PRNC - 99 PUERTO RICO NUCLEAR CENTER PROGRAM ABSTRACTS May 1967 Special Issue for Radiation Research Society Meeting May 7-11, 1967 San Juan, Puerto Rico OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT(40-1)-1899 FOR U.S. ATOMIC ENERGY Commission ---Page Break--- PRNC - 98 PUERTO RICO NUCLEAR CENTER PROGRAM ABSTRACTS May 1967 OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT(40-1)-1899 FOR U.S. ATOMIC ENERGY COMMISSION ---Page Break--- FOREWORD The urgent acceleration of economic development of the countries of Latin America requires the most effective application of all relevant technologies, among which those involving nuclear energy must rank high. Further, the growing concern of the United States with the problems of the tropics tends to increase the demands upon the existing scientific research centers which are tropically located. Here in the tropical environment of Puerto Rico, many of the fundamental problems of development found in Latin American countries are being attacked most vigorously. Puerto Rico now has one of the highest rates of economic growth in the world. The achievements in public health during the past twenty years have been dramatic. Although many of the solutions may not be fully applicable to other countries, Puerto Rico is a community in which the fundamental requirements of successful Latin American economic development may be explored. The Puerto Rico Nuclear Center is a university-associated institution devoted to the application of nuclear energy both to problems of the tropics and to the fulfillment of the educational needs of scientists of Latin America in the nuclear field. The essential thesis is that fruitful economic development takes place upon a foundation of good technology and the latter is an educational responsibility. The Nuclear Center is therefore directed to enlarging the competence of young scientists and engineers who will become the future leaders in the educational systems of their countries. The program presented in these abstracts

reflects the fundamental objectives of the Center in graduate education and in the research related to its mission and to its location. The Center's educational program is sponsored by the US ABC Division of Nuclear Education and Training. Research programs are sponsored by the US ABC Divisions of Biology and Medicine, Physical Research, Isotopes Development, and Technical Information. In addition, core research is sponsored by the Interoceanic Canal Commission. ---Page Break--- TABLE OF CONTENTS: BRIEF HISTORY OF THE PUERTO RICO NUCLEAR CENTER ...eesecseseee DIVISION OF NUCLEAR EDUCATION AND TRAINING Clinical Applications Division Radiotherapy and Cancer Division . Agricultural Bio-Sciences Division . Radioisotope Applications Division | Nuclear Science and Technology Division | Nuclear Engineering Division Reactor Division • Health Physics Division'. : Medical Sciences and Radiobiology Division . PRIC Participation in US AEC Atlas in Action Exhibit... RBBRE Four DIVISION OF PHYSICAL RESEARCH Solid State Physics Program Neutron Diffraction Program Hot Atomic Chemistry Program Bee DIVISION OF BIOLOGY AND MEDICINE 'Terrestrial Ecology Program I: The Rain Forest, Project - : Marine Biology Program +... Estuarine and Marine Ecology Study - Specific Activity Approach .« Schistosomiasis Project = Sugarcane Borer Program Resonance in Radiation Program Radiation Chemistry and Photochemistry Program «+.+.+ DIVISION OF ISOTOPES DEVELOPMENT Radiation Preservation of Tropical Foods «++e+ss+++ ---Page Break--- Brief History of the Puerto Rico Nuclear Center At the 1956 Panama meeting of the Organization of American States, President Eisenhower urged action by the OAS to promote the beneficial uses of nuclear energy. The needs and potentials of Latin American countries were studied by Admiral Paul Foster, then Deputy General Manager of the United States Atomic Energy Commission. This study found great need for technical training in a Latin American framework to make available the latest knowledge and technology in the field. As a Result

Jadnirel Foster recommended to the US ABC the ‘creation of a Nuclear Center in Puerto Rico to be managed by the University of Puerto Rico. The recommendation was approved by the Commission and by the Department of State. Joint planning studies were initiated by the University of Puerto Rico and the US ABC for the proposed Nuclear Center. The responsibility for implementing and administering the contract for the new Center was assigned to the Oak Ridge Operations Office whose Operations Manager, Mr. Sam Sapirie, negotiated with the University the contract which gave substance and direction to the original concept. As part of the forward planning, the Tenth Oak Ridge Regional Symposium was held at the University of Puerto Rico in January 1957. In an address to the Symposium, Chairman Lewis L. Strauss of the Atomic Energy Commission said: "The broadened program will provide the University of Puerto Rico with unique training and research facilities. And because these facilities will be truly outstanding—the most up-to-date in concept and design—and because the instruction will be in Spanish, the University of Puerto Rico may well become a training center for many countries of the hemisphere. I can tell you that we will cooperate enthusiastically in the expansion." In January 1957, Chancellor Juan Benitez appointed an Ad Hoc Committee of the University faculty to explore the development of graduate work in the natural sciences at the University of Puerto Rico, with particular reference to possible developments in the field of nuclear energy. This Committee recommended to Chancellor Benitez the establishment of graduate studies and research at the University and that the proposed nuclear reactor be located in Mayaguez. Representatives of the US ABC and the University of Puerto Rico signed contract AT-(40-1)-1833 to operate the Nuclear Center on October 2, 1957. The University agreed to operate the facilities and program on a cost-reimbursable basis but without fee. Dr. Charles F. Bonilla from Columbia University.

served as Director of the Puerto Rico Thiclear Center for two years beginning October 1957. Dr. José L. Garefa de Quevedo was appointed Head of Research and Head of the Reactor Divisions. Dr. Salvador Cobbs was appointed Head of the Isotopes Divisions. Dr. Fred Soltors was made Head of the Nuclear Science and Technology Division. From October 1959 until June 1960, Dr. José L. Garefa de Quevedo served as Acting Director. On July 1, 1960, Dr. John C. Bugher was appointed Director of PHC. Dr. Bugher served on loan from the Rockefeller Foundation at the request of UPN Chancellor Benfter. In October, Dr. Henry J. Gomberg, who had served as Director of the Phoenix (mission) Project at the University of Michigan, was appointed Deputy Director. On July 8, 1958, groundbreaking ceremonies for the Reactor Building of PREC were held in Mayaguez with Dr. Milton Eisenhower acting as official representative of the U.S. government. On August 23, 1960, the PHNC Research Reactor, a 1 megawatt pool-type unit, was dedicated. In April 1959, an 8000 curie Cobalt-60 Therapy Unit was installed at the Cancer Hospital where it remained until transfer to the Biomedical Building in early 1963. In April 1962, the first section of the PHIC Biomedical Building located in the now Puerto Rico Medical Center at Rio Piedras was occupied. In January 1963, the new Dr. T. Gonadle: lareines Oncology Hospital was inaugurated. This hospital is adjacent to the PHIC Biomedical Building and the PRIC Radiotherapy Division serves as the Radiotherapy Department of the Hospital. This enabled all PIC medical divisions to be united for the first time. In 1963, the Marine Biology Program acquired from the U.S. Army a 200-ton diesel vessel named "Shiai". This vessel proved to be excellently adapted to the requirements for the ocean-going operations of PRC. In 1966, a second vessel, "The Horry Ark", was acquired in anticipation of additional marine biologic survey work. The PRIS Marine Biology group was selected to do

Aquatic and marine ecological studies in Fajardo during 1967 in conjunction with current trans-Sethmus canal statistics. In 1963, a large tract of land in the Luquillo Experimental Forest was

made available by the U.S. Forestry Service to PRIC as the site of a Terrestrial Biology Program. In 1965, a 10,000 curie cesium-137 source was placed so that a portion of lower montane rain forest was exposed to gamma radiation for 99 days. Extensive post-irradiation studies continue in this area. In November 1966, Dr. Joka C. Bugher retired from the Rockefeller Foundation and is Director of PAIC. Under his direction, the PRIC educational program was moved from the graduate and post-graduate levels, together with a continually expanding research program emphasizing many problems best approached in a tropical environment.

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In November 1966, Dr. Henry J. Goldberg was appointed Director of PRIC by University of Puerto Rico President Benitez and the appointment was confirmed by the Council of Higher Education. At this time, Dr. Amador Cobas, who had served as Associate Director for the San Juan-Río Piedras operations of PRIC since September 1959, was appointed Deputy Director for all operations. Dr. Victor A. Marcial, Head of the Radiotherapy and Cancer Division since its establishment in July 1958, was appointed Associate Director for Medical Programs. Dr. Owen H. Wheeler, Head of the Division of Nuclear Science and Technology since 1962, was appointed Associate Director for Mayaguez operations. The total staff of the Nuclear Center at the end of its first year of operation (FY 1958) numbered 113. At present (FY 1967) there are approximately three hundred persons employed at PANC. The Center’s educational program is sponsored by the U.S. AEC Division of Nuclear Education and Training. Research programs are sponsored by the U.S. AEC Divisions of Biology and Medicine, Physical Research, and Isotopes Development. Additional research is sponsored by the Interoceanic Canal Commission.

