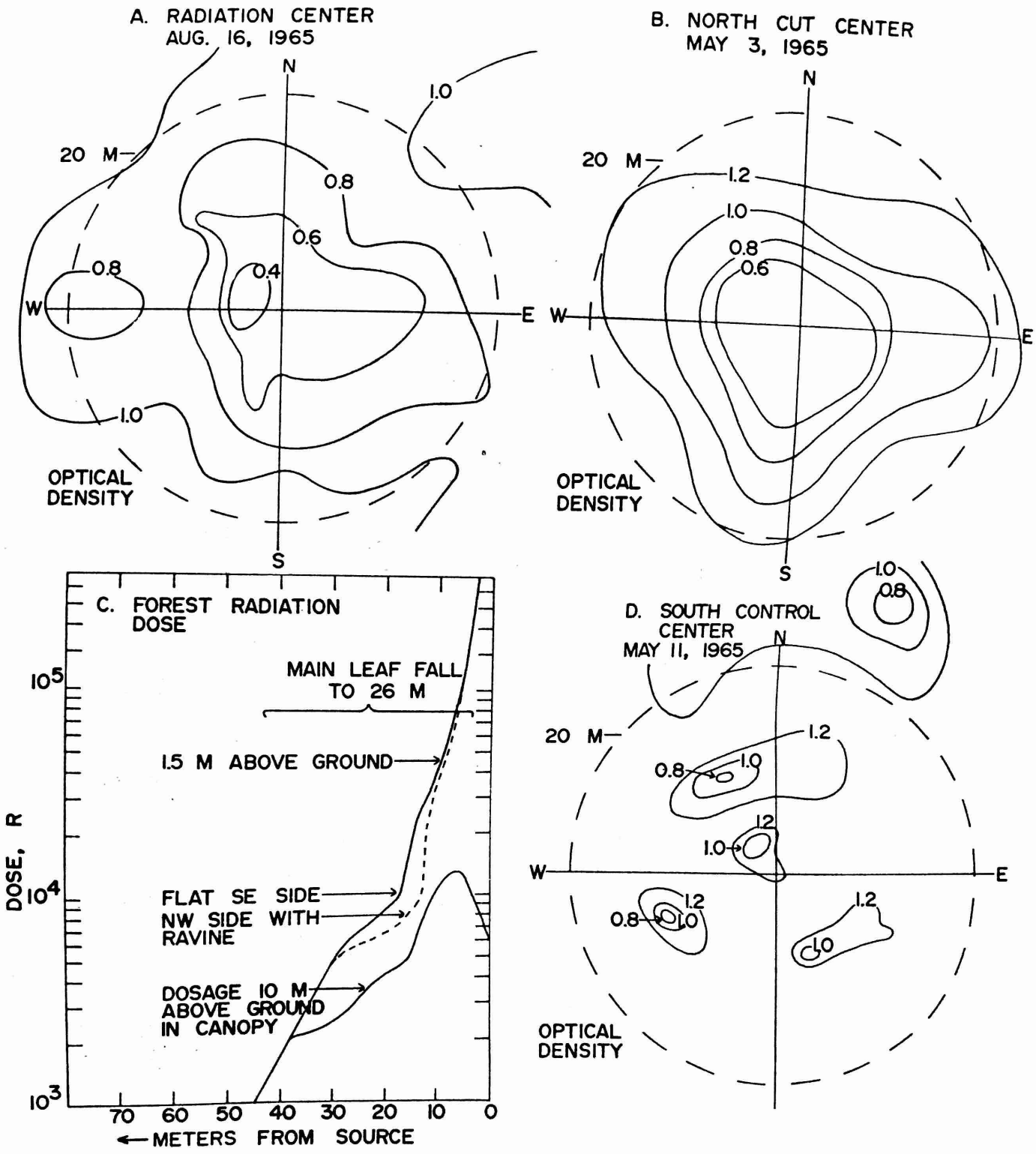


Figure 3. Optical density maps in (A) radiation, (B) cut, and (C) control centers, and (D) graph of radiation dosage received according to distance from center of source.

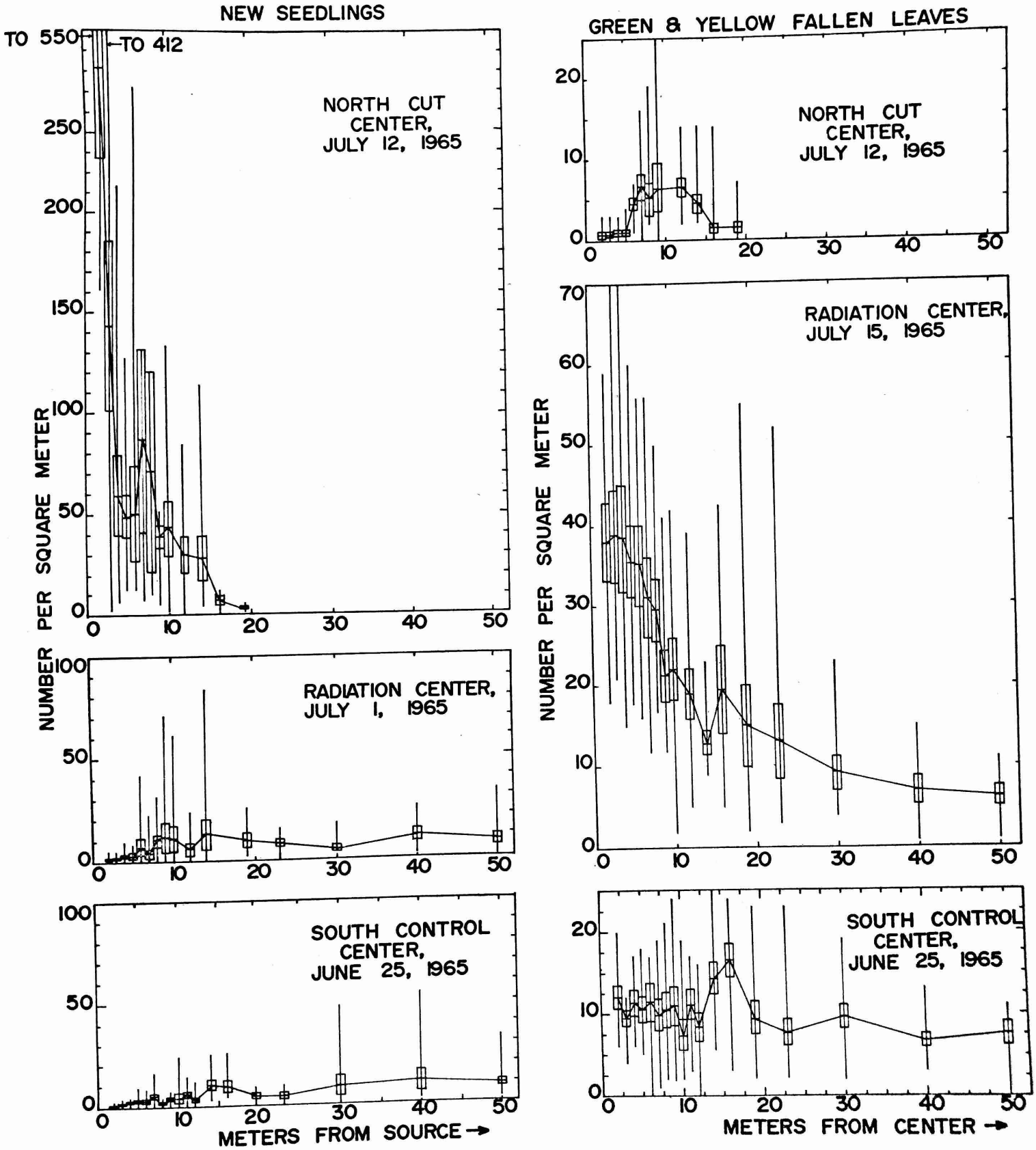


Figure 4. Comparison of new seedlings and recently fallen leaves in radiation cut, and control centers following irradiation.

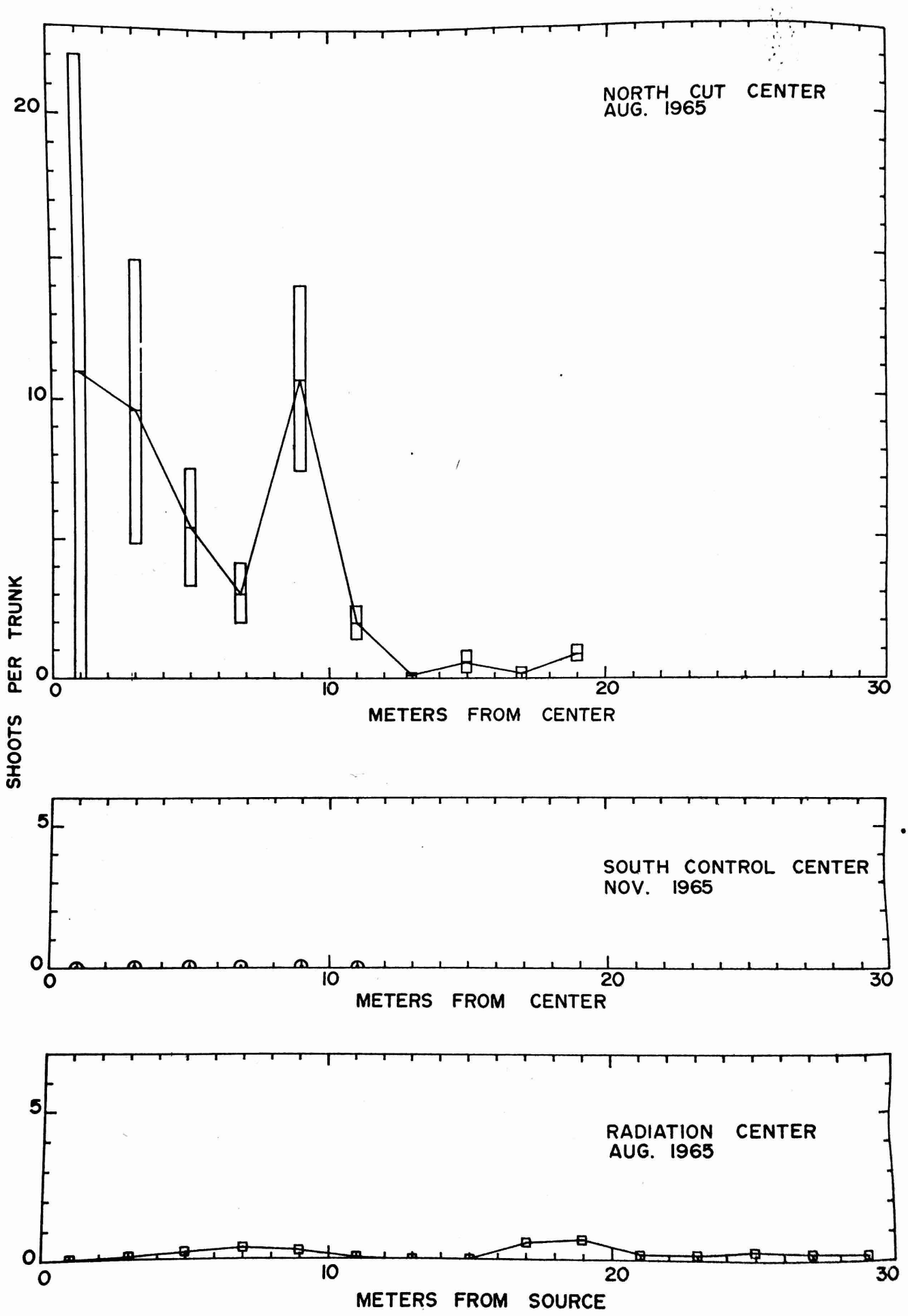


Figure 5. Comparison of numbers of new shoots emerging from the sides of trunks in radiation, cut, and control centers following irradiation.

banana-quits completely missing from several of their territories after irradiation. Dr. Harold Heatwole and Mr. Abel Rossy recovered 40 snails with internal dosimeters, and some of these showed radiation effects on shell deposition.

Several new types of measurements were made of radiation effects on plant species. Mr. Nelson Mercado and others obtained post-irradiation measurements of cambium and bud condition on 3000 limbs and punched terminal leaves so that leaf survival and new leaf growths could be counted later; this was done by Mr. Jaime Ruiz Reyes. Mr. Henry Watson measured 5000 twigs twice to get elongation rate. Mr. Robert Ford Smith recounted leaves on two species of shrubs, drew an isopleth map of viable trees, redrew a cross section after irradiation of the cable-car transect, remeasured crown twigs for growth elongation, recounted seedlings, and repeated microclimate measurements relative to soil conditions.

Post-irradiation surveys were made on microscopic fungi by Mr. James T. Holler and on macroscopic fungi by Dr. Gerald Cowley, both from the University of South Carolina. There were increases in decomposition rates but less diversity. General microbiological appraisals were made by Dr. Marvin Witcamp, Ecology Division, Oak Ridge National Laboratory, with metabolic indices. Even close to the center microbiological processes continued during radiation. Dr. William Steere of the New York Botanical Garden found that the die-back of mosses was partly due to increased light, since it occurred in the cut control, but comparisons of fronts and backs of rocks provided evidence of radiation effect within 10 meters.

Lichens were surveyed by Mr. Theodore Ganutz of Clark University. Dr. Richard Weigert from the Institute of Radiation Ecology, US AEC Savannah River Operations Office, repeated the post-irradiation study of microfauna in litter and leaf decomposition in Fiberglas bags and surveyed termites. A study was made by Mr. George Drewry, Mrs. Susan Drewry, and Mr. Eusebio Díaz on small flying insects caught by the sticky paper procedure relative to the radiation field. A matrix of 600 species by month and by station gradient was put on cards for testing of some theoretical postulates about niche (circuit) division and its disruption by radiation.

The same trees tested before irradiation were used for 1000 post-irradiation chlorophyll *a* determinations. At 10 to 15 meters there was a zone of yellowing leaves in process of falling with low chlorophyll. Outside this was a zone at 15 to 20 meters with augmented chlorophyll in several species. (See Figure 6.) Evidence for shade

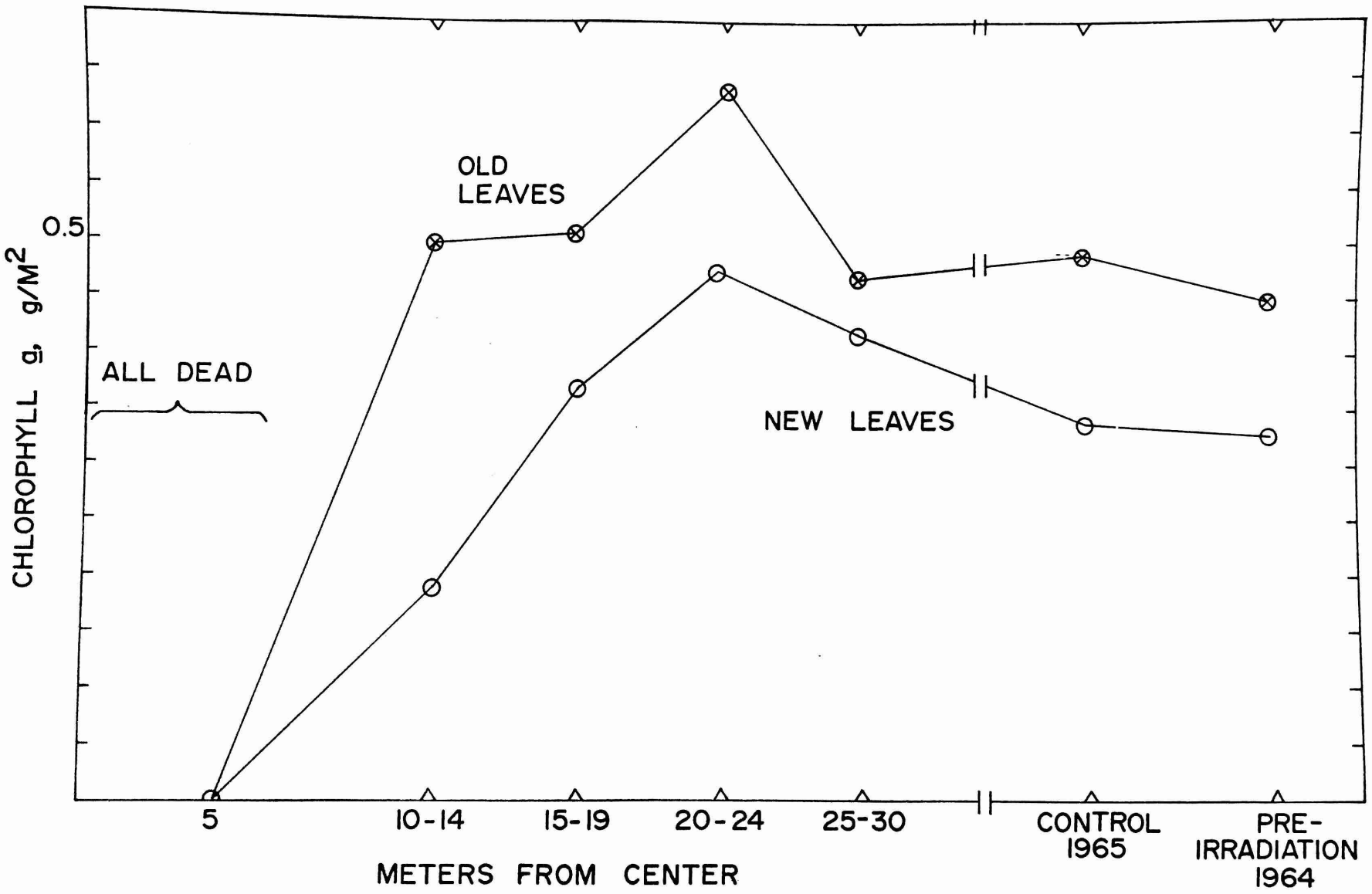


Figure 6. Chlorophyll a content of old and new leaves (mean of five species) as a function of distance from the irradiation source.

adaptation was found by Mr. Gilberto Cintrón in the elfin forest, and low chlorophylls were found in sun-adapted successional replacements in the cut center.

The close collaboration with the Tropical Terrain Detachment of the U. S. Army Corps of Engineers Waterways Experiment Station at Vicksburg increased with several joint efforts: (a) in constructing additional optical density devices tested throughout Puerto Rico and Costa Rica, (b) in pre- and post-irradiation detailed mapping of trees in the sites, (c) in the aerial photographic program, (d) in the study of seedling regeneration, (e) in joint use of computing facilities and personnel, (f) in searching for new vegetation structural measures, and (g) in a joint field trip to the virgin forests in Dominica to obtain data on the type of forest that originally existed in Puerto Rico. The El Verde Forest in Puerto Rico differs from Gleau Glommier, Dominica, in the absence of large trunks, but is similar in many other respects, including root number and fallout retention. Figure 2C shows a huge trunk from the comparable forest in Dominica.

The complex instrument system was kept in operation by Mr. Drewry and Mrs. Smith with an output of 20 roll charts a month. A digital data logging system was installed which samples part of the chart data on tape for transfer to IBM cards. Mr. Drewry completed the design of an apparatus sampling eight channels of forest sounds to augment the record of the sound of the coqui now in its third year. Night sound dropped to about half after irradiation.

