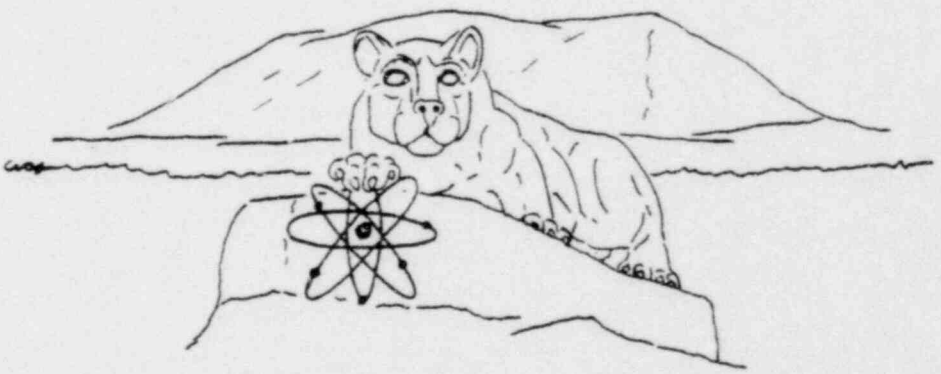
CONTRACT DE-AC02-76ER03409

TWENTY-FIFTH ANNUAL PROGRESS REPORT OF THE PENNSYLVANIA STATE UNIVERSITY BREAZEALE NUCLEAR REACTOR

July 1, 1979 to June 30, 1980



The Breazeale Nuclear Reactor Facility
Department of Nuclear Engineering
College of Engineering
The Pennsylvania State University
University Park, Pennsylvania

July 1980

PSBR 315-498093

Contract DE-AC02-76ER03409

TWENTY-FIFTH ANNUAL PROGRESS REPORT OF THE PENNSYLVANIA STATE UNIVERSITY BREAZEALE NUCLEAR REACTOR

July 1, 1979 to June 30, 1980

Submitted to

United States Department of Energy

and

The Pennsylvania State University

by

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University Park, Pennsylvania

July 1980

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ACKNOWLEDGMENTS

The editor wishes to express his appreciation to all contributors for their timely research and project reports. Special thanks should be given to S. H. Levine for the Introduction, I. B. McMaster and J. R. McKee for the Personnel section, J. L. Penkala for the Education and Training section, and W. A. Jester for the Radionuclear Applications Laboratory summary. In addition, this report would not have been completed on time without the help of the nimble fingers of M. Beward and R. Fasick.

TABLE OF CONTENTS

TABLES

FIGURES

REDEDICATION

The highlight event at the Penn State Breazeale Reactor (PSBR) during the past year had to be the twenty-fifth anniversary rededication celebration. The April 11, 1980 program, organized by PSBR staff member Robert C. Houtz, is reproduced on page two. Videotapes were made of all the proceedings and typed copies of the speeches are available upon request.

The public seminar attracted approximately 40 persons. Fifty invited guests attended the rededication service and reactor facility tour. A copy of the rededication speech appears on page three of this report. At the anniversary dinner, attended by 113 persons, commemorative plaques with a one-third scale replica of a TRIGA fuel element were presented to nuclear engineering faculty, staff, and distinguished guests.

On the following day an Open House was held from 10 A to 2 PM to provide tours for the public. Over 450 persons were guided through the facility to see the reactor in operation and a number of displays on various aspects of nuclear energy.

The original reactor facility, dedicated on February 22, 1955, was designed by Dr. William M. Breazeale while serving on the Penn State faculty from 1955 to 1958. Considered by many to be the father of "swimming pool" reactors, he was the first professor of nuclear engineering at Penn State and taught the first nuclear engineering courses here. The reactor was named for Dr. Breazeale after his death in 1970.

BREAZEALE NUCLEAR REACTOR

TWENTY-FIFTH ANNIVERSARY DEDICATION

Friday, April 11, 1980

PUBLIC SEMINAR (Keller Building Auditorium, 3 PM)
Contribution of Research Reactors to Education, Industry, and Safety

WELCOME

Dr. John W. Oswald, President, The Pennsylvania State University

HISTORICAL EVENTS – Looking Back at 1955
Dr. Eric A. Walker

THE PRESENT – 1955 through 1980
Dr. Henry Gomberg

THE FUTURE – 1980 - 2000
Dr. Bertram Wolfe

5:15 PM

TOUR OF THE BREAZEALE NUCLEAR REACTOR FACILITY
Dr. Warren F. Witzig, Head, Department of Nuclear Engineering

Rededication

RECEPTION AND DINNER
Nittany Lion Inn, 7:00 PM

DINNER SPEAKERS

Master of Ceremonies – N. J. Palladino, Dean, College of Engineering
John W. Oswald, President, The Pennsylvania State University
Clifford L. Jones, Secretary, The Department of Environmental Resources
Energy and Environment Conflict in the 80's

REDEDICATION OF THE BREAZEALE NUCLEAR REACTOR

April 11, 1980

Warren F. Witzig

We are gathered here today to reconfirm and rededicate this facility to the noble purposes proposed twenty-five years ago. That this should occur in the 125th anniversary of our University reflects the constancy of educational values and yet ever changing nature of education.