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Clinical Applications Division SOF Sergio Irizarry, M.D., Chief Scientist IT, Head; Aldo E. Lanaro, M.D., Associate Scientist II; Pedro Juan Santiago, M.D., Associate Scientist I (Part-Time). The main purpose of the program of this Division is teaching and training of Latin American physicians in the diagnostic and therapeutic uses of radioisotopes in humans. Some Status Courses Available: 1. Basic Course Clinical Applications of Radioisotopes. This course consists of great tests, demonstrations, periods of discussion and laboratory work. The main purpose is to emphasize training in the use of clinical radioisotope techniques. 2. Orientation Course Clinical Applications of Radiopharmaceuticals for Medical Residents. This is a non-credit semester course for Medical Residents designed for orientation only in the medical uses of radioisotopes. 3. Course in a Medical Specialty. This is a course emphasizing the application of nuclear techniques in a special field of Medicine. A two-week course in the field of Pediatrics will be offered following the Basic Course in Clinical Applications of Radioisotopes in February and June 1967. 4. Training in Clinical Research. This course stresses research aspects in Clinical Medicine, and is designed to provide research facilities to trainees interested in clinical radioisotope research work. Special activities to increase the number of prospective candidates for the training courses have included several trips to South America by Dr. Lanaro during which he has visited hospitals, universities, and other institutions and participated in scientific meetings. ---Page Break--- Many prospective trainees would come to Puerto Rico provided maintenance expenses could be provided. Clinical Research: To complement the training program, research projects are active in the areas indicated: 1. Thyroid disorders 2. Cancer detection 3. Gastrointestinal absorption Problems of clinical radiation Liver and kidney disorders 2 ---Page Break--- Radiotherapy and Cancer Division of Victor A.

Marcial, Ti, D. Chie? Scientific If, Head; José H. Tend, MH, Di, Chief Scientist I; Joanno Ubisse, 1. De, Chief Scientist; Antonio Bosch, Ii. D., Chief Scientist I; Maria de Lozano, Me, Research Associate T; Zenaida Frias, i, S., Medical Research Statistician. PURPOSE, ‘The main purpose of the Division is to train physicians and allied personnel in all aspects of the application of nuclear energy to cancer. ‘A second purpose is to develop and carry out a research program to improve our knowledge in the cancer and radiation field; comment status. The Division offers three programs in Radiotherapy Training: (1) Radiotherapy Residency Program, The objective of this program is to prepare qualified radiation therapists. This is an approved program that fulfills the requirements of the American Board of Radiology. Physicians with a year's internship or equivalent clinical experience are accepted for this training. The total training period lasts three years, but trainees are required to take an additional fourth year of supervised practice (preceptorship) before admission to the specialty examinations. Trainees acquire a solid background in clinical cancer through supervised work with new, follow-up, and hospitalized cancer patients. They learn to diagnose the disease, determine the extent of the tumor, choose the appropriate treatment, and plan and conduct radiological therapy. Radiation therapy experience is acquired by working with recent therapy machines of various voltages and teletherapy units, which include cobalt and cesium, and with the application of radioactive materials such as radium, strontium, cobalt, and iridium. Trainees also become familiar with non-radiological cancer treatment methods, such as surgery and chemotherapy. In addition, they learn of cancer control activities in Puerto Rico; these include the operation of a Central Cancer Registry, tumor clinic work, cancer detection, and public and professional education in cancer. ---Page Break--- (2) Special Short Term Radiotherapy Training Course.

Special programs are prepared according to the needs of the person. Participants may engage in a research project and may participate in all teaching activities of the Radiotherapy and Cancer Division; but are not given patient responsibility. An additional training activity is offered for Fourth Year Medical Students. Selected candidates receive one month of intensive in-service training, where they are exposed to cancer and radiotherapy clinical problems. Radiotherapists from Latin America are hired as visiting staff. This permits them to become acquainted with the work of this Division and to carry out research projects. To complement the training programs, a number of research projects are active in this Division. These include: (1) Investigation of the Role of Surgical Sterilization in the Etiology of Cancer of the Uterine Cervix; (2) Study of Fractionation of Weekly Radiation Doses in Cancer Patients Under Radiotherapy; (3) Carcinomas of the Uterine Cervix Associated with Pregnancy; (4) Determination of Optimal Tumor-Dose in Radiation Therapy of Cancer of the Esophagus; (5) Controlled Study of the Split-Dose Technique in Radiotherapy of Cancer; (6) Study of Chronocycle Changes in Patients Undergoing Radiation Therapy for Cancers; (7) Exfoliative Cytology as a tool for Determining Prognosis in Cases with Cervical Carcinoma Submitted to Irradiation; (8) Surgical Adjuvant Breast Project; (9) Study of the Incidence of Leukemia in Patients with Cervical Cancer Treated with Radiation; (10) Clinical Dose-Time-Fractionation Relationships. This Division is collaborating in various research projects conducted by other Divisions of PRIC; these are: study of thyroid function in patients with neoplasia, tumor localization studies, gastrointestinal absorption studies, normal and neoplastic tissue cell-cycle studies, mice L.D.-50 studies, etc. ---Page Break--- Agricultural Biosciences Division Ssuuf Robert A. Iuso, Ph. D., Chief Scientist, Head; Joo A. Ferrer Monge, Th. D., Chief Scientist.

K. 8. "Koo, Ph.D., Associate Scientist IT; David W. Walker, Ph.D., Associate Scientist TI; Sreekant H.W. Deshrante, Ph.D., Associate Scientist I; José Cuevas, M.S., Research Associate I.

PURPOSE: To train students at the graduate and post-graduate level for research in agriculture or biology, emphasizing nuclear techniques. To carry on continuing basic research programs which are concerned with problems in tropical agriculture that can be uniquely studied by nuclear techniques. STATUS I. Education and Training Eight students currently are working toward M.S. degrees in biology and agriculture—degrees which will be awarded by the University of Puerto Rico upon completion of coursework and an experimental thesis. In the last five years, several students have continued on for doctoral training in U.S. universities. In the last year, five persons have done postgraduate research in the Division, supported through fellowships from IABA, ORINS, OAS, and the Peace Corps. These trainees spend from 1 to 15 months at PRIC taking courses and/or participating in research projects. They then return to their home countries to develop scientific projects there (e.g., in Taiwan, Uruguay, Guatemala). An additional IAEA Fellow is in prospect. Division staff are currently offering graduate-level courses at the University, where they hold ad honorem appointments. This academic year, courses in Nuclear Techniques in Agriculture, Nuclear Techniques in Biological Research, and in Cytogenetics (both campuses) are being presented. Division staff members have served as Scientific Advisors with the ABC Exhibit "Átomos en Acción" in El Salvador and Guatemala in 1955 and in Costa Rica and Nicaragua in 1966. Revisitations of previous Exhibit sites permit continued contact and cooperation with Central American scientists. ---Page Break--- II. Research Radiobiology 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 attempted.

Initial experiments to determine the radio-sensitivity of seeds and buds to thermal neutrons produced in the PRIC tegavatt reactor have been completed. Subsequently, thousands of seeds and vegetative buds have been irradiated, germinated, and planted in the field. Major chemical screening for sugar content in the individual plants produced is being carried out via automated analytical techniques. Visible mutations such as wider, crisper leaves indicate that other favorable characteristics may be induced. Sugarcane mutants will be propagated and evaluated in the University Agricultural Experiment Station program of crop breeding and improvement. A similar program concerned with the induction of resistance in sugarcane to the mosaic virus disease is underway. Early, a thousand plants have been grown from irradiated seed and these are in the process of mass screening by artificial infection with the virus.

Radionuclide studies in sugarcane important problems of both immediate and long-range application have been studied in sugarcane through the use of radioisotopes. Several field and greenhouse experiments which deal with agronomic practice were completed this year. For example, the effect of soil factors (pH, density, moisture content) on the nutrient uptake and utilization of phosphates, sulfates, and trace elements has been determined. Also, the enhancement of foliar absorption of phosphates by wetting agents was measured; results will be of use in the aerial spray application of fertilizers to sugarcane, an increasingly more common practice. The enzymatic degradation of sucrose in the sugarcane plant by invertase has been the subject of biochemical investigation. Factors which control invertase formation have been determined by measuring the incorporation of added carbon-11 labeled amino acids into the protein fraction of sugarcane meristem tissue. Co-factors such as magnesium ion have been found essential for this incorporation; the protein formation is considerably reduced by the presence of sulfhydryl compound C.