Special attention was given to the autecology of the dominant palm, selected for the subject of a master's thesis by Miss Barbara Bannister, her work including root growth studies, biomass measurements, seedling studies, and continuation of phenology started earlier. Experiments on germination were attempted by Dr. Joe Edmisten of the University of Georgia on the legume Ormosia and by Dr. Elsie Quarterman of Vanderbilt University on three species in the field plots. Seedling quadrats in various designs were measured after irradiation by Mr. Robert Ford Smith, Dr. Frank McCormick, Dr. James Duke, and Mr. Ariel Lugo in separate studies.

Trunk growth and phenological measurements monthly on six species were continued by Mr. Peter Murphy, Mr. Jaime Ruiz, and Mr. Alejo Pinto, and a new series of 110 phenology stations was started on ten additional species. Monthly leaf fall collections were analyzed for phenology and fallout and sent for chemical analyses to England

and to the University of Georgia. Mr. John W. McIntyre from Syracuse University did a study on tree borings.

CHEMICAL AND SOIL STUDIES

Completion of the new field laboratory building and the arrival of Dr. Jerry Kline resulted in acceleration of the chemical studies of the mineral systems of the forest using analyses and tracer experiments. The remarkably high fallout levels in the forest facilitated this work. The gamma spectral work allowed comparisons between the El Verde site and tropical rain forest sites of possible concern to the US AEC such as those in Panama and Southeastern Asia. Samples of foliage and litter were included from Costa Rica, Mexico, Panama, and British Dominica. A gradient in degree of binding was found with altitude, the dwarf elfin forests at high altitude holding the most and the lowland forests with dry seasons holding the least. Algal accumulations on roofs had the highest concentrations of fallout of all materials in Puerto Rico. Spectra on residual soil films on weathered limestones were found with radium. Sample spectra are shown in Figure 7.

Soil studies were added including cutting of profiles, root counts (Figure 8), measurement of oxidation potential and of rate of water drain, gamma spectra, and density and moisture readings with a neutron soil meter. The surface is extremely heterogeneous and low in density because of air spaces among the surface roots, litter, and rocks. Root numbers (Figure 8) and effectiveness of holding fallout were correlated with wetness of the situation. Competing theories explain the high fallout retention on the basis of (1) greater age of leaves and epiphytes in wet situations and (2) adaptation for strong absorptive binding where transpiration is less effective. An anaerobic oxygen-minimum layer analagous to the sea was located in wet situations (blue clay zone in Figure 8).

Mr. Phillip Sollins did a summer study on the electrical conductivity of waters in the forest including rain, water running down trunks, and water dripping through leaves. The increasing values from rain to water through leaves verified quantitatively the mineral cycling system, and the increase in stream conductivity in dry weather indicated the mineralization contribution of the earth under the forest. A diurnal pattern of leaching may reflect diurnal variation in transpiration. (See Figure 9.)

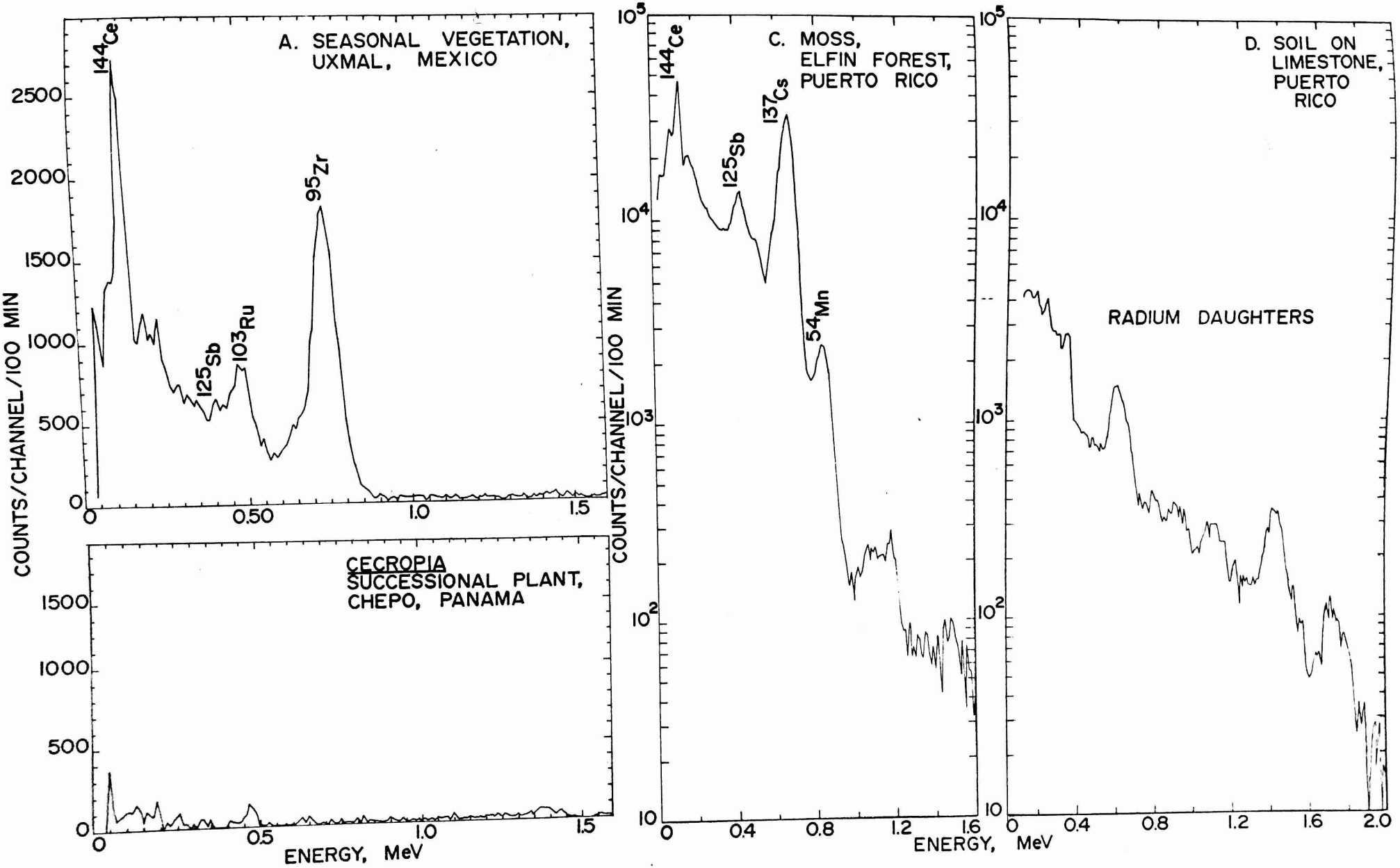


Figure 7. Gamma spectra: (A) young leaves from Mexico, (B) young leaves from Chepo, Panama, (C) moss from the elfin forest of Puerto Rico (3500-foot elevation), and (D) thin solid on limestone in Puerto Rico. (Work done by Dr. J. Kline.)

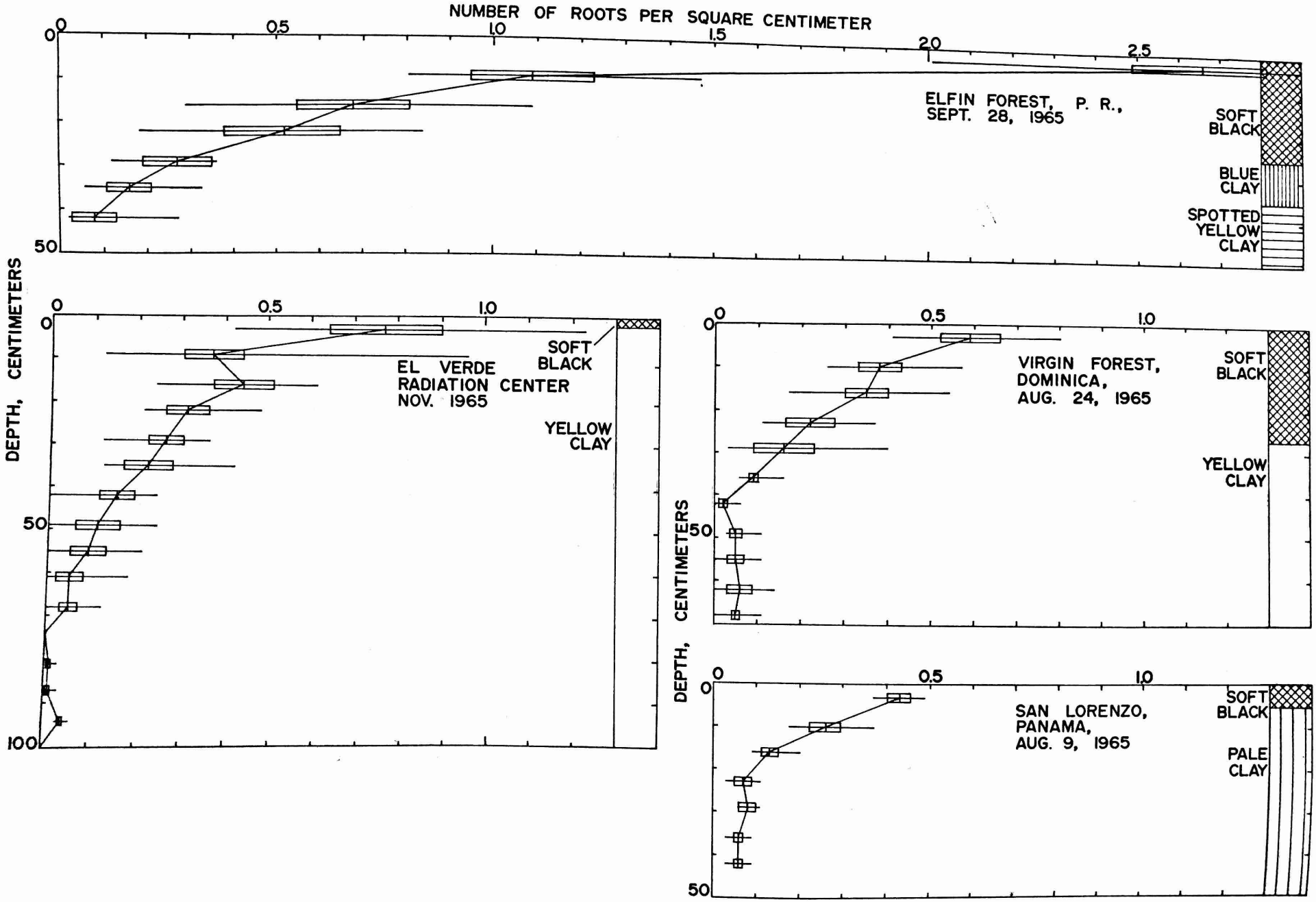


Figure 8. Root counts in soil pits: comparison of elfin forest with less saturated sites at El Verde, sites in virgin forest of British Dominica, and sites in Panama.

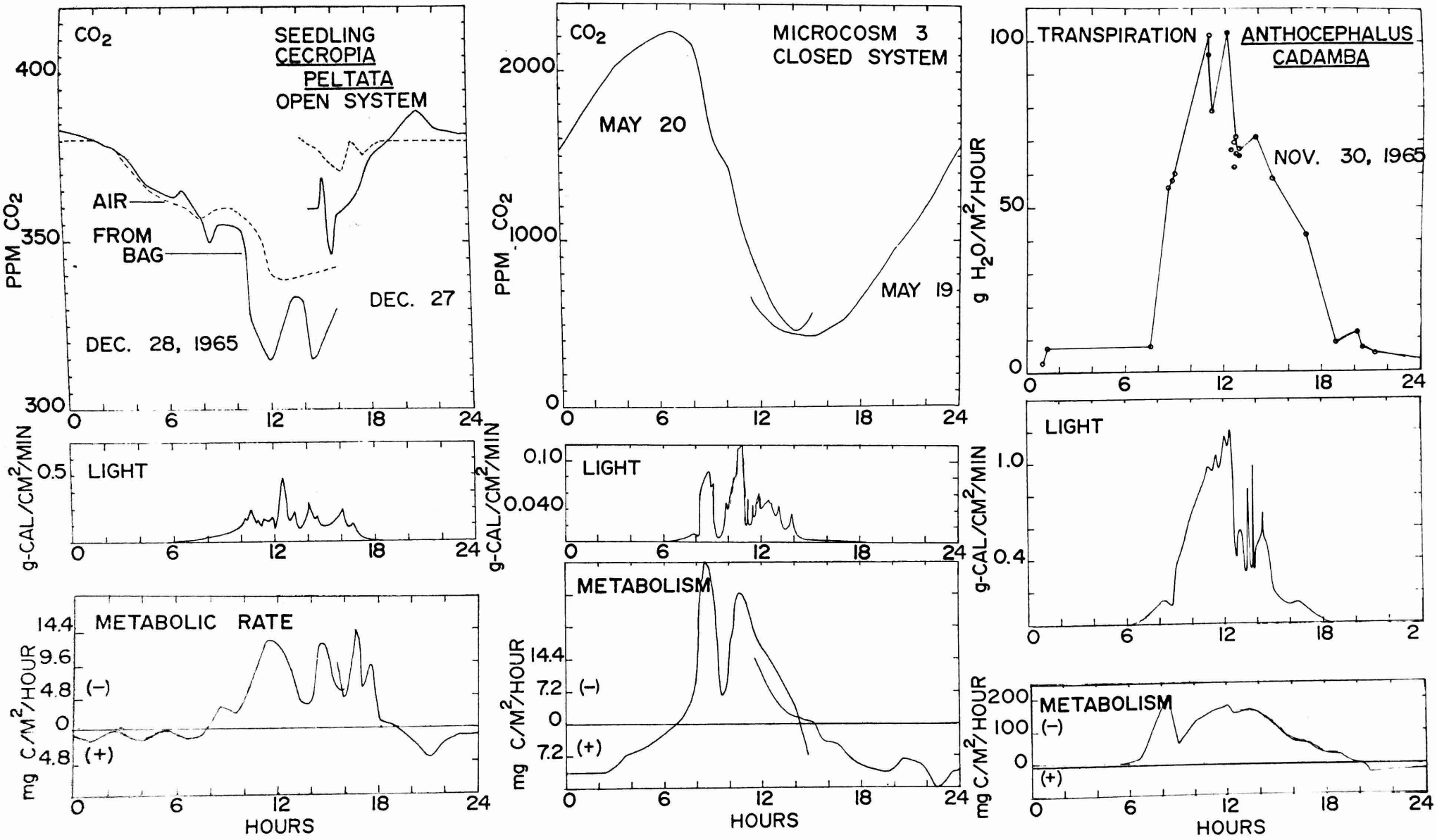


Figure 9. Twenty-four-hour records of metabolism and transpiration in a balanced forest microcosm, in a new seedling after irradiation, and in a rapid-growing exotic.

Post-irradiation soil metabolism was found higher near the center of the irradiated area and less at intermediate distances (Figure 10).

The general chemical analyses of the trees cut in a previous year were completed in England, and a large matrix was prepared with information on 40 species, 1000 trees within 30 meters of the source, and six elements. Ultimately it will be possible to calculate the chemical composition of a prism of forest from these inputs.

METABOLISM AND HYDROLOGICAL BALANCES

Measurements of the metabolism and transpiration of principal forest components were continued with the aim of showing the principal processes and flows capable of moving, binding, and transmitting isotopes. The study of the mineral and energy budgets in the falling leaves continued as indicated in the records shown in Figure 10. Litter decomposition in Fiberglas bags did not go to completion. Mr. Ariel Lugo finished his M.S. thesis on seedlings working with two climax and two successional sun-adapted species. An example of a 24-hour record is given in Figure 9 (left). By the end of the year data had been accumulated on metabolism of soil, termites, frogs, tree trunks, roots, crown leaves, and successional plants. Studies of transpiration had been made and a system developed for simultaneous measurement of respiration and transpiration (see Figure 9, right). The plan to build a giant cylinder to measure transpiration in a large prism of the forest was put into effect with the construction of six towers in a hexagon (see Figure 1), installation of a 15-horsepower motor driving a 6-foot fan, and erection of an aluminum shed with power for measurement systems and a walkup tower. Cheap polyethylene plastic was sewed to the frame, and an initial measurement was obtained before it failed. The water transpiration was 268 grams per square meter per hour. To complete the study of hydrological balance including evapotranspiration, a new plastic for the giant cylinder and a runoff recording weir were obtained and installed.

Fourteen closed microcosms containing forest floor litter, herbs, microbes, and animals maintained a balance of photosynthesis and respiration that was diminished only a third by 25,000 roentgens dosage. An example of a day's record is given in Figure 9 (center).

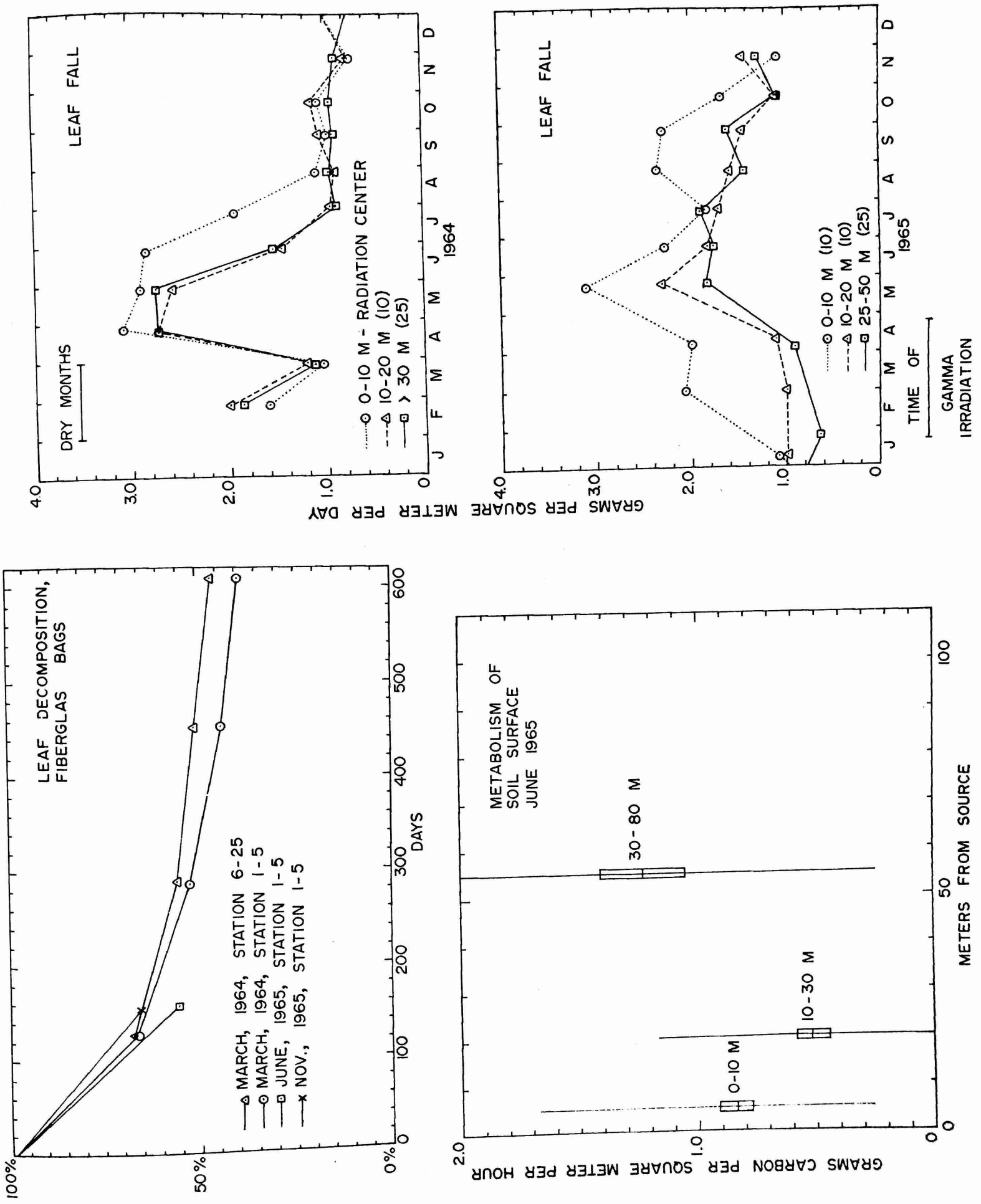


Figure 10. Leaf fall, decomposition rate of litter in Fiberglas bags, and metabolic rate of the soil-litter surface.