Radiation preservation mango: Several exotic tropical fruits have considerable market potential if their ripening could be delayed to permit shipment. To evaluate the process of radiation

preservation, a series of experiments were done, involving 20 varieties of mangoes irradiated to 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 Kr doses of gamma radiation extend the shelf life at 50°F by approximately twenty days for certain varieties of mangoes. Such results hold promise for the radiation preservation of this fruit. Biochemical studies of softening of mangoes during and following irradiation have also been carried out by measuring the 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 polygalacturonase activity in the mango. Other projects within its structure, the Agricultural Bio-Sciences Division currently houses three projects supported through contracts with the UGEC: Radiation sterilization of the Sugarcane Borer, Radiation Preservation of Tropical Foods, and Resonance in Radiation Projects. While these projects are reported elsewhere, it should be pointed out that these are an integral part of the Division's program and, in turn, rely for their senior investigators on Division personnel. Radioisotope Applications Division STAFF R. Uorry Serent, Ph. D., Chief Scientist; Alec Grimison, Ph. D., Associate Scientist II (Furtive); José P. A. Castrilén, Ph. D., Associate Scientist I; Trict If, Mair, Mh. D., Associate Scientist I (Hart-Tine); George Siupoon, Ph. D., Associate Scientist; Gerardo Molina Voc, M.S., Research Associate II; Rosa Sintena Ge Trado, H. B., Research Associate I. PURPOSE The main objective of the program is the offering of sufficient training to scientists in the application of radioisotopes and for analyzing.

radiation to the physical sciences to provide technical competence for their future work. A second objective is the offering of introductory training to scientists, irrespective of their fields of interest, in radioisotopes and ionizing radiation as a background or a complementary preparation for their participation in other programs of FRIC. CURRENT STATUS Courses with University sit 1. Radiochemistry Course (Chemistry 465 - 3 credit hours). A one semester course offered once a year for advanced undergraduate and graduate students. Three one-hour lectures and one four-hour laboratory period per week. Approximate enrollment: 5 to 6. 2. Nuclear Techniques in Biological Research (Biology 372 - 3 credit hours). A one-semester course offered once a year for advanced undergraduate students. Three one-hour lectures and one three-hour laboratory period per week. Approximate enrollment: 5 to 6. 3. Participation in Graduate and Undergraduate Research Courses. Research training in the field of photo and radiochemical reactions and in the application of radioisotopes to chemical studies is offered to students pursuing the B.S. degrees at the University of Puerto Rico. Each student carries out an individual research project in accord with the credits for which he registers in Chemistry 599 and Chemistry 397-390. ---Page Break--- Special Training Courses 1. Basic Course in Radioisotope Techniques - Four-week course now being offered four or five times a year. We have had a total of 272 participants (36 sessions) including 69 Latin Americans. The present rate of participants is approximately 30 per year. (This course was incorporated in the curriculum of the graduate programs of Biochemistry and Microbiology at the U. P. R. School of Medicine as Biochemistry and Nutrition 0, 2 credit hours). 2. Radiological Physics - A special course offered to M.D. Residents in Radiology when requested. ORGANIC CHEMISTRY PROGRAM The purpose of the program is to provide advanced chemical training in organic chemistry with

special emphasis on its nuclear aspects. The projects cover a relatively wide range of subjects in order to offer a broad experience to all members of the group, and the diffusion of the varied aspects of organic chemistry is promoted by group seminars and discussions. CURRENT STATUS The research topics include the use of S-39 in exchange reactions, the use of tritium, C-36, and C-14 for the determination of reaction mechanisms, the synthesis of boron compounds of potential

use in neutron activation therapy, and the gamma radiolysis of dimethyl sulfoxide. The study of the gamma radiolysis of dimethyl sulfoxide is of recent origin, but correlative studies concerned with the physical properties of this substance have been in progress for some time. The boron project is currently inactive because of the departure of the research assistant who was involved in this work. PHOTOCHEMISTRY AND RADIATION CHEMISTRY PROGRAM PURPOSE The purpose of the program is to provide advanced chemical training in photochemistry and radiation chemistry, with special emphasis on the relations and distinctions between these. Also included are projects giving training in the use of quantum chemical calculations for evaluation of the experimental results. ---Page Break--- CURRENT STATUS The advanced chemical training in this area involves active participation in the experimental and theoretical projects detailed under "Matrix Toolstation Studies of Products of Gamma Radiolysis of Heterocyclic Molecules," as well as participation in group seminars. -10- ---Page Break--- Nuclear Science and Technology Division STAFF Owen H. Wheeler, D.Sc., Ph.D., Associate Director, Head (Part Time); Eddie Ortiz, Ph.D., Chief Scientist I (Part-Time); Rev. Ignacio Gontarell, Ph.D., Associate Scientist I (Part-Time); Julio A. Gonzalo, Ph.D., Associate Scientist II (Part-Time); Florencio Vázquez Martínez, Ph.D., Associate Scientist II (Part-Time); Rupert A. Lee, M.Sc., Research Associate III; J. Blisin Trabal, B.S., Research Associate I. SCORE The Division

provides training and research facilities in fields of chemistry and physics related to nuclear science for students in the M.S. degree programs of the Departments of Chemistry, Physics, and Nuclear Engineering of the University of Puerto Rico at Mayaguez. The Division also offers research facilities for workers at the re- and post-doctorate level and the staff members carry out independent research. CURRENT STATUS EDUCATION AND TRAINING Seven graduate students are carrying out research for their M.S. degree in chemistry, one in physics, and one in nuclear engineering at the Division. Members of the Division are currently teaching three courses in the Departments of Chemistry and Physics of the University of Puerto Rico at Mayaguez, in nuclear physics and chemistry, radiochemistry, and solid state physics. Part of this work is carried out in collaboration with the Neutron Diffraction Program. Mr. Rupert A. Lee is completing his thesis work for a Ph.D. in radiation chemistry from the University of Alberta. CHEMISTRY PROGRAM. The fundamental mechanism of the radiolysis of hydrogen chloride and hydrogen bromide is being studied, using both gamma radiation and fission recoil particles. This study is part of a concept for the conversion of fission energy into electrical energy, via a cycle involving radiolysis of a hydrogen halide by fission fragments to provide feed material for a fuel cell. ---Page Break--- Studies are also being carried out on radiation induced reactions of organic compounds in solution, and on the mechanism of thermal rearrangements using Lectopers. A program of research in hot-atom chemistry is now supported by the Division of Research of the ABC. Two other research groups are financed by grants from the National Institutes of Health; one on the Synthesis of Thiasteroids (3 assistants) and the other on the Radiclysis of Peptides (2 assistants). PHYSICS PROGRAM. Radiation damage in ferroelectrics is being investigated by means of hysteresis and dielectric studies, and of measurements of

capacity and conductivity. ‘The effect of temperature changes to +10-3°C in ‘the region of the Curie temperature has been studied. ‘The compounds studied include triglycine sulfate and alkali trihydrogen selenite. Work is being initiated on the formation of color centers in magnesium oxide and alkali halides, and on field emission from highly clean surfaces. Related studies, in conjunction with the Physics Department, University of Puerto Rico at Mayaguez (H. J. Gouberg and B. Cruz-Vidal) ‘are concerned with the efficiency of color center formation in alkali halides as a function of the energy of incident monochromatic x-rays near the K absorption edge of the halide.

a1 ---Page Break--- Nuclear Engineering Division SUFP Donald S. Sasscer, Th. Ds, Chief Scientist I, Head; Avive E Gileadi, Ph. D., Chief Scientist I; Phillip W. Osborne, Ph. D., Chief Scientist I; Kenneth Soderstrom, M. S., Research Associate III; Carlos Wheeler, B. S., Research Associate II; Erick Méndez Weray, M. S., Research Associate I, PURPOSE The main purpose of the Division program is to teach, train and do research in the basic sciences and engineering contributing to development of the use of nuclear energy. University of Puerto Rico students in the program must be enrolled for graduate studies and be accepted in a program leading toward one of the Master of Science degrees in engineering, usually nuclear engineering. Students from other universities in the United States or in Latin America may be accepted for participation in research for completion of thesis requirements. PRNC participates in the ORINS Graduate Fellowship Program for support of U. S. citizens doing thesis research. There are now 15 students working toward M. S. degrees in Nuclear Engineering. In addition to the primary purpose, the Division also provides special non-degree training programs for technicians and for engineers and scientists. CURRENT STATUS ‘The primary effort is on the educational program in Nuclear Engineering carried out in cooperation with the Department of