COMPUTER SECTION

A special US AEC project committee (Dr. Robert Platt, Chairman) visiting in May suggested additional field measurements to record rapid post-radiation changes. With these data accumulating through continued chart output from the electronic instrumentation, there was an excess of people getting measurements in relation to those graphing the data and writing up the results. A computer section was organized with two punch card operators, staff for calculating and graphing, and two sources of computer programming. By the end of the year some 30 phases had been put on cards and programmed for computation of final results.

ANALOG CIRCUIT

As a prelude to next year's work and to meet the request by Dr. Walter D. Claus of the US AEC Division of Biology and Medicine for a plan for a working electrical model of the rain for exhibit purposes, a proposal (PRNC Report No. 67) was prepared based on the passive analog principles developed earlier. The programming of actual data plus experimental manipulations of circuit connections are to provide testing of theories on the relation of cycling to structure. If this is realistic, the analog model can predict consequences of some rain forest management manipulations and reconstruct phenomena observed in the radiation study.

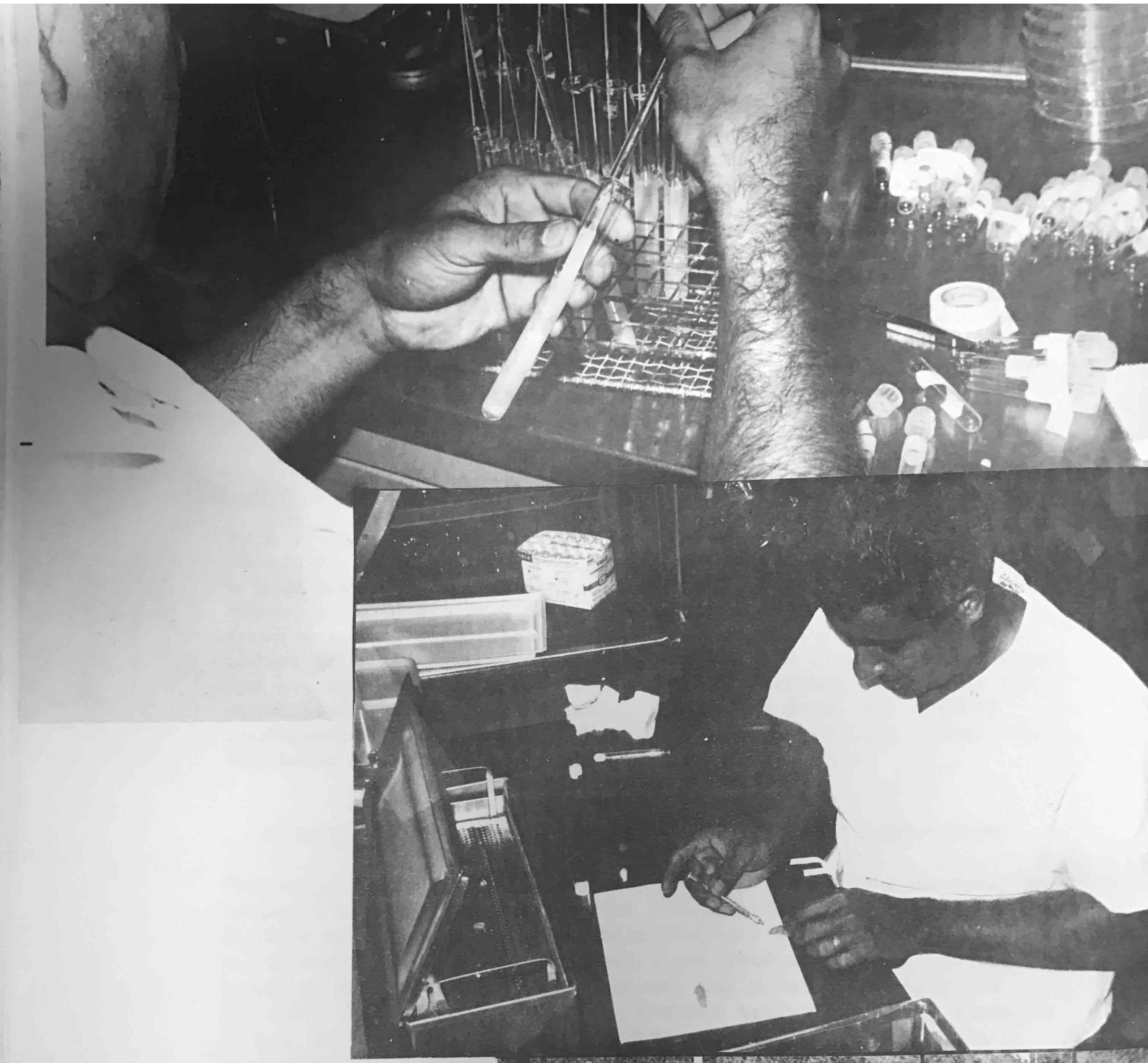
LOGISTICS, THE EL VERDE STATION, AND LONG-RANGE PREPARATIONS

The project operates with its administration, computer section, and chemical programs centered in the PRNC Bio-Medical Building at Río Piedras and its field and visiting programs centered at the El Verde field section. A small air-conditioned laboratory with isotope handling facilities, regulated power, and a hood was built for $20,000. The El Verde house was further equipped as four separate living units for the visiting program, and hot water and cooking facilities were added. Permanent tagging of trees with Latin names was extended to 30 meters in the study centers. Many activity locations were identified by permanent concrete markers to ensure a 10- to 20-year record of post-irradiation events and to allow more than one investigator to work in the same spot and on the same tree.

The El Verde station is now operated by a resident scientist (Mr. George Drewry) with a regular staff of five research assistants

and maintenance men from the nearby village of El Verde plus a continually changing quota of visiting scientists and students from San Juan, Mayaguez, and universities in the United States.

The Ciénaga Alta house five miles from the El Verde station, also on a no-cost contract from The U. S. Department of Agriculture, was outfitted with electrical power and has been used for resident graduate students on fellowships.



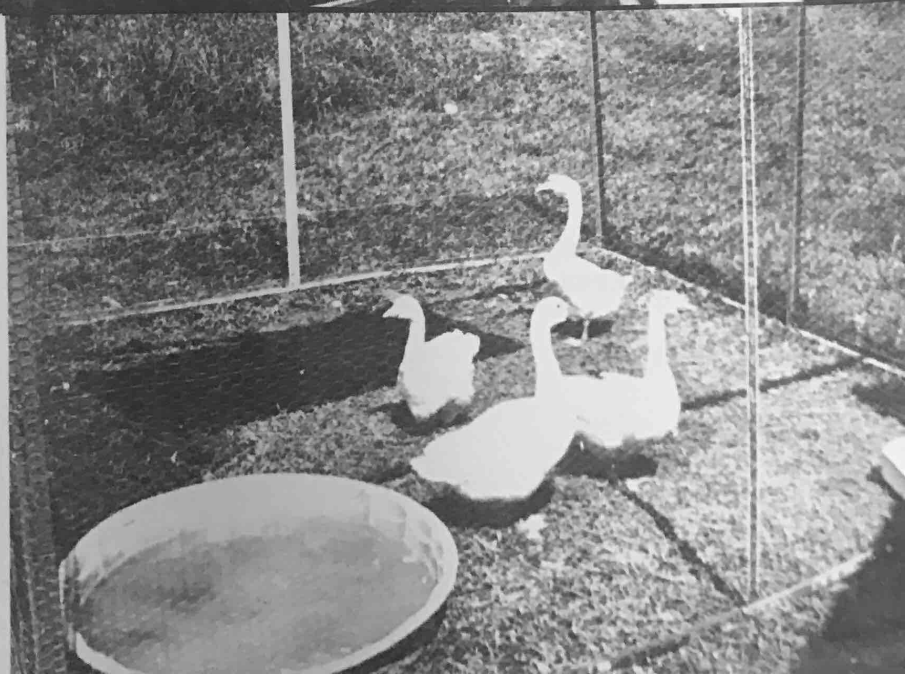


Figure 1. Preparing mosquito suspensions for inoculation into 48-hour-old baby mice used for testing for presence of viruses in mosquitoes.

Figure 2. Baby mice are being inoculated with a preparation of rat serum to test for the presence of virus.

Figure 3. Red blood cells from gesse are used in the hemaglutination-inhibition test for the presence of virus.

TERRESTRIAL ECOLOGY PROGRAM II: RADIATION INDUCED VARIABILITY IN INDIGENOUS ARTHROPOD-BORNE ANIMAL VIRUSES OF PUERTO RICO

M. Paul Weinbren, M. D., Head

This program is designed specifically to study the effects on natural virus cycles (especially Arboviruses) in gamma-irradiated portions of the tropical rain forest. Evidence of Arbovirus activity is being sought by attempting direct virus isolation, in infant white mice (See Figures 1 and 2) and tissue cultures, from trapped arthropods and from blood samples collected from vertebrates in the area. The blood samples are also used to obtain indirect evidence of virus activity by the results of various serological tests. (See Figure 3.) Although some aspects of this study might be covered by laboratory experiments, the program as designed takes advantage of a unique opportunity for study in nature. One hypothesis being tested that is of particular interest is the reactivation of latent virus, which has become latent through identification of its nucleic acid with that of the arthropod host.

In the pre-irradiation period, 90 rodent traps were placed on set lines and trapping weekly a total of 615 Rattus rattus (the only rodent in the area) have been trapped, marked, and released, and 1087 recaptures have been made, the highest retrapping score being 27. During this period light traps were set to catch flying arthropods, and 19,000 mosquitoes of five genera were taken. More than 733 rat sera and all the mosquitoes were tested but yielded no viruses. Of 400 rat sera tested for Arbovirus antibody, 15 gave a positive reaction to Casals Group B. When irradiation began, an additional 50 rodent traps were positioned outside the irradiated area. Both rat and mosquito trapping has continued on a regular weekly basis outside the irradiated area, and also in the irradiated area on the two occasions when the source was lowered for 24 hours and since the period of irradiation ended. About six weeks after the irradiation began viral agents started to be isolated, mainly from rat sera but also from a few mosquito pools and from the brains of two rats that were sick when trapped. From this time until six months after the irradiation period 40 viral agents were isolated, and from that time to the present no further isolations have been made. After exhaustive testing these agents have been identified as Coxsackie A10 or so closely related to this virus that it is indistinguishable by normal laboratory methods.

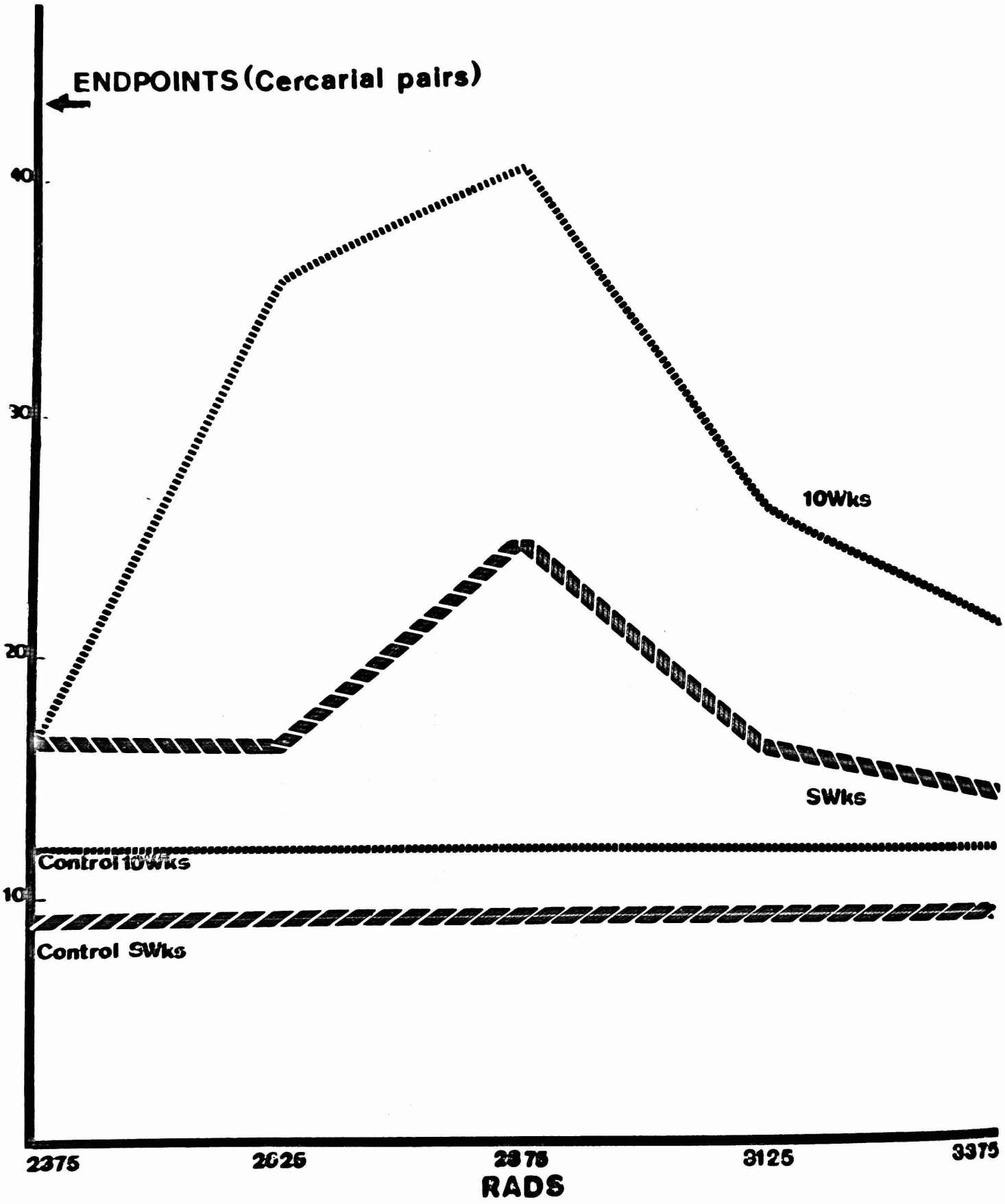


Figure 1. Number of cercarial "pairs," as estimated by the Reed and Muench method from exposure to doubling numbers of normal cercariae, that will result in a mouse passing a total of 100 ova during ten 24-hour observation periods between the 42nd and 60th post-infection days. The test mice were previously "immunized" by 100 cercariae irradiated at different doses of cobalt-60 gamma radiation.

THE MECHANISMS OF ANTIGEN-ANTIBODY REACTIONS FOLLOWING THE INOCULATION OF MICE WITH IRRADIATED AND NORMAL SCHISTOSOMA MANSONI CERCARIAE

John B. Villella, Ph. D., and M. Paul Weinbren, M. D.

This program started early in 1964 and is based on work done by J.B. Villella and H.J. Gomberg at the University of Michigan, and on similar work by E.H. Sadun et al. at the Walter Reed Army Medical Center, Washington, D.C. Both groups reported an acquired resistance to challenge with virulent S. mansoni cercariae after prior exposure to cercariae damaged by exposure to gamma radiation. It is the object of the present program to perfect a delicate means of assessing the degree of protection obtained and then to establish the conditions required consistently to produce maximal protection. Experiments have also been designed to test the duration of the protection conferred and the stages at which various serological tests yield positive results. When the parameters for inducing maximal protection have been established, a detailed study will be made of all detectable reactions occurring between the challenging parasite and the "immune" host, with special emphasis on the factors leading to the disabling of those challenging cercariae which fail to mature. The problems attendant upon reasonably accurate quantitation of the "immune response" or degree of protection conferred upon a mouse exposed to irradiated cercariae are virtually insuperable with the techniques in current use by parasitologists.

A method of assessing the degree of infection has been perfected, which is based on the number of S. mansoni ova that can be recovered from the feces of infected mice by standardized observation procedures. The standard infection was arbitrarily defined as one that results in the mice passing ova at least every other day, to a total of 100 in ten counting days. Preliminary experiments showed that under the conditions prevailing in this laboratory, if fecal collection was begun on the 42nd day, eggs could be detected in the first and virtually all subsequent collections from an infected mouse. Further work indicated that the figure of 100 was a reasonable choice for the cut-off point when deciding whether or not a mouse had received a standard infection. For the purposes of calculation, all animals from which 100 or more eggs were recovered were assumed to satisfy the requirements of the standard infection, while those yielding 99 or fewer eggs were listed as failing to have

done so.

With the system outlined above, a number of estimates have been made of the number of "pairs" of cercariae necessary to induce a standard infection in groups of five CF1 mice. Five estimates made on different dates gave a mean result of 7.7 ± 2.0 cercariae needed per mouse to cause a standard infection. These calculations were made by the Reed and Muench method of calculating 50 percent end points. ID_{50}

An experiment has been completed to determine the optimum amount of radiation for cercarial exposure to induce the greatest degree of resistance to challenge. Groups of 25 mice were exposed to 100 irradiated cercariae per mouse. The radiation levels were started at 2375 rads and increased by steps of 250 rads to 3375 rads. After an eight or ten-week interval the groups of 25 mice were divided into subgroups of five animals each for challenge with doubling numbers of cercarial "pairs" from eight through 128 pairs. At the time of challenge parallel titrations for cercarial virulence were made in normal mice. The results of the experiment are shown in Table 1 and Figure 1. From the graph it can be seen that mice challenged at ten weeks after exposure to cercariae that had received 2875 rads cobalt-60 irradiation have a greater degree of resistance to subsequent infection, and that this is demonstrable over a wider range than is the case with those challenged eight weeks after exposure.

In a related study on experimental schistosomiasis, observations have been made on the developmental anomalies in adult Schistosoma mansoni developed from gamma-irradiated cercariae.

The use of irradiated cercariae for the induction of resistance to subsequent infection against experimental schistosomiasis in mice and monkeys has been reported by a number of investigators. According to several reports, for the protection to be effective it is essential that the developing schistosomules (cercariae in tissue) migrate some distance through the host tissue. Although some may reach the portal-mesenteric circulation and develop to adult form, they may be damaged to the extent that they produce few or no eggs. The worms reaching the portal vessels may be morphologically as well as physiologically aberrant.

The purpose of this study was to make observations on gross morphological changes occurring in the adult form of S. mansoni developed

TABLE 1

Results of Challenge Experiments at 8 and 10 Weeks in Mice Protected by Exposure to Cercariae Irradiated With Different Doses of Gamma Radiation

Period after protection exposure, weeks	Cercarial radiation dose, rads[a]	Challenge titration end point[b]	Control titration end point[c]	End point difference	Protective ratio[d]
8	2375	16	9 ± 2.1[d]	7	1.8
	2625	16		7	1.8
	2875	25		14	2.8
	3125	16		7	1.8
	3375	14		5	1.6
10	2375	16	12 ± 2.1[d]	4	1.3
	2625	36		24	3.0
	2875	40		28	3.3
	3125	26		14	2.2
	3375	21		9	1.7

[a] 25 mice protected at each level.

[b] Challenged with pairs of cercariae at five levels, from eight to 128 pairs.

[c] That number of cercarial "pairs," as estimated by the Reed and Muench method from exposure to doubling numbers, that will result in a mouse passing a total of 100 ova during ten 24-hour observation periods between the 42nd and 60th post-infection days.

[d] Standard deviation of the distribution.

from gamma-irradiated cercariae.

Although this study was concerned with changes in morphology, some of the observations made on numbers of worms developed and on egg production are pertinent to appreciation of the impairment of function concomitant with maldevelopment. The number of schistosomes recovered from those mice that were alive 12 to 16 weeks after exposure to cercariae is presented in Table 2. No abnormalities occurred when cercariae were irradiated at 1000 rads, but

TABLE 2

Number of Schistosomes Recovered From Mice 12 to 16 Weeks After Percutaneous Exposure to 200 Cercariae Irradiated at Designated Doses

Group	Number of mice killed	Radiation dose, rads	Number of worms Mean	± S.D.[b]
1	12	0 (C)[a]	46.3	19.02
2	12	1000	27.4	8.81
3	14	2000	11.0	4.86
4	13	2500	5.2	3.67
5	15	3000	1.4	1.18

[a]Worms from control mice (C) were recovered 6 to 8 weeks after infection.

[b]Standard deviation.

fewer worms were recovered than from the controls. Using 3000 rads, the number of worms was less than three percent of the controls, and malformations were prevalent in all the worms recovered. Of the 15 mice exposed at this level, however, worms could be found in only two. The mice exposed to cercariae which had received 2000 or 2500 rads yielded 23 percent and 11 percent, respectively, of the number of worms obtained from the controls. Eggs were not detected in the liver and intestine of mice exposed to cercariae irradiated at 2500 or 3000 rads, while considerable numbers were found in the controls.

The changes observed in the worms include (a) retardation in growth; (b) malformation of the body; (c) malformation of the reproductive structures: mislocation of testes or ovary, partial development of structures, absence of certain structures, even in rudimentary form; and (d) malfunctions of ovary or testes.

No morphologic changes were evident in worms produced from cercariae irradiated at 1000 rads, but those that developed from cercariae exposed to 2000 rads or more had a variety of malformations, which included stunting and misplacement or absence of reproductive structures in both sexes. One of the more common morphologic changes was that of retardation of growth in both male and female worms. A male schistosome developed from cercariae irradiated with 2500 rads of cobalt-60 gamma rays is compared with a normal male in Figure 2.

Figure 2. Adult *S. mansoni* (10 mm, six weeks old) developed from non-irradiated cercariae as compared with a stunted male (2.7 mm, 12 weeks old) developed from cercariae that had received 2500 rads gamma radiation from cobalt-60. Both parasites were recovered from the portal-mesenteric system of a mouse. (36 X.)

Figure 1. Mr. Víctor Quintana and Miss Josefa Torres filling vials with one of the special diets.

Figure 2. Mrs. Helen Santiago examining larvae in vials in the rearing room.

SUGARCANE BORER CONTROL PROJECT

David W. Walker, Ph. D., Head

The sugarcane borer, Diatraea saccharalis (Fab.) (Crambidae: Lepidoptera) causes direct destruction of plant tissues, often completely destroying young plants, as well as causing sugar inversion in cane stalks. In addition, this pest allows secondary invasion by fungi and bacteria, which in turn reduce sucrose yield. This pest is cosmopolitan in distribution, and is of major importance in most sugar producing areas of the world. It is estimated that this species causes an annual loss of approximately 2.5 million dollars to the sugarcane crop in Puerto Rico alone.

The principal objectives of this research include determining whether Diatraea saccharalis can be rendered sterile by gamma irradiation and studying the bionomics of this species with reference to phases of the life cycle that are applicable to the development of a program of mass-release of sterile adults in Puerto Rico. This project is part of a cooperative effort with the UPR Agricultural Experiment Station.

Work was begun on a modest scale in the spring of 1963. An attempt has been made to consider all the factors of importance to a program of mass-release of sterile adults. Each objective has been evaluated on the basis of its immediate need. The approach has been to explore all the reasons why this method could fail, while concentrating on the principle objectives. A summary of information obtained through 1964 appears in the Annual Report 1964. New information gained and previously reported data that have been substantiated are reviewed below.

Gamma irradiation effects confirmed during the year include the following. (a) The sterilizing dose in adult males and females is 30 kilorads. Exposure of adult males or females to 60 kilorads causes no reduction in egg production. The number of egg clusters produced and the number of eggs per cluster are independent of dosage; it is the egg hatchability that is affected by radiation. (b) Behavioral changes in males irradiated at 100 kilorads were not sufficient to prevent mating with normal females. Males irradiated at 2 to 4 kilorads mated sooner than non-irradiated males when placed with females. Conclusive data have not been obtained on the ability of sterile males to compete with normal males for mating with females; this study is continuing. The diurnal activity of irradiated adult

males or females apparently is not affected by irradiation at dosages sufficient to sterilize them.

Copulation in many lepidoptera involves the transfer of a packet of spermatozoa in the form of a spermatophore, which is placed into the vulva of the female and transferred by the female to a saclike structure, the bursa copulatrix. The bag portion of the spermatophore dissolves and the tube remains; therefore, it is possible to determine the number of times that a female has mated by dissecting the female and counting the number of tubes. It has been found that females mate as many as three times, the average in nature being between one and two times. This provides a useful method for determining mating capacity of irradiated males.

More than 250 diets for laboratory rearing of the sugarcane borer have been tested since the beginning of the project, 100 of them during the past year. These diets are artificial but not synthetic; the ingredients are essentially preparations of the normally preferred host-plant material with supplementary nutrients added. (See Figure 1.) The three best diets contain carrot powder, agar, brewer's yeast, hydrolized casein, ascorbic acid, corn stalk and liquid corn stalk extract, sodium benzoate, methyl-p-hydroxybenzoate, and hydrochloric acid. With these improved diets, the time required for completion of larval development is shorter, egg production is higher, and adult life span is longer. (See Figure 2.) Also, it is possible to rear ten larvae in each vial, whereas with the diets previously recommended by other workers only one larva could be reared per vial. The increased economy and efficiency should make it possible to raise sufficient quantities of adults for a small field test with the facilities available.

Improved techniques for rearing are needed because present methods require a large amount of hand labor to ensure high survival. Handling methods adapted to mass-culture are being tested.

Observations are being made on optimum ratios of sterile males to normal males in competition for mating with normal females. The behavior of the females is also being studied. The objective is to determine the optimum ratio of sterile males to normal field males for release in the field. Since this species mates more than once, the superior mating capacity of irradiated adults is of great importance for a successful eradication program.

Eight cages, each 40 x 40 x 10 feet, are being constructed. (See Figure 3.) In each cage 1000 corn plants will be grown. Adult

sugarcane borers will be released for oviposition on the corn, sterile ones in some cages and normal ones in others for comparison. The results of these tests will indicate population decline on a host plant.

In order to develop a superior laboratory strain that will have an advantage in field release tests, crosses are being made between individuals on the basis of high egg production, strong mating capacity, short larval span, and long adult life span. (See Figures 4 and 5.)

The scientific papers published and presented during the past year are listed in the Appendix. In addition to the work carried on at PRNC, Dr. Walker participated in the US AEC Atoms in Action Exhibit in El Salvador and in Guatemala during the past year. Two projects on insect sterility were initiated in El Salvador, and local scientists were given help in starting a third project in Guatemala.

Figure 3. Workers are planting corn in a field test cage for studying population changes of the sugarcane borer.

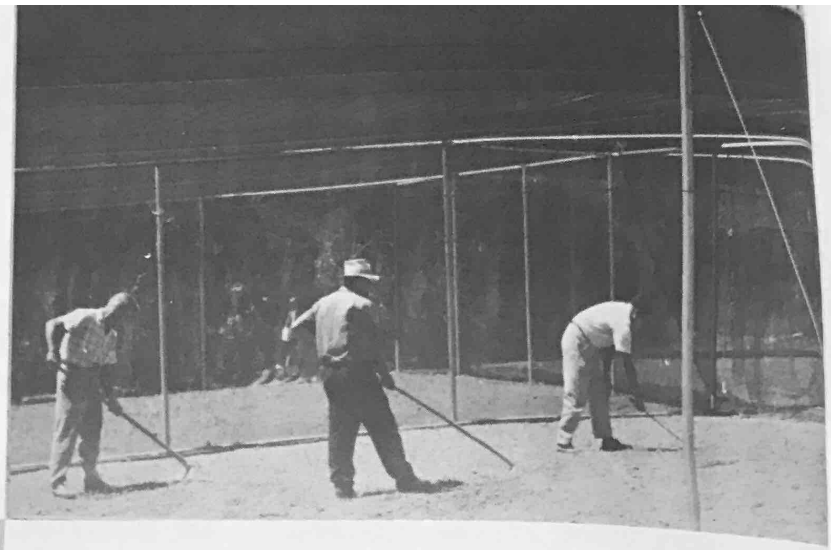
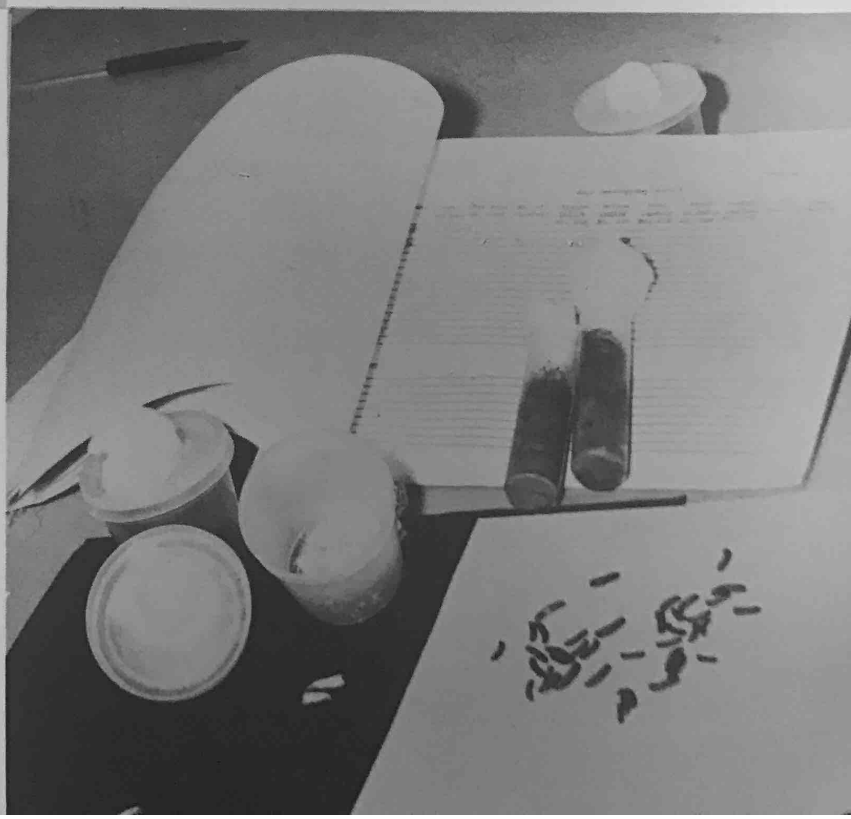


Figure 4. Mr. Víctor Quintana (seated) and Dr. David Walker examining egg clusters hatched in mating cups.

Figure 5. Life stages of the sugarcane borer: eggs and adults in and near hatching cups, larvae and pupae in food vials on an egg hatchability recording sheet, and pupae removed from vial on table.



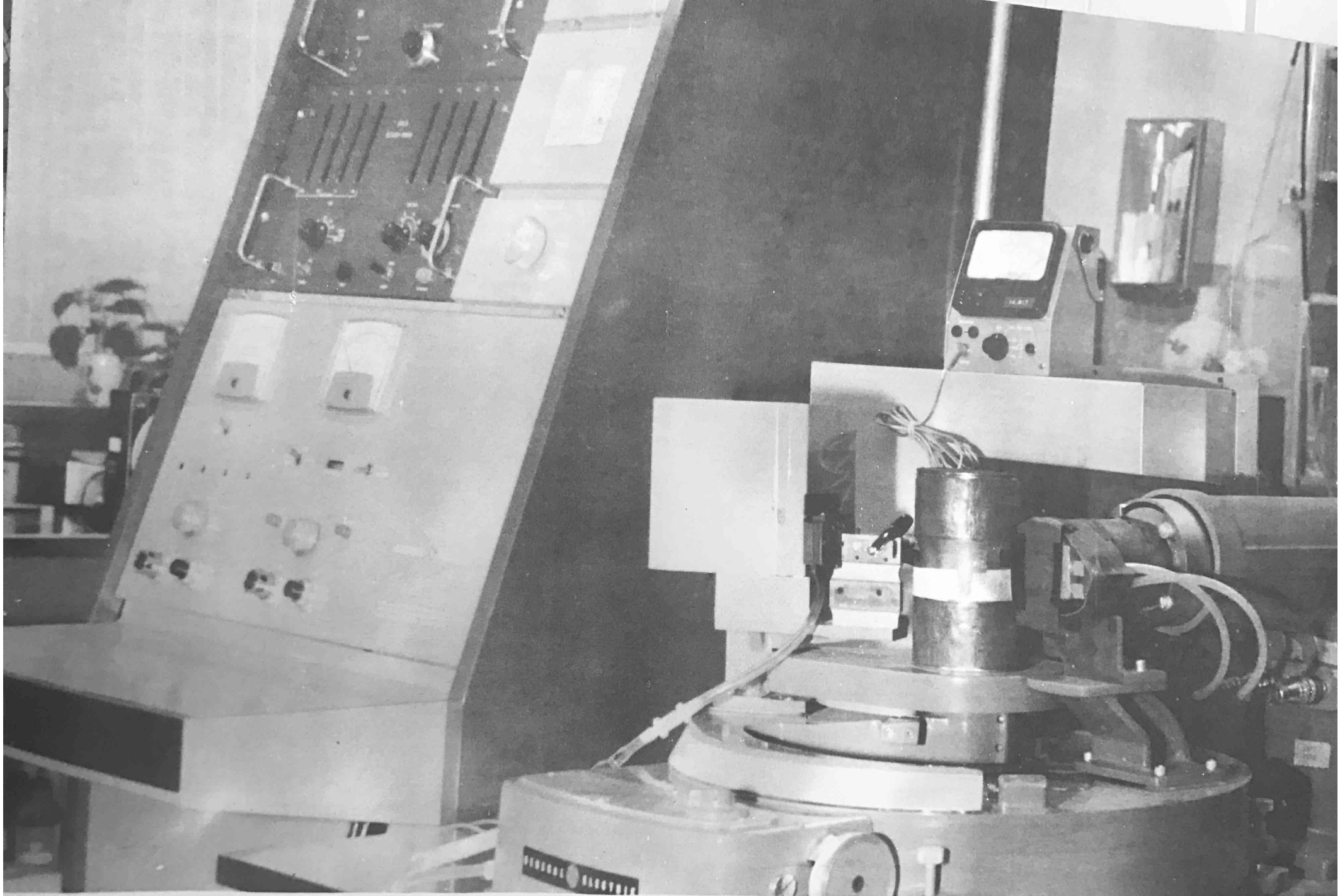


Figure 1. X-ray spectrometer arranged for monochromatic irradiation of enzyme solution. The source and diffracting crystal are shielded to reduce radiation scatter. The sample is in a temperature controlled chamber at the exit of the soller slit.

RESONANCE IN RADIATION EFFECTS PROGRAM

Henry J. Gomberg, Ph. D., Head

The purpose of this program is to answer the question "What are some of the unique effects of ionizing radiation on matter?" To this end, studies have been made on the effects of x-radiation in the 5 to 20-kev energy range upon biological systems. This energy region is of considerable importance since it contains the K-absorption edges of the constituent atoms of most living systems.

Evaluation continues of the hypothesis that radiation damage in a molecule can be a function of the site at which the photon is initially absorbed. It is postulated that absorption of an x-ray photon in the K shell of an atom will produce a highly ionized atom and that the high state of ionization will lead to major disruption of the molecule at the site of photon absorption.

Biological molecules were irradiated with monochromatic x rays at energies above and below the K-absorption edge of selected target atoms. Damage was judged on the basis of effect observed per unit energy absorbed, or per photon absorbed, in the molecular system. Experiments by Dr. R. A. Luse using x-radiation in the energy range 6.4 to 8.3 kev have shown increased inactivation of the metalloenzyme catalase at or near the K-absorption edge of iron (7.11 kev), which is located at the active site of this enzyme. In another biological system studied by Dr. F. K. S. Koo, chromosomes in onion root-tip cells treated with 5-bromodeoxyuridine (BUDR) have exhibited an increase in breakages caused by monochromatic x rays at photon energies equal to or slightly greater than the K-absorption edge of bromine (13.48 kev). In contrast, there is no such effect in cells containing no added BUDR. Hence, in these two important types of molecules - enzyme and nucleic acid - it has been shown that the efficiency of damage production is a sensitive function of the photon energy. The significance of this finding in more complex biological systems (bacterial cells, HeLa cells) is at present being explored. (See Figure 1.)

During 1965 a survey was made by Dr. Luse of the radiosensitivity to cobalt-60 gamma radiation (1.17 and 1.31 Mev) of several metalloenzymes, to serve as a guide to the radiosensitivity of these systems to low energy x rays. In this way, only the most sensitive systems might be chosen for study with the low intensity

monochromatic x-ray beams. Results of this work are tabulated below:

Metalloenzyme	Gamma-Ray Dose for 37% Enzyme Survival (in solution)
Alkaline phosphatase	ca. 1000 krad
Carboxypeptidase A	41
Peroxidase	14
Polyphenol oxidase	35

Similar studies were also conducted with monochromatic ultraviolet light (4.89 ev) to further knowledge of the sensitivity of these enzymes to radiation.

This year marked the initiation of studies designed to relate structural changes in biological molecules (in particular, the metalloenzymes) to the radiation inactivation of these molecules. An atomic absorption spectrometer capable of measuring 0.01 to 10-microgram quantities of metal was installed and used to determine the release of zinc from irradiated carboxypeptidase A. Further studies are under way, which deal with iron release from catalase and with molecular weight changes in such molecules. Loss of peroxidase activity caused by exposure to 60° to 65°C temperature after gamma-ray and x-ray irradiation, has been measured by Dr. P. Paraskevoudakis. Initial results indicate an increased sensitivity to heat stress for the irradiated enzyme. It appears that low dosages of radiation, not adequate to inactivate the enzyme, can produce small changes in the molecule with the result that the molecule is less resistant to other stresses.