Nuclear Engineering of the College of Engineering. Courses being taught are: Core Courses: 1. Elements of Nuclear Engineering (NUCE 605) Four credit hours. Four lectures per week. Characteristics of the atomic nucleus, radioactive decay, interaction of radiation and matter, fast neutrons. 2. Reactor Theory (NUCE 621) Three credit hours, three lectures per week. Neutron balance equation, diffusion theory, solving diffusion theory, bare heterogeneous reactor, reflected reactor, heterogeneous reactor, time-dependent reactor, perturbation theory, transport theory. ---Page Break--- 3. Mathematics of Modern Science I (MATH 675) Three credit hours. Three lectures per week. A more advanced study of topics covered in MATH 475-476. Complex variables, partial differential equations, special functions, transform calculus. 4. Nuclear Measurements and Instrumentation (NUCE 603) Three credit hours. One lecture and two three-hour laboratories each week. Prerequisite: PHYS 455. Characteristics of operation and thorough familiarization used in the application of specialized techniques such as: coincidence and anticoincidence counting pulse analysis, neutron spectrometry, gamma ray spectrometry, etc. 5. Advanced Reactor Theory (NUCE 622) Three credit hours, three lectures per week. Prerequisite: NUCE 621. Advanced transport theory, reactor kinetics, heterogeneous reactor theory. Prerequisites: MATH 675, NUCE 605, NUCE 621. Corequisite: NUCE 676. 6. Mathematics of Modern Science II (MATH 675) Three credit hours, three lectures per week. A more advanced study of some topics covered in MATH 475-476. Star systems, Liouville systems, calculus of variations, integral equations, tensors, finite differences. 7. Reactor Laboratory (NUCE 625) Two credit hours. Two three-hour laboratories each week. Prerequisite: NUCE 621. Laboratory problems involving the nuclear reactor. 8. Graduate Seminar (NUCE 616) One credit hour. Two hours per week. Reports and discussions on special topics in Nuclear Science and Engineering. 9. Nuclear

Reactor Technology (Thu Eg 602) Four credit hours, three lectures and one three-hour laboratory demonstration period each week. Prerequisite: I Bg 605 and II Bg 621. Steady-state and transient thermal conduction in fuel elements; thermal convection in heat exchanger design; liquid metals systems; breeding and conversion; an introduction to the economics of reactor operation; reactor engineering design problems.

Thesis (TIA ES 699) One to six credit hours. One to six research periods each week. Research in the field of Nuclear Engineering and presentation of a thesis.

Supplementary Courses:
1. Nuclear Reactor Metallurgy (TIS Bg 612) Three credit hours, two lectures and one three-hour laboratory each week. Corequisite: MA 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.

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2. Introduction to Nuclear Engineering (ITI Bg 551) Three credit hours. This course is offered for advanced undergraduate and some 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.

Research: The staff of the Nuclear Engineering Division and members of other PRNC Divisions are carrying out research through projects designed for student participation. These include:
1. Methods of reactor shutdown minimizing the after shutdown Xenon peak.
2. Measurement of the transfer function on the L-77 heterogeneous reactor by the modulation technique.
3. Study of the variation of the neutron characteristics occurring during reactor operation due to the changes in isotopic composition of the core.
4. Effects of irradiation on the fracture characteristics of plexiglass.
5. Determination of mass flow rates in pipes by use of the nuclear Doppler effect.
6. Determination of metal to metal diffusion coefficients by

Diffusion of radioactive nuclei. 7. The effect of nuclear irradiation on the emissivity of graphite. 8. Determination of the heat-transfer coefficient for free convection of air between plate-type fuel elements. 9. Monochromatization of reactor beamport neutrons by multiple critical angle scatter. ---Page Break--- Reactor Division SOF Héctor Arcelé, TIS 5, Chief Scientist I, Head; Richard Bram Caupos, H. S., Associate Scientist I, Reactor Supervisors: Eneato Guerra, B. E.'B., Reactor Supervisor; Six Reactor Operators. PURPOSE: The main objective of this Division is the operation, maintenance, and protection of the two TRUC reactors: an L-77 homogeneous reactor and an A. X. F. pool-type regenerative reactor currently operating at one megawatt power level. The Division staff also operates and maintains pneumatic tubes, hot cells, a gamma irradiation room, fuel element irradiators, a gamma pool, and all equipment necessary for the operation of these facilities and participates in the training of reactor operators and supervisors. The Division supports all other divisions and programs associated with the Puerto Rico Nuclear Center. In the pool-type research reactor, two six-inch beam tubes are being utilized by the neutron diffraction program for two neutron spectrometers. A shield for has been built around another six-inch beam tube for future experiments in biology and medicine. A borated water shutter has been built for these beam tubes. A neutron monochromator, based on critical angle reflection techniques, is being built to be installed in a fourth beam tube. The fourth beam tube is scheduled for experiments by Lee on fission product radiochemicals or hydrogen halides. Presently, the research reactor is operated on a sixteen-hour-a-day basis, at a continuous power of one megawatt. Studies are in progress for an increase of power to two megawatts and an increase in operation time to twenty-four hours, five days a week. Ultimate plans are to increase the power level to five megawatts continuously with pulsing.

capability with peak power of two thousand megawatts. The 1-77 reactor is used for teaching and experiments suitable for a water boiler homogeneous type of source. An oscillatory system for dynamic experiments is being built. ---Page Break--- The demand for two different modes of operation of the pool reactor, namely, continuous, steady state, full power for researchers, versus variable flux, changes of configuration and intermittent operation required for any training program led this Division to present a proposal for the construction of another reactor to be installed at the other end of the pool. This low power reactor is to be built and put into operation by members of the Division. This reactor will be operated on an on-off basis with the primary purpose to provide a flexible facility where nuclear engineering and other graduate students may perform laboratory experiments and research projects related to Division work. The Division participates in the training of reactor operators and supervisors, and supervises thesis work related to reactor physics. Among others, the Reactor Division has trained two reactor supervisors from Colombia, who are now in charge of reactor operations at the Colombia nuclear research reactor. The Division gave operator training to the BOWS startup team. The training consisted of providing practical experience in reactor startup and shutdown. It also participated in the training of twelve ROWS reactor operators in a ten-week summer course. In addition, two thesis problems of BOWS students studying for the degree in Nuclear Engineering at the University of Puerto Rico at Mayaguez were supervised by personnel of the Reactor Division. In the field of technical help to other organizations, members of this Division have been in close contact with the Colombia reactor. The director of the Division is a member of the BONUS Safety Committee, and also participated in a study group meeting in Caracas, organized by the International Atomic Energy Agency. ---Page Break--- Health Physics Di

SIF Peter Paraskevoudakis, Ph.D., Associate Scientist TI, Acting esas Pedro Cruz, M.S., Research Associate TT; Heidi Fabén, M.S., Associate in Health Physics, and five Health Physics Assistants. The Division has two general responsibilities: (1) services associated with radiation and industrial safety, and (2) training and education. CURRENT STATUS In the area of services, Health Physics conducts the following programs: 1. Personnel Monitoring - This is the most extensive program. Dose assessment mainly by way of sensitive film is provided to the Nuclear Center, Bonus Power Plant, and the Cancer Hospital at Río Piedras. During fiscal year 1966, more than 13,000 film packets were processed. 2. Area Monitoring - This program is limited to FRNC controlled areas and provides information on the operation of the different facilities of the installation in their relation to the use of radioactive material. 3. Environmental Surveillance - This program involves the collection and analysis of environmental samples such as soil, water, and vegetation beyond the area of the PRIC site. 4. Waste Disposal - The Health Physics Division has the responsibility for management and control of radioactive wastes generated by PRC. 5. Radioactive and non-Radioactive Hazardous Material Handling - The Division carries out routine inspections and checks to ensure safe handling of this type of material. Part of the program includes indoctrination of the personnel using the material in proper safety procedures. 6. General Laboratory Safety - This program is in essence an extension of the previous one. Emphasis is given to the supervision of operations not covered under item 6 such as compliance with fire, electrical construction codes, etc. Periodic inspections and indoctrination of personnel form an integral part of this program. In addition to these programs, Health Physics is in charge of supervising and directing decontamination operations. The Division creates facilities, one for the calibration of radiation.

nenitering equizment and the other for 2 miclear Scciient dosinetry center based on a dosimeter aysten originally Geveloped by Hurst. in the area of training and education the staff participates in the teaching ond training of students ani staff nenbers in the principles anf practice of Tadiation cafety, Tair ineluies Realenie couress, seninare ané thesis recearch. In cooperation Attn the

Univerelty or Ruerto Rico, the Division offers « curriculum Jeading to ants § degree in Health Mysics, This is an approved program fer the Atonie Energy Comission Syecial Fellovehip in Inalth Physics. A graduate course in liealth Paysice is offered, for students not specializing in this field, vith acadenic Credit granted through the Biclogy Depertuent of the University ce Puerto Rico in Heyaquez. The Divicion also carries out research fo cupport investigations in other divisions and programe. A recent development is the provision of dosinetry standards for researchers throughout FRI, Ucing mcm techniques and Gevelopine nev ones, as needed, Health Physics provides energy fant dose Information for al) neutron and genmsa ray radiation facilities such as the reactor beam tubee, pneusstte tubety {hermal column, pocl aren, the neutron ani the gomn irradiation Foons, the eedsle-5O sources, anc other major sources ao thoy fare introduced. “19. ---Page Break--- Medical Sciences and Radiobiology Division oorF Jorge lt, Chiriboga, 1. D., Ascietant Director for Sefentitic Progra, Acting leet; figiro tiartinas Siva, HM. D., Assoetate Bientist 1 Julio T. Colin, A. D., Associate Sientist (kt honoren); Joo8 fice} Correa, Vi. D., Aetociate Stentiet (Ad henoren); Tvelisse Rodrfcuez de Oquendo, II. S, Tosearch Aggociate I; na Sylvia Cuessda de Rodrigues, 11. S., Research Assceiste (Mo nonoren); Conrado Asenjo, Fh. De, Chief Selentist (hd honovea); Joos A. del Castillo, Pas Dey Chiet Sctentist. (Ad honorea): Lule Otero Willaderbé, Fa. Dey Associate Sientizt. PROS 1, To toach ond conduct research at different levels within the Field or Radiation

Biclegy. 2. To establish projects which have a bearing on the problems of Tropical Medicine (Field and laboratory studies on the effects of radiation on host-parasite relationships). 3. To maintain a tissue culture facility to serve as a medium for training and research. CURRENT STATUS Training - A four-week course in Tissue Culture and Radiobiologic Techniques at Cellular and Subcellular Level was offered from October 17 to November 10, 195. The course is designed to give emphasis to the basic aspects of tissue culture such as the applications of this technique to virology, radiobiology, etc. Microautoradiographic techniques, cytogenetic preparations, labeling and liquid scintillation counting of nucleic acids at a cellular level, and other techniques are included. Research - Work is being done on various research projects. The following will be a brief review of the more important ones: 1. Two cell lines derived from a Danish choriocarcinoma are under study with special interest in karyotypes and metabolic functions. It is hoped that the radiobiological effects in vivo and in vitro can be compared. ---Page Break--- 2. Diploid human cells are under culture and the effects of radiation on the aging process are being studied. 3. A group under the direction of Dr. Dol Castillo is trying to maintain living muscle cells of Ascaris in the tissue culture media. 4. The effect of radiation on the host-parasite relationships in latent arthropod-borne viruses has been started utilizing tissue culture and host animals. 5. The Schistosomiasis studies conducted in this Division are reported in a separate abstract. ---Page Break--- Participation of the Puerto Rico Nuclear Center in the USAEC Atoms in Action Exhibit in Latin America STAFF Fausto J. Muñoz Ribédeniera, B. Ch. E., Research Associate II, Program Director; Eugenia P. de Ramirez, Administrative Assistant; PRIC scientific staff participates as needed. PURPOSE PRIC has been assigned responsibility for conducting a program of scientific research as part of the USABC Atoms in

Action Exhibit. Research projects are selected on the basis of possible economic interest, the present status of scientific development in the host countries, similarity of projects to current PRIC research, and availability of PRIC staff to serve as consultants. A subsequent follow-up and evaluation of the experimental results is carried out by the PRNC scientists who participate in the Exhibit. CURRENT STATUS The Atoms in Action Exhibit has now visited four Central American countries. In February and March 1965 the Exhibit visited San Salvador, El Salvador, and in August and September 1965 the Exhibit was held in Guatemala City, Guatemala. In February and March

1966 the Exhibit was in San José, Costa Rica and in October and November 1966 the Exhibit was in Managua, Nicaragua. Salvadorean researchers used gamma radiation to determine the mortality sterilization dosages for Leucoptera coffeella, an insect pest in coffee, and Heliothis zea, a cotton and corn pest. Preliminary results on radiation preservation of shrimp and cantaloupe melons were satisfactory. Genetic studies in beans have shown in the first crop a total weight increase of 25 percent and in rice a stiffer straw has been obtained. Gamma radiation also improved coffee flavor and taste. Four graduate students of the University carried out thesis research with exhibit equipment. In Guatemala entomology studies were focused on Toxoptera postica, a citronella and lemon grass plantation insect pest. In genetics, the maximum survival dose for corn was determined. Experiments to determine radiation effect on coffee flavor and taste, beer, and essential oils were performed. Researchers from the Central American Institute for Industry (ICAITI) carried out investigations on canned pineapple sterilization by gamma radiation and investigators of the Nutritional Institute for Central America and Panama (INCAP) used Incayarina to study the degradation of vegetable protein under gamma radiation. Twelve hundred undergraduate

Estudente voluntarily attended a special program prepared by the FRNC personnel, and six graduate students of the University of San Carlos performed thesis research under the guidance of PRNC lecturing scientists. Balvaderean researchers came to Guatemala to continue genetic studies on dears and rice and entomological studies on Heliothis zea. PRI personnel played an important role in the donation of the gamma irradiation facility of the exhibit from the Regional Office for Central America and Panama Affairs (ROCAP, U.S. Department of State), to ICAITI. The research activities in Costa Rica dealt primarily with agricultural problems with additional topics in the physical sciences. Radioactive tracers were utilized to study organic chemical reactions. Projects carried out included work on fish, potato, and coffee preservation by radiation; bean softening by radiation, radiation effects on corn, rice, and bean seed viability, effects of gamma radiation on the hysteresis cycle of triglycine sulfate crystals, effects of formic acid concentration on the Fricke dosimetry system, radiation chemistry of titanium sulfate solutions in sulfuric acid, and other chemical studies. In Nicaragua, research projects have been started in food preservation using bananas, bean softening, sorghum seed viability, and sorghum genetics. Experiments are also being carried out in neutron dynamics. -3- ---Page Break--- Solid State Physics Program STUDY OF RADIATION DAMAGE IN ORGANIC CRYSTALS USING ELECTRICAL CONDUCTIVITY STAFF Amador Cobas, Ph. D., Associate Director; Shuvel Zvi Weitz, Ph. D., Chief Scientist; Alfredo J. Torruella, Ph. D., Associate Scientist (Ad honorem); George M. Simpson, Ph. D., Associate Scientist; Jesús M. Tharrats, Ph. D., Associate Scientist (Ad honorem); James A. Muir, Ph. D., Associate Scientist I. PURPOSE The effects of radiation on organic crystals is the primary interest in this project. It is felt that such studies on well-defined crystalline structures can provide a firm foundation for a later

study of more complex materials, including those of direct biological interest. Anthracene has been chosen as the initial material for study because this substance has been studied more than any other organic material. CURRENT STATUS ‘The damage induced by radiation is studied by measuring the changes in the electrical and optical properties before and after irradiation. ‘The measurements at present are performed on anthracene single crystals. The electrical properties are studied by measuring the steady state and transient current voltage characteristics. By applying an injecting electrode to the crystals (either highly absorbed light or iodine in a sodium-iodide solution) the current through the anthracene is space charge limited. From the transient and steady state behavior of the space charge limited current (SCLC) - voltage characteristics carrier transport and trapping properties, such as mobility, trap density, trap depth, trapping lifetime, and capture

cross section can be deduced.” In this lab it was found that the measurement of the SCLC through anthracene is a very sensitive tool for the detection of damage induced by radiation. Our results indicate that by irradiating anthracene crystals with gamma or x-rays, hole traps are introduced in the crystals. The presence of these traps was detected using steady state space charge limited current techniques using a NaI-P solution as the hole injecting electrode. = abe ---Page Break--- From the changes in the steady state space charge limited current voltage characteristics for a crystal before and after irradiation the density of the introduced traps was calculated. The density of these was found to vary linearly with the absorbed radiation dose. The lifetime of the injected free carriers was measured using 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 irradiated anthracene crystals were

compared with the current voltage characteristics of crystals grown from irradiated anthracene powder and very little difference was found. This result indicates that the defects introduced by irradiation are molecular rather than crystalline. In order to try to get a better understanding of the mechanism involved in the space charge limited currents in insulators, which we use as the detection method in our investigation of radiation damage in anthracene crystals, a thorough theoretical study of injection of carriers into insulators has been done. Solutions for the time dependence of the current have been obtained for the case where the reservoir of the free carriers at the injecting electrode is time dependent. In this analysis, the transient space charge limited current, where the carrier density at the reservoir is infinite and constant in time, becomes a special case of the problem. The optical properties are studied by measuring the radiation-induced changes in the absorption spectrum, in instantaneous fluorescence, and in delayed fluorescence. The delayed fluorescence is measured in scintillation-grade anthracene crystals. They are exposed to radiation doses from 10^2 to 10^9 R. The excitation is by a high-intensity red flash. The triplet excitons are produced by direct absorption in the triplet band and the singlet excitons are produced by two-photon absorption and by triplet-triplet annihilation. The temporal response of the blue scintillation is continuously monitored both during and subsequent to the excitation. Gamma radiation creates centers in the crystal that quench the singlets and the triplets. The centers are paramagnetic and reduce the lifetime of the triplets; however, they do not affect the bimolecular triplet interaction rate constant. The density of the triplet quenching centers induced by one roentgen corresponds to the density of the hole traps measured by the e.c.l.c. method. By calculating the density of the singlet quenching centers using the value of the bimolecular singlet inter-