Supplementing the irradiation studies of biological molecules in the development of special equipment that permits absolute measurement of the very low photon fluxes generated in the highly monochromated (±50 ev) x-ray beams. A gold-foil calorimeter, sensitive to extremely low intensity beams (about 5 microwatts power) was put into operation in 1965. It measures intensities of monochromatic x-ray beams below 40 kev. The performance of the original model, developed at the University of Michigan, has been improved by Dr. Paraskevoudakis through the use of a specially constructed Wheatstone bridge and by use of thermistors of low impedance. In addition, design and construction of high intensity field emission x-ray sources have been carried out by Dr. F. Vázquez, and the effect of various parameters (vacuum, cathode material, applied voltage, and cathode-anode spacing) on electron emission has been

tested. Details of this work have been cited in the Annual Report 1964.

From the initiation of this program, information on the underlying processes of the resonance phenomena has been sought. Study of a relatively simple crystal system such as the alkali halides seemed desirable since it might relate to the far more complex biological molecules, which have certain crystal-like properties. To this end, in cooperation with the UPR Department of Physics in Mayaguez, a program was developed emphasizing the effects of monochromatic x rays on crystal structure as measured by F-center production. In 1965, this research has been continued primarily by Mr. Baltasar Cruz, an instructor at UPR who holds an Oak Ridge Institute of Nuclear Studies Graduate Fellowship and is a candidate for a Ph.D. at Harvard. (See Figure 2.)

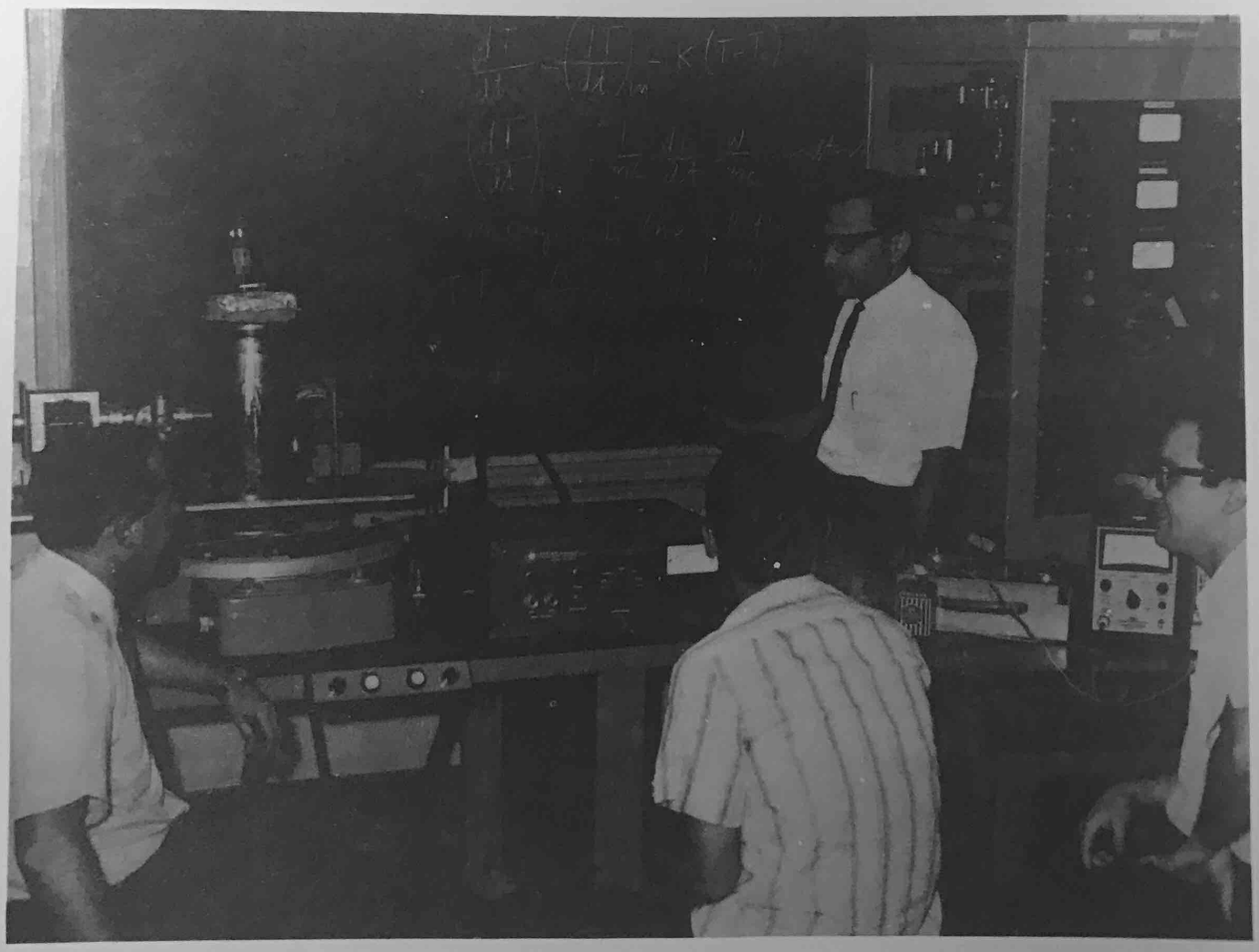


Figure 2. Staff discussion of the new high-sensitivity calorimeter for absolute measurement of low energy x rays.

PHYSICAL RESEARCH PROGRAMS

Research in physical sciences represents approximately one-tenth of the PRNC program and is sponsored by the United States Atomic Energy Commission Division of Research.

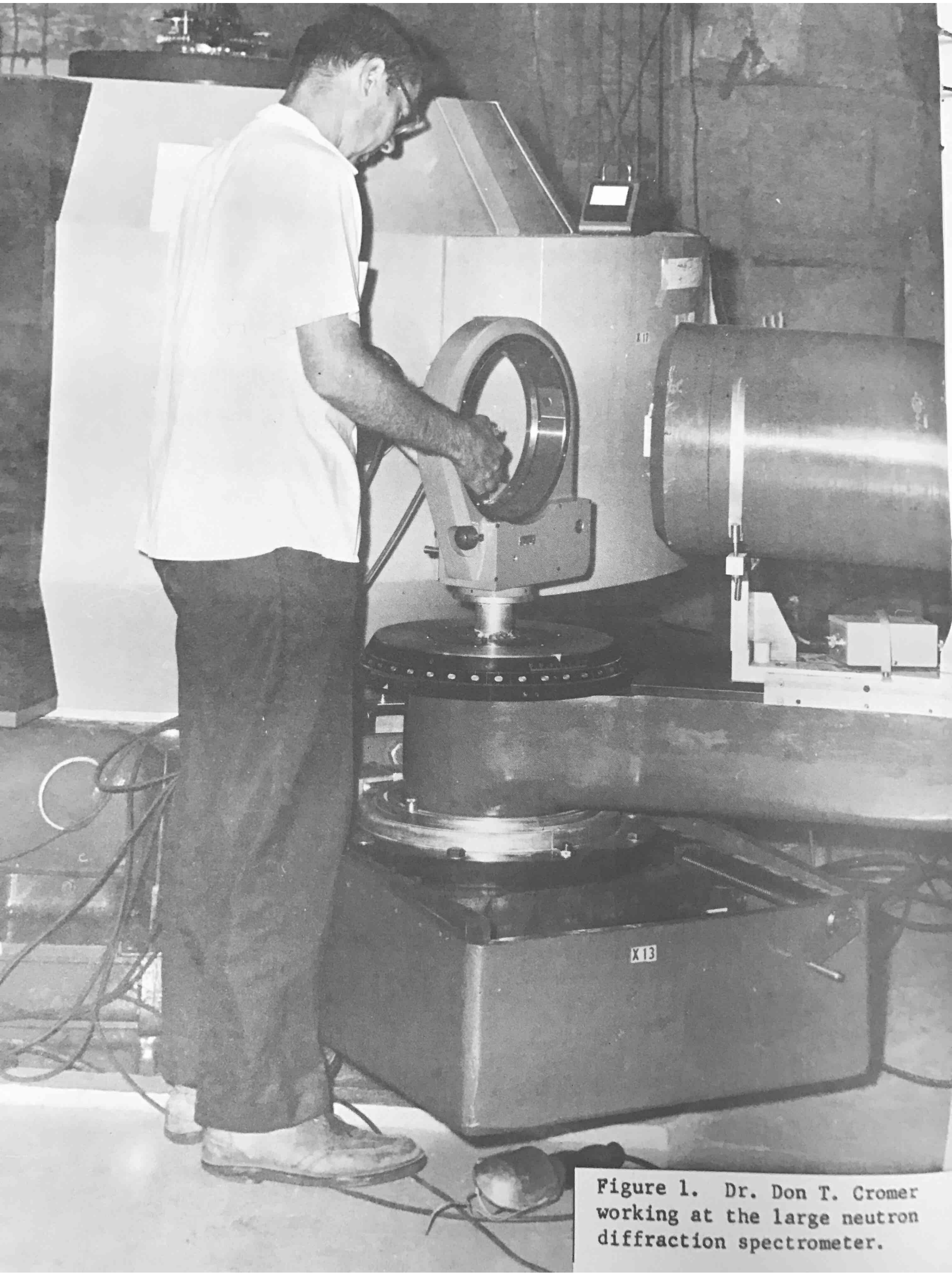


Figure 1. Dr. Don T. Cromer working at the large neutron diffraction spectrometer.

NEUTRON DIFFRACTION PROGRAM

Mortimer I. Kay, Ph. D., Head

The neutron diffraction group at the Puerto Rico Nuclear Center is working on two types of problems: (1) the chemical binding of atoms in crystals and molecules and (2) the nature of ferromagnetism. Both are related to the spatial arrangement of atoms in molecules. If either x rays or neutrons are scattered from crystals, patterns can sometimes be analyzed that show the arrangement of atoms in the crystal. Since the amplitude of x rays diffracted is proportional to the atomic number of the scattering atom, if both light and heavy atoms occur in the same compound, the contribution of the light atom is very weak and its position can be determined only with great difficulty. Neutrons, however, are scattered by the nuclei of the atoms; therefore, diffraction of neutrons by light elements compares favorably with that from heavier elements, and the coordinates of the lighter atom may be determined with greater precision than with x rays. In compounds having atoms with unpaired electrons, a neutron-electron spin interaction is also present. Since the magnetic properties of substances are related to the way the electron spins are arranged within the crystal, determination of such spin arrangements by neutron diffraction provides information about magnetic structures. Figure 1 shows the neutron diffraction spectrometer.

HYDRATED FORMATES

Determination of the crystal structure of the room temperature phase of copper formate tetrahydrate has been completed. This was originally studied by other workers with the object of ultimately investigating the magnetic phase transitions at 17°K and 50°K. The x-ray data of Kiriyama et al. (Acta Cryst. 7, 482, 1954) showed a unit cell of symmetry $P2_1/a$ with lattice constants a = 8.15, b = 8.18, c = 6.35 Å, β = 101.5°. The structure consists of alternating layers of copper formate and water parallel to the ab plane. The layer at z = 0 (Figure 2) consists of copper formate, and the layer about z = 1/2 contains water (Figure 3.) The neutron diffraction data confirmed the copper, carbon, and oxygen positions of Kiriyama et al. and in addition showed an interesting set of hydrogen positions, indicated in Figure 3. This structure contains disordered water molecules, and we believe it is a superposition of the four structures given in Figure 4.

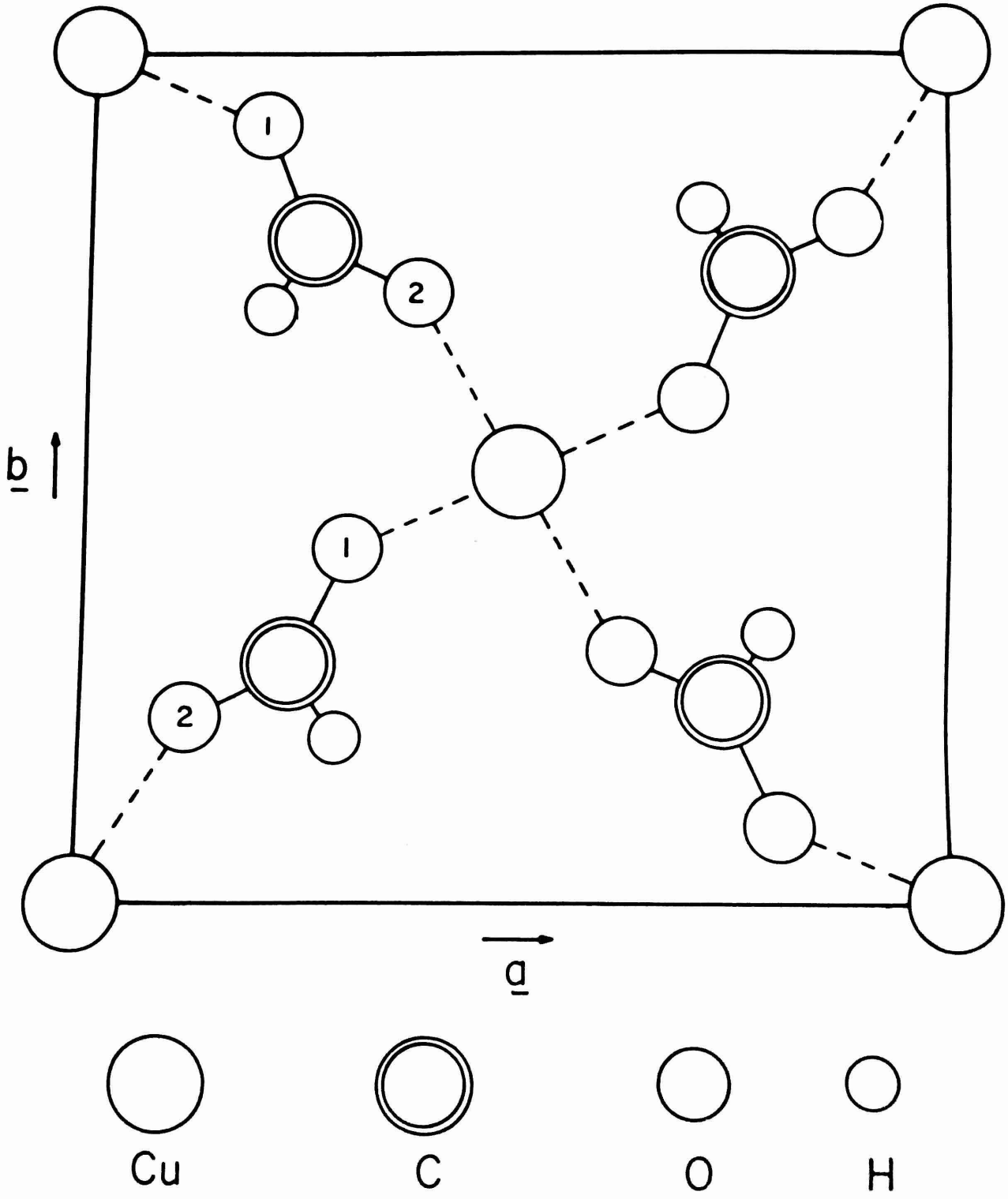


Figure 2. Copper formate layer near $z = 0$.

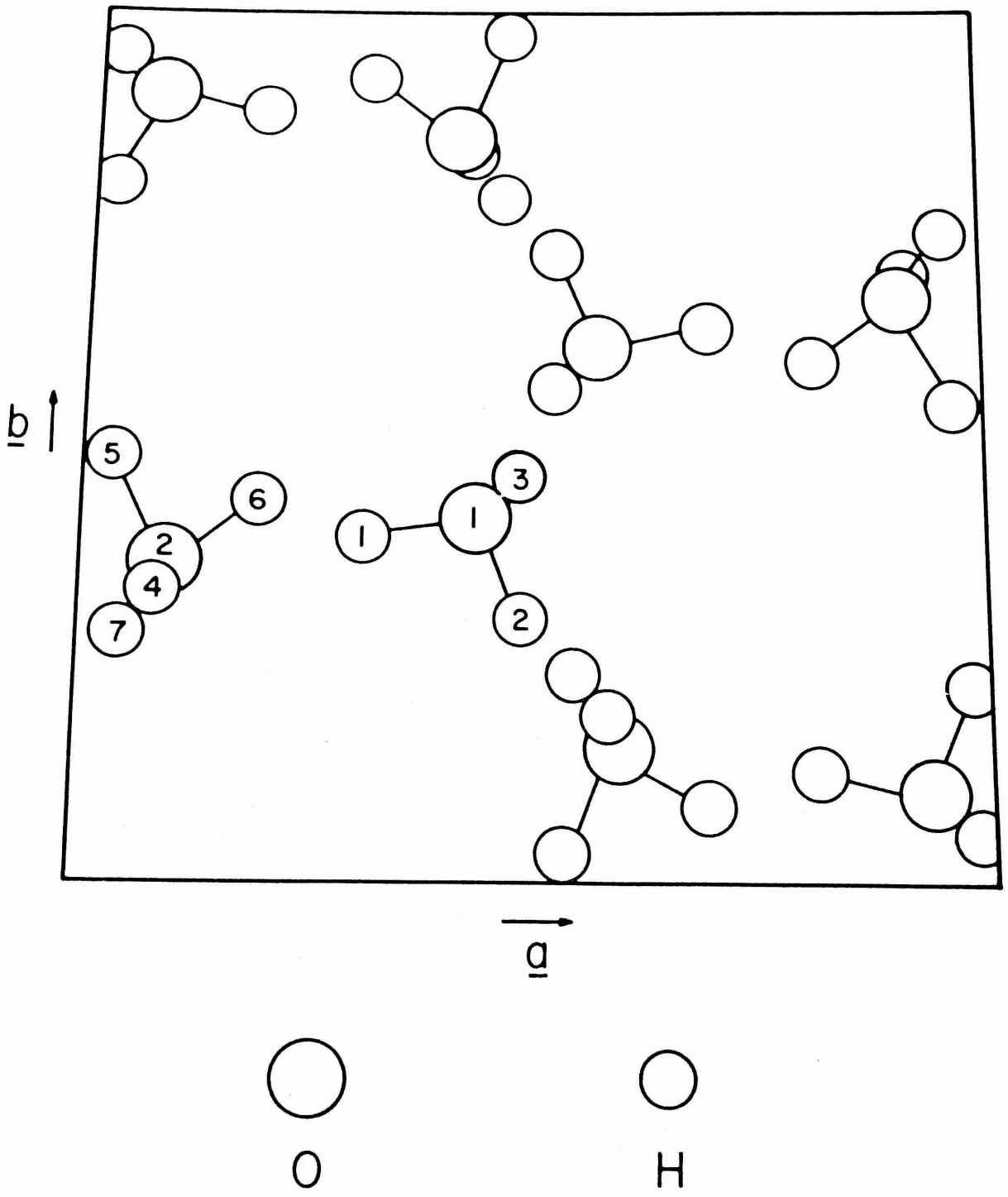


Figure 3. Water layer near $\underline{z}$ = 1/2 showing disordered positions.

It is interesting that the disorder is such as to permit all possible short O-O contacts to be hydrogen bonded all the time. On noting the disorder, we decided to look for a phase transition. A very strong dielectric anomaly was indeed found at -38.9°C (Figure 5.) Figure 6 shows hysteresis loops in the vicinity of the transition. The double loop is indicative of antiferroelectricity. There is a very small thermal hysteresis (0.3°C) in the transition. A dc biasing field moved the transition to a lower temperature. Both these effects are indicative of first-order transitions. X-ray data and hk0 neutron data, taken below the transition temperature, indicated no change in space group and, indeed, very little change in intensity, which showed that the average structures above and below the transition are similar. We hope to investigate the effect of an electric field on the crystal structure immediately below the transition temperature. A determination of the hydrogen positions in manganous formate dihydrate is now under way.

ALUMS

The alums are a large class of double salts having the general formula $A^{+1}B^{+3}(RO_4)_2 \cdot 12H_2O$ where A can be NH_4, CH_3NH_3, Na, K, Rb, Cs; B can be Al, Ga, Cr, Fe, V; and R can be S, Se, or Te. Fluoberrylate alums are also known. These compounds are cubic, space group Pa3, although this symmetry can be achieved statistically only with the ammonium and substituted ammonium alums. The alums were all thought to be isomorphous until the x-ray work of Lipson (Proc. Roy. Soc. A151, 347, 1935) showed three different types, which he named α, β, and γ, in the order of their discovery.

The type of alum formed depends on the size of the monovalent cation. If the cation is small the γ-alum forms. The only known representative of this class is $NaAl(SO_4)_2 \cdot 12H_2O$. The β-alum forms if the cation is large, and the α-alum, which is by far the most common type, occurs if the cation is of intermediate size. All the alums contain two crystallographically different water molecules, each associated exclusively with either the monovalent or trivalent cation. The trivalent cation is always surrounded by six water molecules in a nearly regular octahedron, but the orientation of the octahedron with respect to the cell axes is different in each of the three types. The monovalent cation in the α- and γ-alums also has six waters in a nearly regular octahedron.

The large cation in β-alum can accommodate twelve oxygen neighbors.

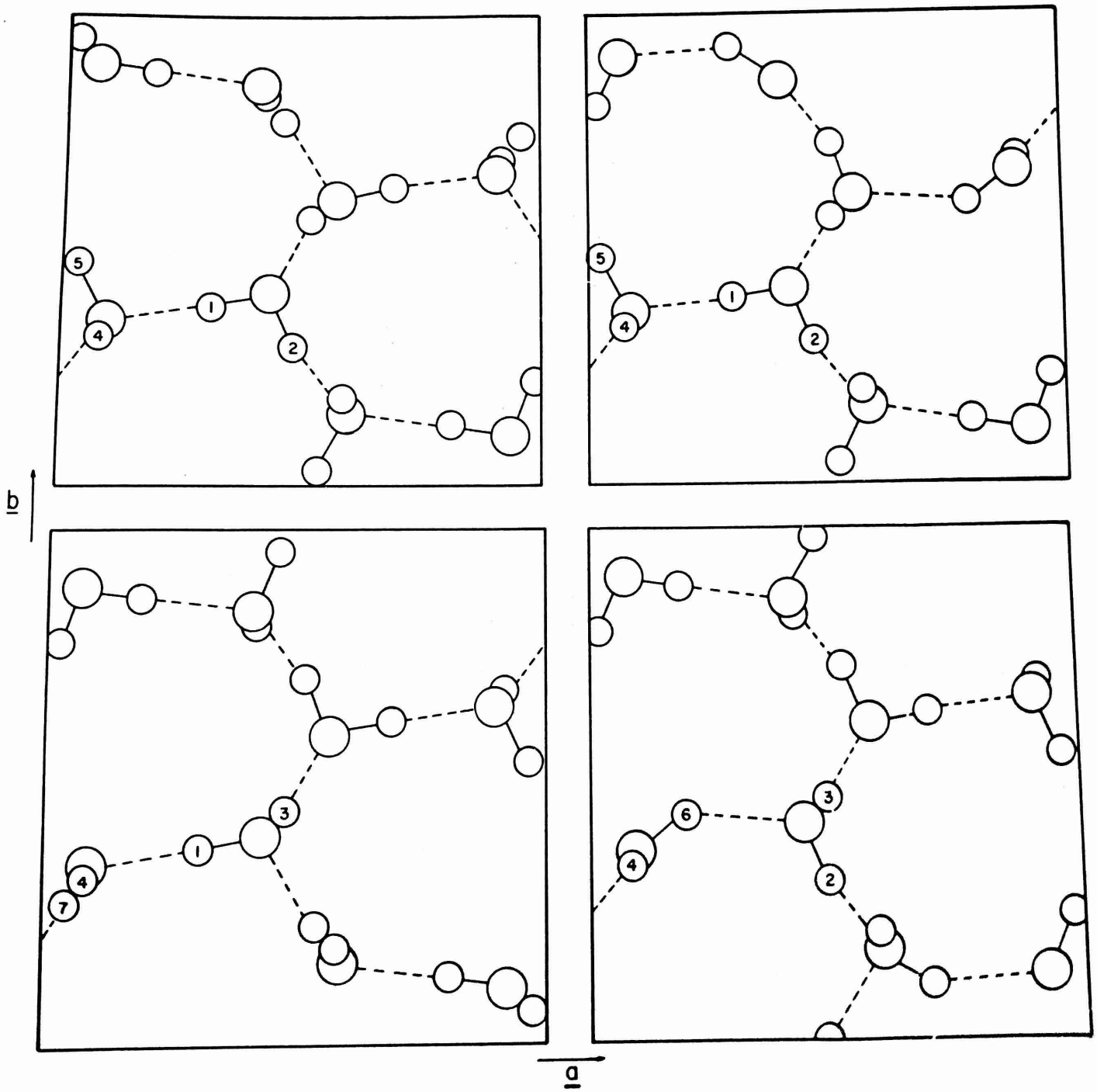


Figure 4. Four water arrangements which when superimposed give the structure shown in Figure 3.

To attain this large coordination number, the water octahedron is compressed along the threefold axis and stretched out normal to this axis until it is nearly planar. The two ends of the resulting trigonal antiprism are separated by only about 0.06 Å. The sulfate groups at each end of this antiprism are then moved along the threefold axis toward the central cation until six sulfate oxygens are about the same distance from the cation as are the water molecules. A slightly distorted cubic close-packed array of oxygens thus surrounds the cation.

In the γ structure, six water molecules approach the small sodium cation much more closely than in the α structure. This motion cannot take place unless the hydrogen bonding system changes. The most striking result is that the sulfate groups become oppositely oriented along the threefold axis.

X-ray data have been taken on examples of the three types of compounds at Los Alamos Scientific Laboratory, and neutron diffraction data at the Puerto Rico Nuclear Center. The structure, including hydrogen atoms of Cs alum (a β-alum) has been completed and the others, NH_4 alum (α) and Na alum (γ), are in process of refinement. A difference Fourier projection showing the positions of the hydrogens in Cs alum is given in Figure 7. The refinement shows that the octahedron about aluminum is oriented almost exactly along the cell axes and is only very slightly distorted. The Cs-$O_S(2)$ distances are a little longer than the Cs-$O_W(1)$ distances, 3.454 Å vs. 3.367 Å.

The sulfate group is an almost perfect tetrahedron. Corrections to the S-O distances were computed according to the in-phase assumption of Busing and Levy (Acta Cryst. 17, 142, 1964). The direction of maximum motion of $O_S(1)$ is normal to the S-O bond. The largest axis of the $O_S(2)$ thermal ellipsoid makes an angle of 85.7° with the S-O bond, and the smallest axis makes an angle of 9.1° with the bond.

There is only one possible system of hydrogen in this structure. All hydrogen atoms take part in hydrogen bonds, and all oxygen atoms except $O_W(2)$ have at least one hydrogen bond. The hydrogen positions could be reasonably guessed from the heavy atom locations obtained by x rays. Hydrogen atoms could be clearly observed in a three-dimensional difference Fourier computed with reflections having $(\sin\theta)/\lambda < 0.4$ Å^{-1}. The O-H bond lengths were corrected for thermal motion according to Busing and Levy by using the isotropic thermal parameters obtained from the neutron diffraction data. These distances agree well with other neutron diffraction analyses of hydrated crystals. H(1) on $O_W(1)$ is bonded to three H(1) atoms.

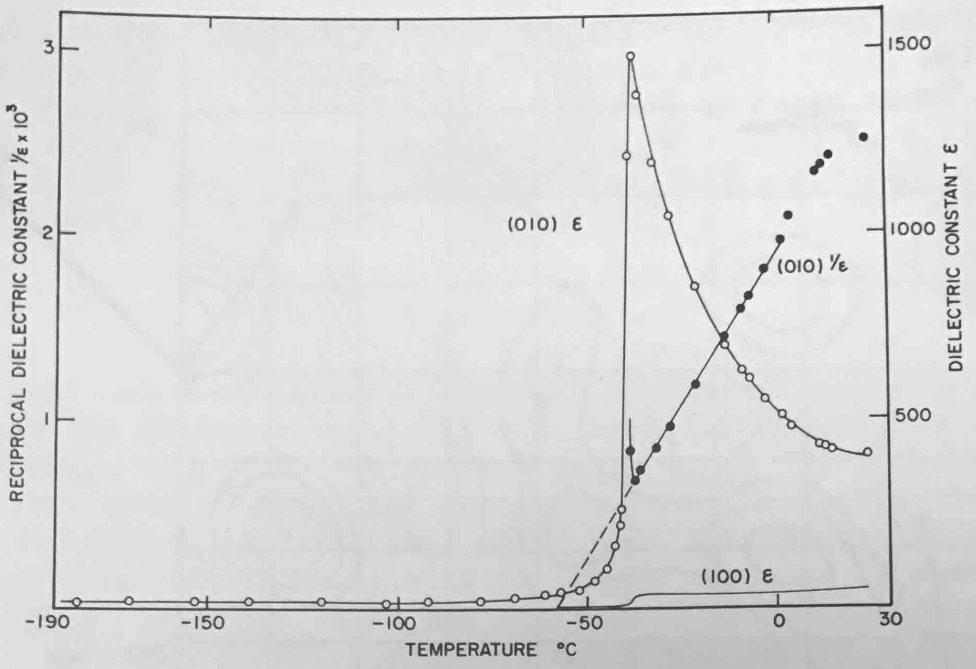


Figure 5. Dielectric constant versus temperature in copper formate tetrahydrate at 1000 cycles per second.

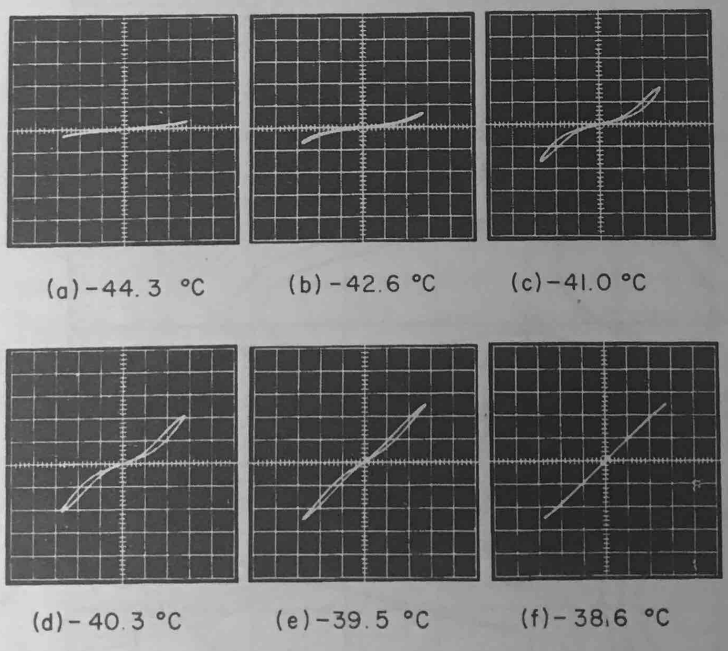


Figure 6. Double hysteresis loops of (010) copper formate tetrahydrate plate at various temperatures below T_C at 60 cycles per second. Sweeping amplitude: 19 kV/cm.

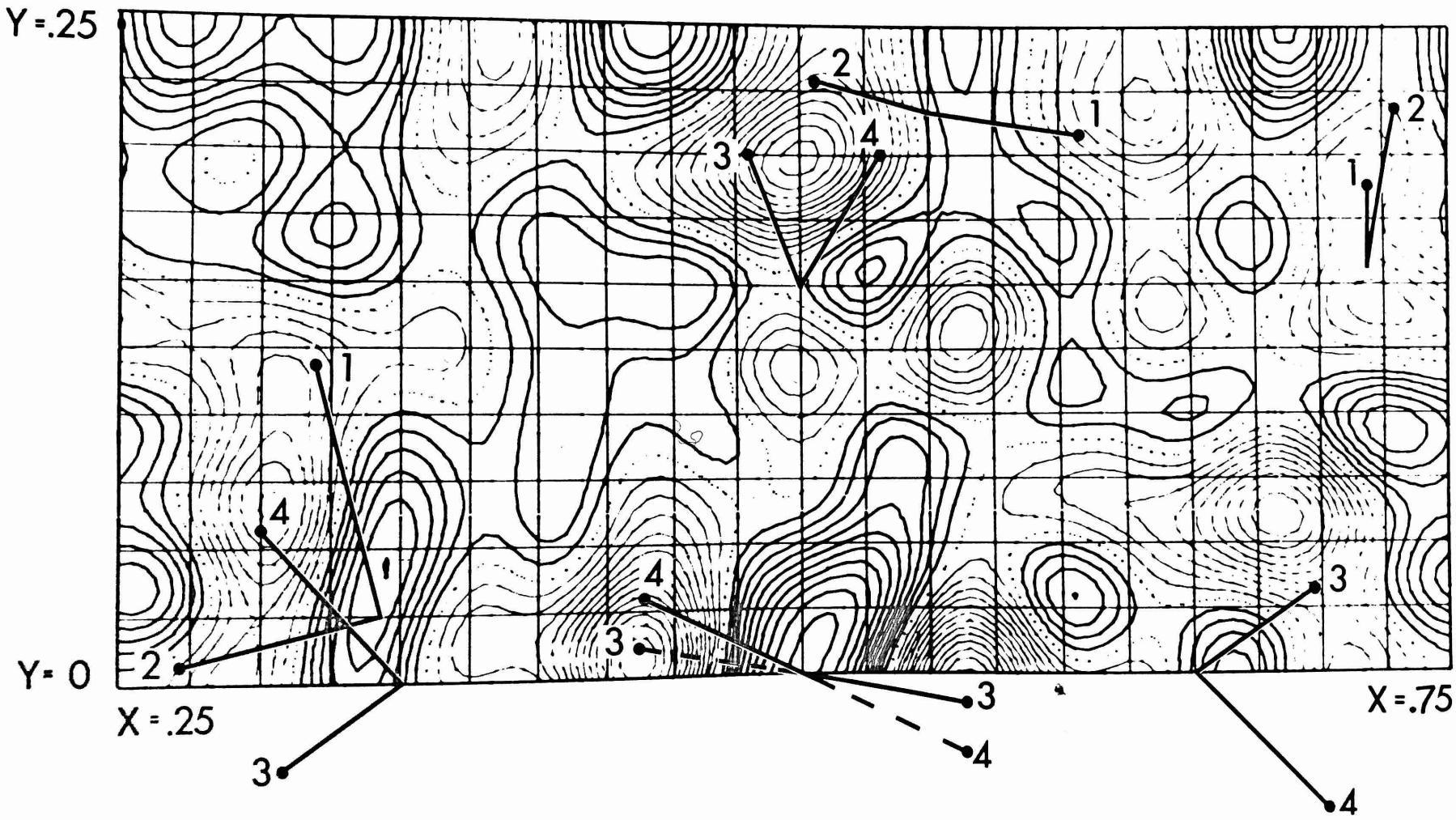


Figure 7. Neutron difference diffraction projection showing hydrogen atoms only. Contours are at equal arbitrary units. Heavy lines are positive contours, light lines are negative contours, and the zero contour is dotted.

A somewhat elongated trigonal pyramid consisting of the three hydrogen atoms and the sulfur atom thus surrounds $O_S(1)$. H(2) on $O_W(1)$ and H(3) on $O_W(2)$ are bonded to $O_S(2)$. These hydrogen atoms and the sulfur atom are nearly coplanar with $O_S(2)$. H(4) on $O_W(2)$ is bonded to $O_W(1)$. The angles involving H(1), H(2), and H(4) about $O_W(1)$ are nearly tetrahedral.

d-TARTARIC ACID

Early in 1965 Okaya and Stemple (private communication) redetermined and refined the structure of d-tartaric acid, $(HCOHCOOH)_2$, originally published by Stearn and Beevers (Acta Cryst. 3, 341, 1950). Their results were in essential agreement with the earlier less accurate structure. In addition, their data indicated that a possible alternative hydrogen bonding scheme proposed by Donohue (J. Chem. Phys. 56, 502, 1952) was incorrect. To determine accurately the hydrogen atomic positions, which are barely discernible from x-ray data, neutron diffraction data were taken at PRNC. The results of the hydrogen bond distance calculations are given in Table 1. These results clearly show the apparent contraction of the O-H or C-H bond distances obtained from x-ray data. The effect is due to the shift of the hydrogen electron into the bond.

MAGNETIC STRUCTURES

The structure of the ζ-phase of Pd_3Mn_2 consists of a tetragonal distortion of the CsCl structure, a = 2.87, c = 3.61 Å, with the (0,0,0) position occupied by Pd atoms and the (1/2, 1/2, 1/2) position occupied by disordered Mn(4/5) and Pd(1/5) atoms. Recently, a detailed investigation of the magnetic and thermodynamic properties of the two phases was carried out by H. Yamauchi (J. Phys. Soc. Japan 19, 652, 1964), and he suggested that these properties could be explained by using one of two possible antiferromagnetic lattices. These have $a_{mag} = \sqrt{2}a_{chem}$, $c_{mag} = c_{chem}$ or $a_{mag} = a_{chem}$, $c_{mag} = 2c_{chem}$. A neutron diffraction powder pattern showed that the correct magnetic unit cell is the first, i.e., the transformation is given by $a_{mag} = \sqrt{2}a_{chem}$ and $c_{mag} = c_{chem}$. Analysis of the intensity data shows that the Mn moment is oriented perpendicular to the c-axis with a saturation value of 4.2 ± 0.2 μ_B. The Pd moment is no more than 0.4 μ_B. The temperature dependence of the magnetic moment followed the Brillouin function for S = 4/2 quite closely.

TABLE 1

Distances and Angles Containing H:
Comparison of Neutron and X-Ray Data

	Neutron	X-ray
CARBOXYL GROUP		
O(2)-O(4)		2.63
O(2)-H(4)	1.00	0.9
H(4)-O(6)	1.64	1.8
O(2)-H(4)-O(4)	172°	176°
O(5)-O(3)		2.71
O(5)-H(6)	1.00	0.9
H(6)-O(3)	1.71	1.9
O(5)-H(6)-O(3)	168°	152°
HYDROXYL GROUPS		
O(1)-O(6)		2.84
O(1)-H(3)	0.98	0.8
H(3)-O(6)	1.86	2.1
O(1)-H(3)-O(6)	171°	157°
O(4)-O(3)		2.91
O(4)-H(5)	0.97	0.8
H(5)-O(3)	1.95	2.1
O(4)-H(5)-O(3)	169°	172°
CARBON		
C(1)-H(1)	1.15	0.92
C(3)-H(2)	1.14	0.95

The structure of Fe_2SiO_4, a joint problem with Brookhaven National Laboratory, is in the final stage of analysis. The magnetic structure described in PRNC Report No. 59 is essentially correct, although new single-crystal data collected at Brookhaven should give more precise components of the magnetic vectors.