action rate constant obtained from photoconductive measurements, it was found that this density is larger by three orders of magnitude than the density of the triplet quenching centers. Measurements are in progress to determine the bimolecular singlet interaction rate constant by optical methods. These measurements will permit determining the yield by which free carriers are produced in the singlet-singlet annihilation process. ---Page Break--- By way of multiple techniques, an individual single crystal of anthracene can be used as a wide range dosimeter; triplet-triplet annihilation in the range 10° to 10^4 R, space-charge limited current in the range 10^3 to 10^6 R, fluorescence quenching in the range 10^9 to MR, and absorption spectroscopy above 10^7%. ---Page Break--- Neutron Diffraction Program STAFF Mortimer I. Kay, Ph.D., Chief Scientist 1, Principal Investigator; Seymour F. Kaglan, Ph.D., Associate Scientist II; Robert Kleinberg, Ph.D., Associate Scientist II; Isaac Almodévar, Ph.D., Associate Scientist II (part-time). PURPOSE The Neutron Diffraction Program is concerned with ideal and imperfect arrangements of atomic nuclear and magnetic spin systems in solids. Of particular interest to the program are magnetic structures

of inorganic salts and the determination of the role of hydrogen in structures having important physical and chemical properties. CURRENT STATUS In collaboration with Dr. K. Okada, who returned to Japan in August after a two-year stay at PRC, the hydrogen positions in copper formate tetrahydrate have been determined at room temperature and some electrical measurements made on the compound in the vicinity of the phase transition at -10°C. Since antiferroelectricity was discovered, future work will consist of determining atomic positions in the presence of an electric field with the objective of demonstrating the atomistic basis for the electrical properties. Manganous formate dihydrate has been studied and the hydrogen positions determined. A comparison of the disordered tetrahydrate

with the dihydrate structure shows clearly the reason for the greater stability of the latter. Dr. D. T. Cromer spent a year at PRIC on leave from Los Alamos Scientific Laboratory. While he was here, data was collected on the three types of alums A°B"3(SO4)p.12H2O. The combination of PRIC neutron data with IASL x-ray data has led to a complete elucidation of the α, β, and γ velun structures. The role of +1 cation size, hydrogen bonding, and disorder on the structure has been elucidated. Interesting non-harmonic thermal fluctuations have been noted. Neutron diffraction data was combined with x-ray diffraction data taken by Okaya and Stemple at TBM to produce a refined structure of tartaric acid. ---Page Break--- Data has been taken on HAk(SeO3)2 (room temperature) and Hal at (150°C) to study the ferroelectric transitions of interest to the solid state physicists in Hayaquer. The magnetic structure determinations of CoCl2 and MnCl2 Hexahydrates have been completed using data collected by Dr. #. Kleinberg at the U.S. Naval Research Laboratory. Other transition metal salts will be examined in the future. Work on the structure of solid SnCl2 by neutron diffraction using isotopic replacement of the Sn to help separate terms in the radial distribution function is being carried out by Dr. Howard L. Ritter. Dr. Ritter is Research Professor of Chemistry at Miami University in Oxford, Ohio and is currently spending one year as an Oak Ridge Research Participant in this Program. ---Page Break--- Hoi-Atom Chemistry Program STAFF Owen H. Wheeler, D. Sc., Ph. D., Associate Director, Principal Investigator; Martha Innis McLain, M.S., Research Associate; and 43 Assistants. SCOPE The mechanism of the formation of radioactive products in the neutron activation of organometallic compounds containing carbon-metal bonds is being investigated. Studies include work with short half-life isotopes. CURRENT STATUS Studies have been completed on triphenylphosphine and its oxide and on tetraphenylphosphonium chloride, and also in

Diphenyl sulfide, sulfoxide, and sulfone. Other work on cdbaltocene and nickelocene has been completed and several publications are being prepared. Research in progress covers studies on similar compounds of mercury, thallium, iodine, selenium, bismuth, and tin. The effect of radical scavengers is being studied. A gas-chromatographic counting system is being constructed for vapor phase studies. ---Page Break--- Terrestrial Ecology Program, Part 1 The Rain Forest STAFF Jerry R. Kline, Ph.D., Chief Scientist I, Principal Investigator; Carl F. Jordan, Ph.D., Associate Scientist I; George Drewry, M.A., Associate Scientist I; and visiting investigators. PURPOSE (1) To study effects of gamma irradiation from 10,000 Curies Cesium on the Rain Forest system at El Verde. (2) To study some mineral cycles of the rain forest in relation to fallout, atomic excavation, and plant nutrition. (3) To characterize the circuits and metabolic energy pulses of a complex terrestrial ecological system so as to understand the consequences of irradiation and fallout storage. CURRENT STATUS A. Radiation Effects Studies The Rain Forest Project at El Verde involves irradiation of a plot of lower montane forest with gamma radiation from a 10,000 Curies Cesium source. After 15 months of pre-irradiation studies and preparations at the radiation and control areas, irradiation began January 19, 1965. The main site was irradiated for 3 months, the

innermost zones receiving one million R. Post-irradiation measurements are in progress showing effects of radiation according to dosage received, according to species, and according to various categories of ecologies and cytological structure and function. Data emerging provide some factual basis for predicting effects of radiation on rainforests and the rates of regeneration of the living system. B. Recovery and Succession Studies The radiation center is now in an active process of recovery from the effects of the gamma radiation. Studies are in progress to document the invasion of the area.

by new plants and to observe the recovery of old damaged plants. The radiation center has been subdivided into a grid of one meter squares which are being studied individually for the occurrence of new plants and their rates of growth. Such studies will be repeated at regular intervals and the information gained will be used to construct a series of maps which will show a continuous record of the changes which occur during the recovery stage. Another method of documentation of the recovery process involves photographic comparisons of the irradiated area with other areas in the forest which have been damaged. Observations of this type indicate that the character of recovery in the irradiated area is different from that in areas of the forest which have had catastrophic damage from cutting or herbicides. C. Mineral cycles A quantitative understanding of the mineral circuits through tropical systems is essential to understanding the nature of such machinery, the soils, and the ways such systems may process radioactivity entering in relation to AEC-related activities. Understanding mineral cycling will be the primary objectives of new measurements in the rain forest project. 1. Radionuclide Balance in the Rain Forest The experience of investigators in the temperate zones indicates that a substantial proportion of fission products found in plant communities is in the form of surface contamination on leaves and that only a minor part of these isotopes ever enter the metabolic pathways of the plants. Nevertheless, such observations at El Verde as the extensive surface root development, and root invasion of organic litter and logs suggest that this forest might be well adapted to the conservation of minerals by maintaining them in reasonably closed cycles. This view is reinforced by preliminary observations of soils which indicate low levels of fission products while the decaying litter at the soil surface contains a large amount of radioactive isotopes. An experiment in progress was designed to

test whether fall-out isotypes were recycled from the forest floor through roots into understory plants. In this experiment, 134Cs, Y-90, Rb-87 were sprayed in carrier-free aqueous solution directly on the forest floor. The results after one year indicate that most of the accumulated radioactivity remained where it was first placed and much of the original organic litter was still highly radioactive. The rate of uptake of the isotopes by the understory trees was almost undetectably slow. 2. Effect of Gamma Irradiation on Fission Product Retention by Forest Trees Samples were taken before and after the irradiation from forest trees in the irradiated control centers. Measurement of Cs-137 and MeV in these samples by gamma-ray spectrometry indicated no detectable effect of irradiation on the leaching of these elements in the forest system by rainwater. ---Page Break--- Neutron Irradiation studies Thermal neutron irradiations of soils from various points in Puerto Rico and from Panama have been carried out. The most prominent isotopes which can be observed in these soils regardless of origin are: 59Fe, Mo-99, Na-24, Sm-151, and 1936n. Samples of plant ash are also being prepared for study by thermal neutron irradiation. Plans have been completed and equipment constructed for an attempt to carry out fast neutron activation studies of soils and plants utilizing a special nuclear reaction which may generate fast (siev) neutrons in the presence of thermal neutrons. 4. Natural Radioactivity in the Environment Preliminary surveys of soil specimens from various locations in Puerto Rico have revealed certain sites of unusually high levels of radium daughters. These sites, which contain a factor of 6 more

natural radioactivity than the El Verde site, may be of considerable value in future studies of the behavior of radioisotopes of the Uranium decay series in natural environments. A suggested preliminary use for these sites is to study the possibility of radon transpiration by plants by examining wood from the trees of these locations.