A computer program, PRNC Report No. 78, has been written to calculate magnetic structure factors.

Papers published or presented at meetings are listed in the Appendix.

VISITING PERSONNEL

Two visiting scientists participated in the neutron diffraction project last year. Dr. Don T. Cromer of Los Alamos Scientific Laboratory spent one year here (terminating in December 1965) on research and teaching leave. He took neutron diffraction data on the alums, on which he had taken x-ray data at Los Alamos. The two techniques complement each other. The x-ray data may be interpreted to give heavy atom positions, and the neutron data to give hydrogen positions. In addition, Dr. Cromer participated in the various other problems of the project and helped add to the library of diffraction programs.

Dr. Kenkichi Okada from Nagoya Institute of Technology spent two years here (terminating in August 1965). His main interest is in ferroelectric phase transformations. He participated in the structure work on copper formate tetrahydrate and discovered its antiferroelectric phase transformation at -38.9°C, measuring the electrical properties of the crystal about the transition point. He also worked with Dr. J. Gonzalo on radiation effects in ferroelectrics.

Close cooperation continues with Brookhaven National Laboratory, although on a somewhat smaller scale than in the past. Joint work continues on magnetic problems (Fe_2SiO_4 and $CuCrO_2$), and Dr. B. C. Frazer, Dr. M. Blume, and Dr. D. Cox visited PRNC during the year.

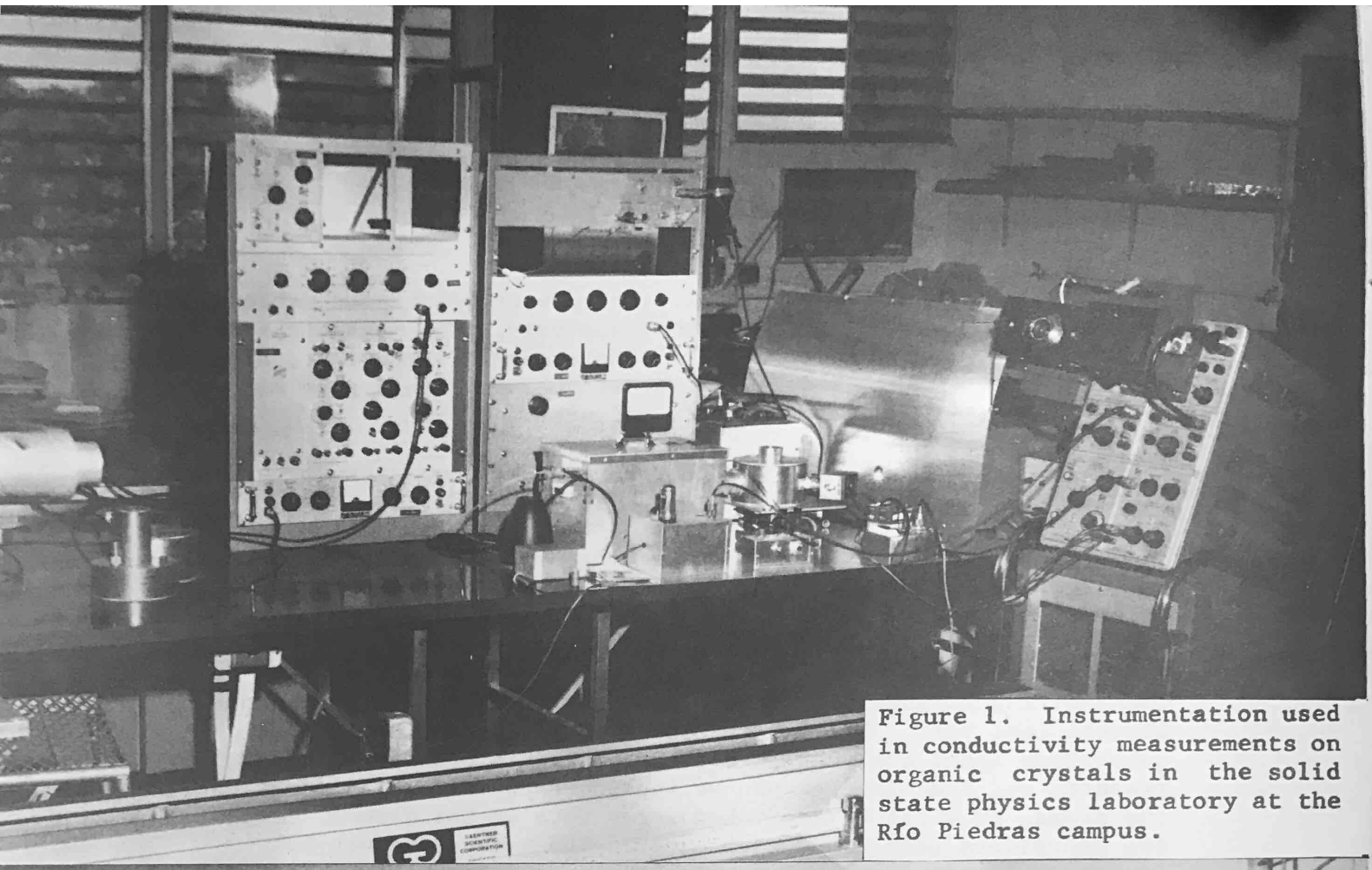


Figure 1. Instrumentation used in conductivity measurements on organic crystals in the solid state physics laboratory at the Río Piedras campus.

Figure 2. Section of the solid state physics laboratory used

SOLID STATE PHYSICS PROJECT: STUDY OF RADIATION DAMAGE IN ORGANIC CRYSTALS BY ELECTRICAL CONDUCTIVITY MEASUREMENTS

Amador Cobas, Ph. D., Head

The primary purpose of this project is to study the effects of radiation on organic crystals. Studies on well-defined crystalline structures should provide a firm foundation for later study of more complex materials, including those of direct biological interest. Anthracene was chosen as the initial material to work with because it has been the subject of more studies than any other organic material.

This project is housed at the Facundo Bueso Science Building at the Río Piedras University Campus because of the shortage of space at the PRNC Bio-Medical Building. When the project was started in January 1962, it was in a room with a total floor space of about 360 square feet. In February 1965, it was moved into a room with a floor space of about 900 square feet plus two offices with a combined area of about 240 square feet. The increase in space has made it possible to set up the equipment more advantageously and to make additions to the staff. (See Figures 1 and 2.)

Four pieces of new equipment were purchased. A fast response, high sensitivity, cathode-ray oscilloscope and a high intensity, short duration, light flash were purchased for use in transient space charge limited current measurements on crystals before and after irradiation. A steady state, high intensity, light source was bought, which will be used to do exciton-exciton interaction measurements. An evaporator was purchased for use in applying evaporated electrodes to the crystals so that conductivity measurements can be done at different temperatures.

This year Dr. George Simpson, who recently received his Ph.D. degree from Notre Dame University, joined our staff. His thesis, "Photosensitized Reactions in Solution," was done under the direction of Prof. W. H. Hamill. Dr. G. J. Dienes, Senior Physicist and Head of the Solid State Physics Group at Brookhaven National Laboratory, is spending his six-month sabbatical leave at PRNC starting in December 1965. He will be active with this project and will be doing some theoretical work on the radiation sensitivity of biological materials.

Also, the project has had the collaboration of Dr. Donald Frey, Dr. Seymour Trester, and Dr. Alfredo Torruella, all Lecturers in Physics at the University of Puerto Rico. Two research assistants, both graduate students working toward an M.S. degree, have been assigned to this project by the UPR Physics Department.

During the year the project has had the services of these consultants:

Dr. Werner Brandt
Associate Director, Solid State Physics and Radiation Laboratory, New York University, New York, N. Y.

Dr. Jehuda Goldstein
RCA Laboratories, Princeton, N. J.

Dr. Richard Jarnagin
Professor of Chemistry, University of North Carolina, Chapel Hill, N. C.

Dr. Murray Lampert
RCA Laboratories, Princeton, N. J.

Dr. Abraham Many
Head, Semiconductor Physics Laboratory, Hebrew University, Jerusalem, Israel

Dr. Peter Mark
RCA Laboratories, Princeton, N. J.

Dr. Martin Pope
Research Professor, Solid State Physics and Radiation Laboratory, New York University, New York, N. Y.

Dr. Morris Shamos
Head, Physics Department, New York University, New York, N. Y.

Visitors include:

Dr. J. L. Amorós
Professor of Physics, Southern Illinois University, Carbondale, Ill.

Dr. Willis K. Lamb
Professor of Physics, Yale University, New Haven, Conn.

Dr. Zbigniew Kopech
Visiting Scientist, Solid State Physics and Radiation Laboratory,
New York University, New York, N. Y.

Dr. Abraham Zoke
Senior Scientist, Weizman Institute, Rehovoth, Israel

RESULTS

The results obtained so far indicate that irradiation of anthracene crystals with gamma rays or x rays introduces hole traps into the crystals. The presence of traps was detected by steady state space charge limited current techniques with NaI-I_2 solution used as the hole injecting electrode. The density of introduced traps was calculated from the changes in the steady state space charge limited current voltage characteristics of the crystal before and after irradiation and was found to vary linearly with the absorbed radiation dose. The lifetime of the injected free carriers was measured by the transient space charge limited current technique, and the results indicate that the capture cross section of these traps for hole trapping is approximately of molecular size.

The current voltage characteristics of crystals grown from irradiated anthracene crystals were compared with those of crystals grown from irradiated anthracene powder, and very little difference was found. This indicates that the defects introduced by irradiation are molecular rather than crystalline. Absorption changes in the visible spectrum have been observed after the crystals have been exposed to a radiation dose of approximately 10^8 rads.

To gain a better understanding of the mechanism involved in the space charge limited currents in insulators, which are used as the detection method in this investigation, a thorough theoretical study has been made of injection of carriers into insulators. Solutions for the time dependence of the current have been obtained for the case in which the reservoir of free carriers at the injecting electrode is time dependent. In this analysis the transient space charge limited current with infinite, constant carrier density at the reservoir becomes a special case of the problem.

Several papers have been presented at meetings, and two papers are in process of being published.

RADIATION PRESERVATION OF TROPICAL FOODSTUFFS

The food irradiation program (08 Program) was started during the latter part of 1965 and is supported by the United States Atomic Energy Commission Division of Isotopes Development.

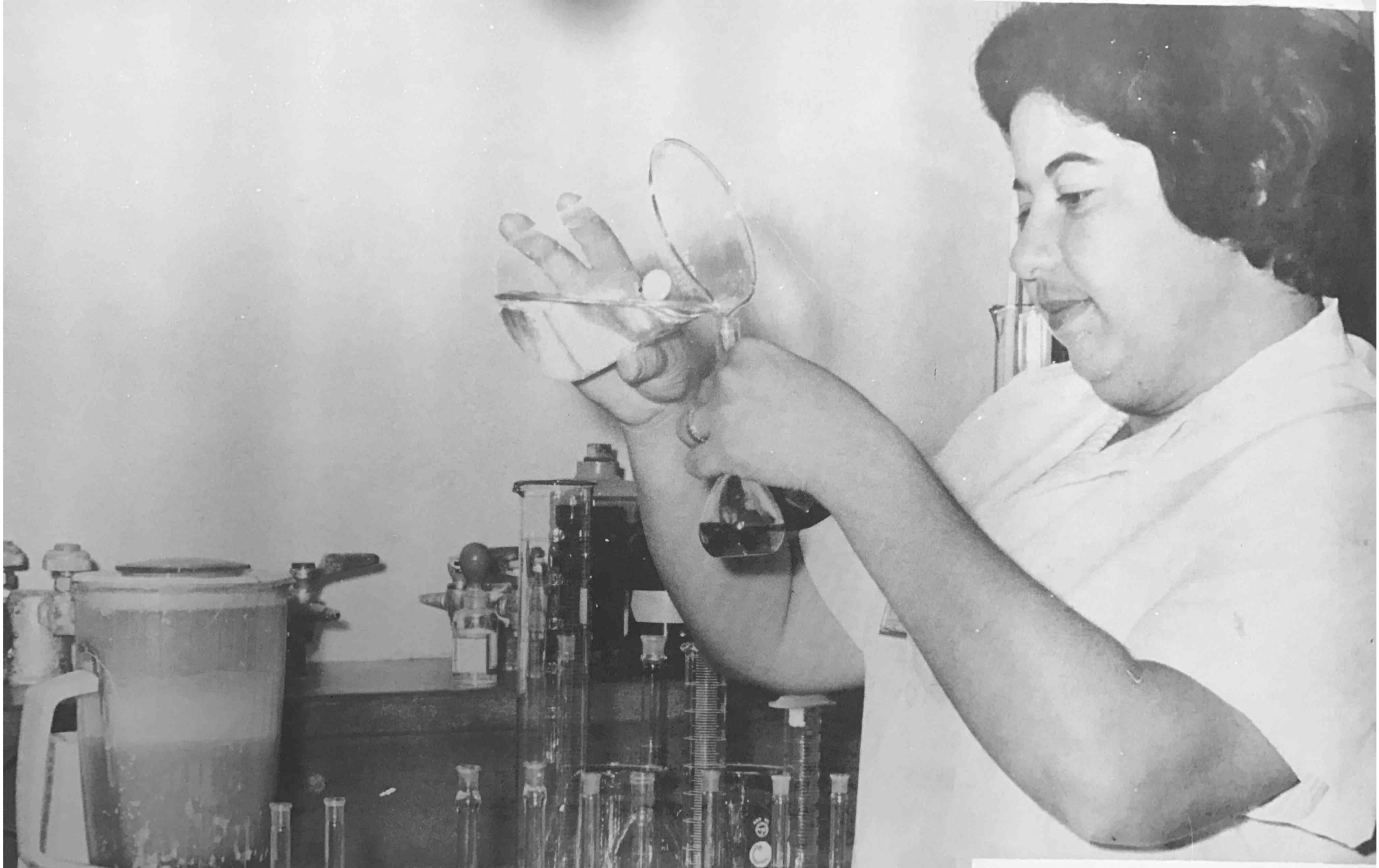


Figure 1. It is known that the starch content decreases as bananas ripen. It has been determined that Irradiation has no effect on ascorbic acid, total sugars, acidity, carotene, and reducing sugars.

RADIATION PRESERVATION OF TROPICAL FOODSTUFFS

Horace D. Graham, Ph. D., and Robert A. Luse, Ph. D.

This project is designed to explore the feasibility of radiation preservation of tropical foods, in particular bananas and mangoes. This is done through examination of two aspects of the general problem.

1. Determination of those factors of pre-irradiation condition, radiation dose, and post-irradiation treatment which delay ripening and maximize the shelf life of the food product. Here qualitative or semiquantitative criteria of ripening, such as softening, changes in color, spotting, and taste are utilized. These are supplemented by measurement of those characteristics associated with ripening, such as starch to sugar conversion and pulp acidity.

2. Measurement by appropriate biochemical assay of changes in various nutritional factors that accompany radiation pasteurization. This part is amenable to quantitative assay of vitamin levels and how they are affected by radiation dose and treatment.

This project was begun in October 1965, when support from the United States Atomic Energy Commission Division of Isotope Development was approved. The project was based on past studies of the Agricultural Bio-Sciences Division staff and will permit extension of these studies.

Experiments using Monte Cristo variety bananas obtained from the University Agricultural Experiment Station plantation have dealt with retardation of ripening as a function of the gamma irradiation dose and post-irradiation treatment. The dose range found most suitable for this banana variety is between 20 and 40 kiloroentgens. Post-irradiation temperatures of 68°, 75°, and 80°F have been tested.

The following criteria have been used to judge banana ripening: (a) visual observation and firmness of fruits; (b) analysis for starch and for sugars, since during ripening the initial high starch concentration of the fruit declines while the concentration of sugar rises; and (c) analysis for pulp acidity, since during ripening the acid content of the pulp increases.

Assays for carotenoids and vitamin C are being run routinely on all irradiated fruit as a function of time after irradiation and results correlated to stage of ripening and irradiation dose. Other biochemical assays to permit further evaluation of the effects of irradiation on food quality are under development.

APPENDIX

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Héctor Troche Maldonado
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Agustín Cajigas, M.D.

PAPERS PRESENTED

1. Adam, W. and Grimison, A., Molecular Orbital Theory Applied to the Orientation of Nucleophilic Substitution in Pyridine, Quinoline, and Isoquinoline, presented (by A.G.) at Am. Chem. Soc. Mtg., Atlantic City, Sept. 1965.

2. Alexander, A. G. (UPR Agr. Expt. Sta.) and Maretzki, A., Studies of Acid α-Glucosidase and β-Fructosidase From Sugarcane Meristem, presented at Am. Chem. Soc. Mtg., Atlantic City, Sept. 1965. (Read by L. Amorós.)

3. Almodóvar, I., Okada, K., Kay, M. I., Frazer, B. C. (BNL), Hurst, J. J. (BNL), Cox, D. E. (BNL), and Brown, P. J. (BNL), Neutron Diffraction Studies of Crystal and Magnetic Structures of Some Cu(II) Salts, presented (by I.A.) at 3rd Carib. Chem. Symp., Caracas, Jan. 1965.

   Almodóvar, I. - See also Cox, D. E.; and Kay, M. I.

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62. Sodestrom, K. G., Activities in Engineering and Related Fields at the Puerto Rico Nuclear Center (in Spanish), Rev. Col. Ing. Arq. Agr. P. R. 15, No. 1, 34-8 (1965).

S destrom, M. H. - See Ferrer Monge, J. A.

63. Stevenson, R. A., Lugo Ufret, S., and Diecidue, A. T., Trace Element Analyses of Some Marine Organisms, in 5th Inter-Am. Symp. on Peaceful Applications of Nuclear Energy, Valparaíso, March 1964, pp. 233-9, IANEC-OAS, Washington, D. C., 1965.

Szmant, H. H. - See Castrillón, J.; and Cobas, A.

Torres, S. - See Facetti, J. F.

Trabal, E. - See Cantarell, I.; and Facetti, J. F.

64. Vázquez, F., Production of F-Centers with Monochromatic X-Rays (in Spanish), in Proc. 1st Conf. on Nuclear Spectroscopy and Solid State Research, Lima, Feb. 1964, pp. 119-22 (publ. 1965).

Vega, R. - See Cantarell, I.

65. Walker, D. W., Bionomics of the Sugarcane Borer Diatraea saccharalis (Fab.). I. A Description of the Matin Behavior, Proc. Entomol. Soc. Wash. 67, 80-3 (1965).

66. Walker, D. W., Progress Report, Sugarcane Borer Project (FY-1965, Technical Report No. 1), PRNC 63, May 1965.

67. Weinbren, M. P., Terrestrial Ecology Program, Part II: Radiation Induced Variability in Indigenous Arthropod-Borne Animal Viruses of Puerto Rico. Progress Summary Report No. 1, PRNC 35, April 1964.