for equilibrium mixtures of lead-210 and polonium-210. 5. Radioisotope Persistence in the Rain Forest The radionuclides Mice, 9521-950, Strontium, and 137Ce were observed to have extremely high persistence in the tropical forest at El Verde. Measurements made on samples collected from the forest on a monthly basis indicated that the rate of removal of the above nuclides from the forest system was controlled primarily by the physical half-life of the nuclide and that a biological half-life could not be experimentally defined. Such measurements were made at a time when the input of nuclides into the forest was negligibly small. They were interrupted by the arrival of fresh nuclear debris between 12 and 24 days after the Chinese atmospheric weapons test of May 1965. The sampling program is continuing. D. Circuits and Networking A special PRIC proposal was prepared outlining an electrical analog circuit that might be prepared if authorized and budgeted. The system on the passive principle allows for flows in 36 compartments for which there are data available to set storage constants and rates. This system is under construction at the University of North Carolina by Howard J. Dus who is a consultant to the project. 32 ---Page Break--- The giant cylinder experiment was used to provide water budget and carbon metabolism data on the rain forest. The water budget data was of particular interest for predictions of the fate of tritium in a tropical forest since this isotope is likely to be produced in large quantities by nuclear excavations. Attempts are being made to use the giant cylinder to study an annual cycle of metabolism and water use in the forest. -3 ---Page Break--- Marine Biology Program StF Frank G. Lowan, Ph. D., Chief Scientist 71, Program Director; Donald K. Phelps, Ph. D., Chief Scientist I; Robert Y. Ting, Ph. D., Associate Scientist I; John H. Martin, Ph. D., Associate Scientist II and Rail McClin, M. S., Research Associate I. PURPOSE. The Marine Biology Program at the Puerto Rico Nuclear Center was

started in January 1962 and is composed of six major research projects and supporting areas of research, all of which are interrelated into an integrated research activity. The program was designed to provide measurements of the distribution and movement of trace elements in restricted but complete ecological land biogeochemical systems. The research includes investigation of the lithosphere and the marine bio- and geospheres. Specifically, the distributions and movements of selected trace elements are being followed from the rocks, animals, and soils of three river watersheds into the river waters, organisms and sediments, thence into the marine water at depths and distances offshore, through the marine biosphere and into the marine sediments. CURRENT STATUS In order to obtain information on the interactions of the marine biosphere and hydrosphere, measurements are being made to determine the influences of biological productivity, biological half-lives of trace elements, food webs, characteristics of trophic levels, and physical and chemical oceanographic factors upon the distribution of trace elements in the marine waters offshore from the west coast of Puerto Rico. The effects of physical and chemical oceanographic conditions upon the distribution of organisms are being studied, with special emphasis on observations of the effects of varying amounts of mineral-rich silt upon the distribution patterns of marine organisms. (1) Measurements of biological elements, (2) Measurements for given radioisotopes, (3) Measurements of radioactivity and isotopes now The research projects include productivity, (2) analysis for elements of concentration factors of selected isotopes ---Page Break--- present in the marine organisms, waters, and sediments off the west coast of Puerto Rico, (5) background measurements in physical and chemical oceanography, and (6) distribution of rare

earths in the Atlantic System. Supporting areas of research include investigations of the effects of interactions of river and sea water upon the

precipitation of trace elements in estuarine environments, chemical and physical characteristics of marine sediments deposited from three rivers which drain watersheds containing limestone, serpentine, or rocks of volcanic origin, the characteristics of variability in trace element content of populations of organisms from a given environment, and the development of methods for analyzing trace elements in a variety of sample types. -35- ---Page Break--- Estuarine and Marine Ecology Study - Specific Activity Approach STAFF Frank G. Lowman, Ph. D., Chief Scientist IZ, Program Director; Donald J. P. Swift, Mh. D., Associate Scientist 1; Rail MeClin, MH... Research Associate I; Henry Beeselievre, Research Associate III; plus technical staff. PURPOSE The program is part of a feasibility study for a sea-level isthmian canal in Central America under the management of Battelle Memorial Institute and is designed to develop and carry out investigations of stable element distributions throughout the marine and estuarine environments in the Darien area of Panama including the Gulf of Panama and the waters off the continental shelf in the Caribbean Sea from Punta Mosquito, Panama to Barranquilla, Colombia. The degree of potential hazard to man through contamination of these environments by radionuclides may then be predicted from these data. CURRENT STATUS This program is an extension of the Marine Biology Program at PRIC which is supported by the Environmental Sciences Branch of the USAEC Division of Biology and Medicine. A unique feature of the program is the "specific activity" approach-- a procedure of sampling and analysis which holds promise of successful application to marine contamination problems. This method is based upon two premises: 1. That the distribution patterns of biologically-available stable elements in the organisms and their environment may be used to predict approximately the distribution patterns of introduced radioisotopes of the same elements. 2. That if the specific activities (Ci of

radioisotope/gran of Corresponding stable element of carrier element) in the estuarine Grand Marine environment are maintained below the allowable specific Activities for radioisotopes in the human body, then no individual can obtain greater than the allowable amount of radioactivity from food derived from these sources. ---Page Break--- On the basis of the preliminary assessment of potentially critical radionuclides a field collection program has been developed and two research vessels with an eight-man operating crew and seven scientific investigators will be sent to Panama in February 1957. The field team will remain in the Panama area for three months making the collections which will include soils, river waters, sediments and organisms, marine water and sediments, and marine organisms including mollusks, plankton, seston, crustacea, and fish. At the end of the first three-month survey, which will be conducted during the "dry" season, the research vessel "Shimada" will return to Puerto Rico. In August the collections for the “rainy” season will be made in Panama. The "Shimada" and the crews will return to the site at that time. Stable element analysis for 10 elements will be done on approximately 1250 samples in the Mayaguez laboratory. The distribution patterns of the stable elements for which corresponding potentially dangerous radioisotopes may occur will be determined. From these data the expected specific activities in human food items may be calculated and compared with those published in radiological safety guides and regulations: -3- ---Page Break--- Schistosomiasis Project EFFECT OF IRRADIATION ON HOST-PARASITE RELATIONSHIP IN SCHISTOSOMA MANSONI Starr Jorge Chirtboga, M. D., Assistant Director for Scientific Programs, Acting Program Director; Julio T. Colén, Ph. D., Associate Scientist (A nonresident); Ramiro Martinez Silva, M.D., Associate Scientist. Schistosomiasis is a parasitic disease that occurs in Puerto Rico and in many other areas of the world. Its hosts are some mammals including man and some

snails. It is calculated that at least one hundred million people suffer from it. No valid control of the disease is available and the situation is so hopeless that in the opinion of an authority in this field “unless some means of control is discovered, the increase of the disease caused by the new Aswan Dam in Egypt will nullify any economic benefits the Dam may yield." The Puerto Rico Nuclear Center is conducting research on Schistosomiasis using radioactive isotopes and other nuclear energy methods. The goal is to obtain a better understanding of the mechanisms regulating the host-parasite relationship that eventually will lead to the control of Schistosomiasis. Studies at PRC approach the problem from three different aspects: First, radiation effects on the host-Schistosoma mansoni relation; Second, radiation effects on the snail-Schistosoma mansoni relation; Third, radioisotope applications for better understanding of the Schistosoma natural history. The possibility of using irradiated cercariae of Schistosoma as a vaccine to protect against the disease is under study. Experimental results show a degree of protection in some animals. Experiments using irradiation to make a strain of snails resistant to the penetration and development of the parasite that can also compete with the normal snails in the field are also being conducted. The biology of the parasite and the snails is not well known in the actual endemic areas. For this reason, experiments are conducted with isotopes to study the habits of the snails and the parasite in collaboration with the United States Public Health Service in order to learn how to break the life cycle. ---Page Break--- Sugarcane Borer Program Induced Sterility for Population Control of the Sugarcane Borer (Diatraea saccharalis) in Puerto Rico STAFF David W. Walker, Ph. D., Associate Scientist II, Principal Investigator. PURPOSE The program was begun in 1963 to determine the potential for control by radiation sterilization of the sugarcane borer (Diatraea saccharalis).