68. Wheeler, O. H., Oxidation of Anilines With Manganese Dioxide, Chemistry & Industry 1965, 1769.

69. Wheeler, O. H. and Montalvo, R., Irradiation of Estrone and Derivatives in Acetic Acid, Radiation Research 26, 353-62 (1965).

70. Wheeler, O. H. and Montalvo, R., The Radiolysis of Estrone and Estradiol, Science 150, 493-4 (1965).

WEEKLY SEMINARS, RIO PIEDRAS

Dr. Aldo E. Lanaro, Radioisotopes in the Study of the Urinary System, January 15.

Dr. Walter J. Moore, Indiana University, Chemistry of Brain and Memory, January 29.

Dr. Gilbert H. Fletcher, University of Texas, The Experimental Basis of Radiotherapy, February 5.

Dr. Eric Wigg, UPR, Gamma Radiolysis of HCl - Ethylene Mixtures, February 12.

Dr. William E. Gordon, Arecibo Ionospheric Observatory, The Arecibo Ionospheric Observatory, February 19.

Dr. H. H. Szmant, Solvent Effects, February 26.

Dr. Henry Kaplan, Stanford University School of Medicine, Recent Radiobiological Developments of Importance to Radiotherapy, March 5.

Dr. Florencio Vázquez, Field Emission X-Ray Tube, March 12.

Dr. Freddy Vélez Herrera, Dr. I. González Martínez Oncologic Hospital, Chemotherapy of Cancer, March 19.

Dr. Werner Brandt, New York University, Positronium, March 22.

Mr. Baltasar Cruz, F-Center Formation in Crystals, March 26.

Dr. Francis K. S. Koo, Resonance Action of Low Energy Monochromatic X Rays on Chromosome Incorporated With 5-Bromodeoxyuridine, April 2.

Dr. Seymour Trester, Large Photovoltages From Thin Germanium Films, April 9.

Dr. Lester J. Reed, University of Texas, Studies on Organized Enzyme Systems: the Pyruvate and L-Ketoglutarate Dehydrogenase Complexes, April 23.

Dr. Howard T. Odum, What are the Seasons in the Rain Forest?, April 30.

Dr. Michel Ter-Pogossian, Washington University School of Medicine, St. Louis, An Image Tube Scintillation Camera for Use With Radioactive Isotopes, May 7.

Dr. Maurice Paul Weinbren, Discussion of the Activities in the Medical Sciences and Radiobiology Division, May 14.

Dr. Felipe N. de Jesús, Lymphangiography in Cancer, May 21.

Dr. Amador Cobas, Radiation Damage Measurements in Anthracene Crystals, May 28.

Dr. Waldemar Adam, Molecular Orbital Theory Applied to Proton Chemical Shifts in Heterocyclics, June 4.

Dr. José M. Tomé, Cancer of Nasopharynx, June 12.

Dr. J. Frank Mc Cormick, University of North Carolina, Studies in Radiation Ecology, June 18.

Dr. José P. A. Castrillón, Sulfur-35 Exchange Reactions, June 25.

Dr. Oscar Vázquez, Determination of Thyroidal and Renal Plasma ^{131}I Clearance Rates as a Routine Diagnostic Test of Thyroid Dysfunction, July 2.

Mr. Juan J. Rigau, The Stereochemistry of beta-Hydroxy Sulfoxides, July 9.

Mr. Ariel Lugo, Metabolic Studies in the Rain Forest, July 16.

Dr. Sakae Shimizu, Kyoto University, Chemical Binding Effects on Half-life of Uranium, July 23.

Dr. Alex Alexander, UPR, The Invertases of Sugarcane, July 30.

Dr. Ricardo Méndez Bryan, UPR School of Medicine, Clinical and Metabolic Aspects of Gout, August 6.

Dr. Roberto Rodríguez, UPR School of Medicine, Indications for the Use of the Artificial Kidney, August 13.

Dr. Jerry R. Kline, Neutron Activation Studies in Soils, August 20.

Dr. Raúl Pérez Escobar, UPR Agr. Expt. Sta., Reclamation of Salty Lands, August 27.

Mr. Arnaldo Carrasquillo, Boron Chemistry, September 3.

Dr. Jorge Chiriboga, Effect of Whole-Body Gamma Irradiation on Synthesis and Excretion of Glucuronides, September 10.

Dr. Sergio Irizarry, Brain Scanning, September 17.

Dr. Karl Meyer, Columbia University, Biology and Chemistry of Mucopolysaccharides, September 15; Biology and Pathology of Mucopolysaccharides, September 17.

Mr. James A. Singmaster, UPR Agr. Expt. Sta., Pesticide Regulations, Toxicology, Handling, and Residues, September 24.

Dr. Graciela Serna Maytorena, Effects of Ionizing Radiation on the Skin, October 1.

Dr. Enrique Pérez Santiago, UPR School of Medicine, Present Status of Folic Acid Metabolism, October 8.

Dr. Alec Grimison, Quantum Biochemistry - Fact or Fiction?, October 15.

Dr. Víctor A. Marcial, Time-Dose-Fractionation Relationships in Radiation Therapy, October 22.

Dr. John B. Villella, Morphologic Changes in Schistosoma mansoni After Gamma Irradiation, October 29.

Dr. Efraín Toro-Goyco, UPR School of Medicine, Preparation and Analytical Uses of Sephadex, November 12.

Dr. Andrew Maretzki, Biochemical Studies in Sugarcane With Freeze-Dried and Fresh Tissues, November 26.

Dr. Robert A. Luse, Inactivation of Metallo-Enzymes by Ultraviolet Light and Gamma Radiation, December 3.

Dr. Edwin Roig, Some Important Aspects of Gamma Radiolysis, December 10.

Mrs. María P. Lozano, Recent Studies on LiF Dosimetry, December 17.

Dr. Harold L. Atkins, Brookhaven National Laboratory, The Uses of Technetium in Organ Scanning, December 30.

WEEKLY SEMINARS, MAYAGUEZ

Dr. Murray Lampert, RCA Laboratories, Princeton, New Jersey, Space Charge Limited Currents and Double Injection, Parts I and II, January 14 and 15.

Dr. R. C. Von Borstel, ORNL Division of Biology, Cell Killing by Radiation, January 14.

Dr. Frank J. Sinamore, ORNL, Oligonucleotype, an Amphibian Embryonic Development, January 25.

Dr. Julio A. Gonzalo, Radiation Damage in Ferroelectric Triglycine Sulfate, February 2.

Dr. Juan F. Facetti, Szilard-Chalmers Reaction in Sb Compounds, March 2.

Dr. B. Post, Polytechnic Institute of Brooklyn, High-Melting Metal Borides, March 8.

Mr. Ferdinand Rosa, UPR graduate student, Calorimeter Design, March 9.

Dr. Florencio Vázquez, Field Emission X-Ray Tube, March 16.

Mr. Gilberto Vélez, UPR graduate student, Measurement of Temperature Gradient of Water Cooling System in PRNC Reactor, March 23.

Dr. Phillip W. Osborne, Research in Metallurgy, March 23.

Dr. Werner Brandt, New York University, Collective Effects in Atomic Spectra; and Similitude in the Penetration of Heavy Ions Through Matter, March 25.

Mr. Heriberto Cuebas, UPR graduate student, Energy Spectrum Determination of X Radiation Around the PRNC Reactor, March 30.

Mr. Radamés Lamenza, UPR graduate student, Power Raise Possibilities From 1 to 2 MW in PRNC Reactor, March 30.

Mr. José Cuevas, Research Facilities in Agriculture at PRNC, April 1.

Dr. Francis K. S. Koo, Resonance Radiation Effects in a Genetic System, April 13.

Mr. Francisco Jiménez, UPR graduate student, G Value Determination of Fricke Dosimeter for Monochromatic X Rays From 5 to 15 kev, April 20.

Dr. Peter Paraskevoudakis, Wavelength Dependence of Horseradish Peroxidase Inactivation by Soft X Rays, April 27.

Mr. William Pérez Varela, UPR graduate student, Use of Soil and Concrete as Reactor Shielding Materials, May 4.

Mr. Néstor Rubén Ortiz, UPR graduate student, Dielectric Constant for Ferroelectric Materials, May 4.

Dr. José Ferrer Monge, Criteria of Radiation Protection, May 11.

Mr. Fausto Muñoz Ribadeneira, PRNC Participation in US AEC International Atoms at Work Exhibits, May 18.

Mr. Héctor Barceló, Operational Problems of the Swimming Pool Reactor, May 25.

Dr. Amador Cobas, Radiation Damage Measurements in Anthracene Crystals, June 1.

Dr. Donald Phelps, An Ecological Consideration of Stable Element Distribution in Añasco Bay, June 8.

Dr. Howard T. Odum, Progress on the Rain Forest Radiation Project, June 22.

Mr. Rafael Montalvo Zapata, Study of the Radiolysis of Steroids in Solution, June 29.

Dr. Max Lombardi, ORINS, ORINS Participation in the Atoms at Work Exhibits in Central America, July 13.

Dr. Sakae Shimizu, Kyoto University, Some Particular Nuclear Phenomena Including the Shell Electrons, July 20.

Dr. Erich A. Farber, University of Florida, Applications of Solar Energy, July 28.

Mr. Fernando Plá Barby, UPR graduate student, Fuel Burnup Calculations in BONUS-Type Reactors, August 3.

Mr. Angel R. Escalona, UPR graduate student, Neutron Dosimetry Around the PRNC Reactor Facilities, August 3.

Mr. Erick Méndez Veray, UPR graduate student, Propagation of a Crack in Irradiated Plexiglass, August 10.

Mr. José Dávila Navedo, UPR graduate student, Transfer Function Measurement of the L-77 Reactor, August 10.

Prof. Herman Sulsona, UPR, A Field Emission of the Stress Corrosion Cracking of alpha-Brass, August 25.

Mr. R. W. Clack, Kansas State University, Transient Behavior in MTR-Type Fuel, August 27.

Mr. Angel Sánchez del Río, UPR graduate student, Reactivity Change Due to Xenon Formation Under Various Operating Conditions in Pool-Type (PRNC) and BONUS-Type Reactors, August 27.

Mr. José Rivera, UPR graduate student, The Effects of Impurities on the Ferroelectric Properties of Colemanite Single Crystals, September 1.

Dr. David A. Armstrong, University of Alberta, Calgary, Radiolysis of Hydrogen Halides, September 8.

Rev. Dr. Ignacio Cantarell, Electron-Excess Color Centers in Alkali Halides, September 22.

Dr. Howard L. Andrews, Disposal of Radioactive Waste, October 6.

Dr. Jerry R. Kline, Neutron Activation Studies in Soils, October 27.

Mr. Rupert A. Lee, Kinetics and Mechanism of the Pyrolysis of Alkyl Halides, November 3.

Dr. Graciela Serna Maytorena, Effects of Ionizing Radiation on the Skin, November 10.

Dr. Peter Paraskevoudakis, Neutron Dosimetry Program at the Puerto Rico Nuclear Center, November 17.

Dr. Alec Grimison, Quantum Biochemistry - Fact or Fiction?, November 24.

Dr. Don T. Cromer, X-Ray and Neutron Diffraction Studies of the Alum Structure, December 1.

Mr. Carlos E. Reoyo Sánchez, UPR graduate student, Maximum Fuel Element Temperature as a Result of Water Loss, December 8.

Dr. Jorge Chiriboga, Effect of Whole-Body Gamma Irradiation on Synthesis and Excretion of Glucuronides, December 15.

Dr. Robert A. Luse, Inactivation of Metallo-Enzymes by Ultraviolet Light and Gamma Radiation, December 22.

PRNC STUDENTS BY COUNTRY*

From FY 1958 Through FY 1965

COUNTRY	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL
Argentina	1		2	1	4	1	2		11
Bolivia	1				1	4	1		7
Chile	1	1	2	2			1	1	8
Colombia	1	5	3	6	3	6	7	4	35
Costa Rica		2					1		3
Cuba		1	3				3	1	8
Dominican Republic			1			14	1	1	17
Ecuador	3		1	1			1	1	7
El Salvador			1		1	1	2		5
Formosa								1	1
Great Britain					1		1		2
Guatemala				1		1	2		4
Haiti			1						1
India	1				1				2
Japan							1		1
Mexico		5	1	1	2	1	3	2	15
Nicaragua			1	1					2
Panama						1	1		2
Paraguay					1	3	2		6
Peru		1	3	1	1	1	5		12
Philippine Islands	1								1
South Africa					1				1
Spain		1	3	3	3	2	1		13
Uruguay		1	1	1		1		1	5
Venezuela		3	4	3	2			1	13
Total Non-U.S. Citizens	9	20	27	21	21	36	35	13	182
U.S. Citizens	50	52	71	74	101	161	176	198	883
TOTAL STUDENTS	59	72	98	95	122	197	211	211	1065

*An individual is counted once each Fiscal Year he is training.

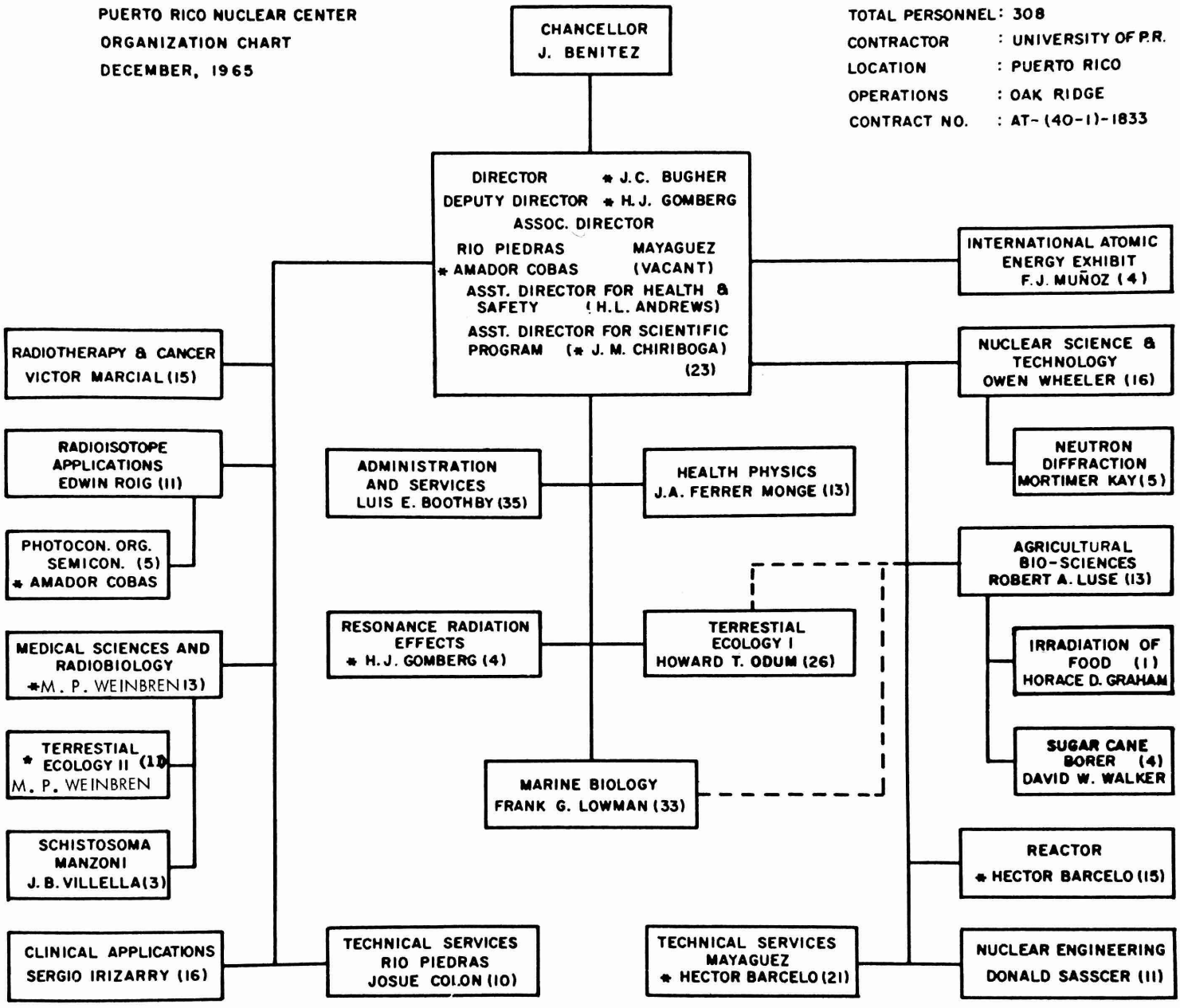
July 1, 1965

Student Enrollment at Puerto Rico Nuclear Center
During Fiscal Years 1964 and 1965

		FY-1964		FY-1965	
	Months	Students	Stu. Mo.	Students	Stu. Mo.
Radioisotope Techniques Course	1	15	15	28	28
Chemistry - Thesis Research	12	5	60	7	84
Chem 465 - Radiochemistry	4	5	20	4	16
Clinical Applications of Radioisotopes	2	7	14	8	16
Orientation in Clinical Uses of Radioisotopes	4	-	-	14	56
Advanced Course in Nuclear Medicine: Nephrology	-	-	-	1	1
Radiotherapy and Cancer Residency	12	2	24	2	24
Short-Term Radiotherapy Training	-	1	3	-	-
In-Service Training in Radiotherapy and Cancer	-	1	3	-	-
One-Month Cancer Course	1	4	4	11	11
Radiological Physics Conferences	4	-	-	15	60
Biol 372 - Nuclear Techniques in Biological Research	4	10	40	4	16
Applications of Radioisotopes to Sugarcane Research	-	-	-	1	3
Radioisotope Applications in Agriculture	-	1	3	-	-
Special Training in Solid State Physics					
Applied Health Physics Techniques and Procedures	-	-	-	-	-
Radiobiology Institute	1.5	20	30	20	30
Radiation Protection Course	.5	-	-	19	10
Basic Radiation Orientation Course	-	12	12	-	-
Fundamentals of Radiological Hygiene	4	30	120	13	52
Río Piedras Totals		114	350	147	407
Nuclear Engineering	8	-	-	20	160
Nuclear Science and Technology	8	17	136	10	80
Health Physics	8	1	8	-	-
Agricultural Bio-Sciences	8	7	56	6	48
Reactor Supervisor Training	6	2	12	-	-
Reactor Operator Training	2	-	-	12	24
Individual Courses - PRNC	4	75	300	21	84
Mayaguez Totals		102	512	69	396
Oak Ridge Research Participants	3	-	-	2	6
Oak Ridge Graduate Fellows	12	-	-	2	24
ORINS Totals		-	-	4	30
Río Piedras - Individual Courses, UPR	4	33	132	113	452
Mayaguez - Individual Courses, UPR	4	-	-	55	220
UPR Totals		33	132	168	672
Grand Totals		249	994	388	1505

PUERTO RICO NUCLEAR CENTER
ORGANIZATION CHART
DECEMBER, 1965

TOTAL PERSONNEL: 308
CONTRACTOR : UNIVERSITY OF P.R.
LOCATION : PUERTO RICO
OPERATIONS : OAK RIDGE
CONTRACT NO. : AT-(40-1)-1833



* DUAL FUNCTION

APPROVED FOR AEC
Floyd Brent
AREA MANAGER
PUERTO RICO AREA OFFICE

APPROVED FOR CONTRACTOR
John C. Bugher
DIRECTOR
PUERTO RICO NUCLEAR CENTER