Crambidae, Lepidoptera), and to study the bionomics of this species as it relates to mass-release programs. Stas Ganma radiation doses suitable for sterilization of the sugarcane borer have been determined. Adults are sterilized at 35 kilorad doses without affecting their life span, oviposition rate, or mating behavior. Immature stages are much more radiosensitive, with 9 kilorad causing over 90% lethality. Factors involved in the mass-rearing of the Puerto Rico strain of this species have been studied. These include the following: 1. Artificial diet: Vigorous adults of high fertility can be produced on a diet containing carrot powder, legume corn stalk extract, corn stalk fiber, ascorbic acid, agar, casein, sodium benzoate, and methyl parahydroxybenzoate. Survival on this diet is eighty percent or higher, and adequate numbers are being produced to conduct small-scale field tests. Assuming fifty percent survival, food cost is approximately one-fifth of a cent per adult. 2. Optimum rearing conditions: Light, temperature, and humidity are controlled during laboratory rearing. Under these conditions, six days are required for egg maturation, thirty days for larval development, and seven to eight days for pupation. Adults produced from this diet live longer and produce more viable eggs than comparable individuals grown on sugarcane and other host plants. Eggs are collected daily and are placed on the food immediately after hatching. Pupae are removed from the food as they form. Sex is determined in the pupal stage. Adults are collected as they emerge from the pupal case. 3. Mating conditions: Mating takes place in the dark (less than 1 lumen) and is initiated by temperature reduction and light decrease. Males are attracted to females by a sex attractant and by the specific wing beat frequency. Mated females begin laying fertile eggs within one hour after mating. Peak oviposition occurs on the second and fourth days after mating. Three hundred fifty eggs are laid per female (average) and under.

normal conditions egg hatch is one hundred percent from fertilized females except during the period from December to March. A large field cage has been constructed to permit determination of

population decline under field conditions using corn as the host plant. Corn planted in the cage has been infested by a known number of normal adults collected from nature. Population overflooding by irradiated males and/or females has been done to measure population reduction. Larval populations are measured by direct visual observation of larval tunnels in stalks, and adult male population is determined by trapping at night during nuptial flight. ---Page Break--- Resonance in Radiation Program STAFF Henry J. Gonberg, Ph. D., Deputy Director and Robert A. Luse, Ph. D., Chief Scientist (part-time), Principal Investigators; Francis K-8. Koo, Ph. D., Florencio Vazquez, Ph. D.; and Peter Paraskevoudakis, Ph. D., Associate Scientists (all part-time). PURPOSE To answer the question "What are some of the unique effects of ionizing radiation on matter?" To this end, the project has studied x-radiation effects in the 5 to 2 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. STATUS 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. Using monochromatic x-rays, biological molecules were irradiated at energies above and below the K-adsorption edge of selected target atoms. Damage was judged on the basis of effect observed per unit energy absorbed, per photon absorbed, in the molecular system. Experiments in the energy range 6.4 to 8.3 KeV have shown increased inactivation of the

Metalloenzyme catalase is located 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, chromosomes in onion root tip cells treated with 5-bromodeoxyuridine have exhibited an increase in breakages caused by sonochromatic X-rays at photon energies equal to or slightly greater than the K-absorption edge of bromine (GSR). In contrast, there was no much effect on pelta somaraine in aged BUDR. Hence, in these two important types of molecules—enzyme and nucleic acid—there 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 (e.g., bacterial cells, HeLa cells) is at present being explored.

Current project activity has been directed to several biological systems in an attempt to find optimal systems for demonstrating the resonance phenomenon. At this point, the effect has been shown in both the metalloenzyme catalase and BUDR-labeled chromosomes. Efforts now will be directed to developing mechanisms of the effect based on more quantitative studies. Initially, this will involve biochemical studies on structural changes in the catalase molecule irradiated at or near the K-absorption edge of iron. Supplementing the irradiation studies of biological molecules is the development of special equipment which permits absolute measurement of the very low photon fluxes generated in our highly monochromated (~50 eV) x-ray beams. In addition, design and construction of high-intensity field emission type x-ray sources have been carried out, and the effect of various parameters (vacuum, cathode material, applied voltage, and cathode-anode spacing) on electron emission has been tested.

Radiation Chemistry and Photochemistry Program MATRIX ISOLATION STUDIES OF PRODUCTS OF GAMMA RADIOLYSIS OF HETEROCYCLIC MOLECULES
Alec Grayson, Ph.D. Associate Scientist; George Stamped, The Deputy Associate Scientist.

Haricl H. Ihr, Th. De, Associate Scientist, and Research Assistants. PURPOSE The program is concerned with the effects of gamma radiolysis on simple heterocyclic molecules, which can be

considered as a model for more complex substances of biological importance. Unstable species formed in this gamma radiolysis are trapped by carrying gamma irradiations in solid matrices at 77K, and are studied under these conditions to elucidate their structure. CURRENT STATUS Optical dewars have been designed and tested for the examination of optical spectra at liquid nitrogen temperatures. Current projects include the investigation of color centers formed by gamma irradiation of heterocyclic compounds in methyltetrahydrofuran and carbon tetrachloride matrices. These two solvents have been chosen to enhance radical anion and radical cation formation, respectively. Foot agreement has been obtained on the literature values for the efficiency of production of color centers in the parent solvents. Systems which have proved particularly interesting are murine and syresine in methyltetrahydrofuran, and pyrrole in carbon tetrachloride. The lect system is currently being investigated also by photochemical irradiation of rigid solutions. Theoretical work includes the prediction of the UV and electron spin resonance spectra of likely radical species, being molecular orbital and valence band techniques. A set of valence band calculations on triplet states of simple heterocyclic compounds is being done in collaboration with Dr. Zauli at the Instituto di Chimica Fisica, University of Bologna. ---Page Break--- Radiation Preservation of Tropical Foods STAFF Horace D. Graham, Ph. D., and Robert A. Iuse, Ph. D., Chief Scientists (Part time), Principal Investigators; Sureckant N. Deshpande, Ph. D., Associate Scientist I (Part time). PURPOSE To determine the feasibility of radiation preservation of bananas and mangoes, 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 delays ripening and extends the shelf life of the food product. More qualitative or semi-quantitative criteria of ripening, such as softening, changes in color, spotting, and taste are utilized. These are supplemented by measurement of those characters associated with ripening, e.g. starch to sugar conversion and pulp acidity. Measurement by appropriate biochemical assay of changes in various nutritional factors that accompany radiation pasteurization. The part is amenable to quantitative assay of vitamin levels and how they are affected by radiation dose and treatment. STATUS Bananas of the variety Monte Cristo and mangoes of the varieties Native, Hafu, Seedi uezano have been irradiated. SEER HEY Pec acd ay tev. dosage of Good radiation can be used for the preservation of these tropical fruits. Major emphasis is placed on the influence of irradiation on the retardation of ripening in the fruits and on the levels of nutritionally important biochemical components such as acids, carotenoids, sugars, starch and on titratable acidity. Studies also are made of the effect of gamma irradiation on the depolymerization of some of the pectic constituents of mangoes. Bananas of known history and 90-120 days old at the time of cutting have been irradiated at 10, 20, 30, 40, and 50 Kilorads and then, along with non-irradiated samples (controls), stored at 60°F, 75°F, and 60°F. Every seven days samples are withdrawn and analyzed for the components named above. At 66°F, using bananas 6-104 days, no retardation of ripening has been noticed. On the contrary, some stimulation was evident, but the pattern was erratic. At 50 kilorads, intense blackening of the fruits occurred; hence all subsequent work was limited to 40 kilorads. Retardation of ripening occurred at 75° and at 20-30 kilorads, but there was no consistent relationship between the radiation dose and the extent of retardation. At this temperature and at the irradiation dose of 40 kilorads, there was

Little or no effect on the level of sugar concentrations, but the titratable acidity increased and ascorbic acid decreased by about 25%. At 80°F, retardation of ripening was more pronounced, but the fruits ripened much faster than at 75°F. Mature or almost ripe mangoes have been irradiated at 50, 100, 150, and 200 kilorads and stored at 50°F; non-irradiated controls were also included. Biochemical analyses were done on representative samples as described above for banana. All

fruits stored at 50°F kept well. The irradiated fruits remained green for 30 days. Fruits of the "Native" variety irradiated at 250 kilorads or above showed severe blackening of the pulp. This blackening progressed from the seed outward and was not noticed in the other varieties. Burning or blackening of the skin occurred in all varieties when irradiated at 150 and 200 kilorads. The wide natural variations from fruit to fruit and from batch to batch hinder making any valid conclusions as to the effect of irradiation on the biochemical components assayed. Pectic constituents of mangoes of the variety Sundareshe irradiated at 500, 1,000, 1,500, and 2,000 kilorads have shown a consistent decrease in the molecular weights of their highly methylated water-soluble pectinic acid fractions with increasing radiation dose. However, increase in radiation dose did not cause a severe degradation of the low methoxyl pectins or the protopectins extracted from these fruits. Fractionation of pectin from control fruits with molecular sieve chromatography indicated the occurrence of at least two major fractions of distinct molecular size. It was inferred that the radiation-depolymerized pectins constitute sub-fractions of these major fractions. Study of their molecular weight distribution patterns therefore is contemplated, in order to determine the relationship between pectin depolymerization and fruit softening.