At a time when Luddities under deceptive banners are so very vocal, the educational usefulness - even the need of this nuclear facility, its research and its teaching faculty - is very clear. This creation of man has provided and will continue to provide new knowledge, experienced professionals, and service to all citizens of the Commonwealth. Our realization that the Deity allows mankind only to discover knowledge that we are capable of using, with wisdom, reminds us of our need for humility. The role of nuclear science and engineering in contributing to the quality of life is reaffirmed in this rededication.

Thus, we rededicate this facility, the Breazeale Nuclear Reactor, to the pursuit of knowledge, research, service to the Commonwealth, and the education of our youth in the tradition of a Land Grant University. To honor this occasion, two bronze plaques have been struck. A faculty member has taken the motif of the Nittany Lion by Warnecke and extended its forepaw to control a symbol of the atom and nuclear energy. This motif is the centerpiece of the plaque. An inscription around the edge of the plaque reads, "Breazeale Nuclear Reactor, Research, Training, Education, 1955-1980." One plaque will be hung in the lobby of this facility and one other in the Nuclear Engineering Department.

I. INTRODUCTION

The Twenty-Fifth Annual Progress Report of the operation of The Pennsylvania State University Breazeale Reactor is submitted in accordance with the requirements of Contract DE-AC02-76ER03409 with the United States Department of Energy. This report also provides the University administration with a summary of the operation of the facility for the past year.

Administrative responsibility for the Breazeale Reactor facility resides in the Department of Nuclear Engineering in the College of Engineering. It is operated, primarily, as a facility of the University that is available to all colleges of the University for their education and research programs. In addition, the facility is made available to Commonwealth industries to provide services that are essential in solving their research and development problems.

The period of this annual report covers a very special time — the 25th year after the dedication of the Penn State Nuclear Reactor on February 22, 1955. Since that time, the facility has been named the Breazeale Nuclear Reactor and on Friday, April 11, 1980 the facility celebrated a twenty-fifth anniversary rededication.

This facility has continued to provide invaluable service to the Commonwealth as a center of analysis and training in support of the Three Mile Island (TMI) clean-up. As an example, the reactor facility was used in experiments conducted by W.A. Jester and A.J. Baratta in support of a Citizen's Radiation Monitoring program for 48 residents living within a seven mile radius of TMI.

A new laboratory is being established to perform low level radiation measurements of drinking water samples. It is anticipated that this laboratory will be made operational during the next report period and receive EPA certification to perform these measurements for municipal water companies as required by the Safe Drinking Water Act

(P673-523). This laboratory is a part of the Radionuclear Applications Laboratory which continues to have growth in industrial research projects.

The facility continues to be a focal point for many educational and training activities where undergraduate and graduate laboratory experiments are performed. Education activities are also conducted to provide students from high schools and other colleges and universiti s in Pennsylvania the opportunity to use the Breazeale Reactor. There were 122 groups totaling more than 2,648 people who visited the facility on guided tours during the year. This total does not include visitors for business purposes, small groups, and many casual visitors who are also guided through the facility.

It is also important to recognize that the reactor provides experimental facilities that are necessary in the performance of some contracts; otherwise, faculty and students would either conduct their reactor experiments out of the Commonwealth of Pennsylvania at additional costs to them or eliminate this portion of the work from their contracts. During the past year 51 Penn State University faculty and staff and 28 graduate students made use of the facility for research.

The reactor staff and the Nuclear Reactor Safeguards Committee continue to review the operation of the facility in an effort to maintain the safety and improve the efficiency of its operation and to provide conditions conducive to its utilization. The Nuclear Reactor Safeguards Committee met four times to confer with the staff on unusual experiments, review operational records, and consult on special operational problems. No NRC inspections were conducted during the period covered by this report. With the accident at TMI, and the increased public sensitivity to nuclear radiation, the NRC is imposing more and more restrictive rules and regulations on this facility. These rules and proposed rules consume large amounts of staff time and restrict movement within the facility by people not on the permanent staff. It is anticipated that these conditions will continue into the future.

A thorough independent audit of the Breazeale Reactor's operation was conducted by Forrest J. Remick of the Vice President for Research and Graduate Studies office and Gordon E. Robinson of the Nuclear Engineering Department at the request of the Department Head Dr. Warren F. Witzig. The purpose of the audit was to determine the University's ability to meet the license requirements as required by the technical specifications, government regulations, and established procedures. No violations of compliance were found; however, the audit did result in several constructive suggestions which have been incorporated into the operation of the facility.

The following sections of this report are intended to provide an outline of the various aspects of the operation of the facility. Personnel, operation and utilization, statistics and research are summarized in the various sections that follow.

II. PERSONNEL

R. Lowery and P. Carier resigned from the BNR staff during the year. Both accepted other positions within the University.

Bonnie Ford has accepted a fixed term appointment at the facility effective July 1. She will be working with Dr. Jester to set up a new water analysis laboratory and assisting with work in neutron activation analysis.

Dennis Shaulis has been added to the facility staff as a part-time maintenance worker.

There were no changes in membership of the Nuclear Reactor Safeguards Committee. G. M. Faeth of the Mechanical Engineering Department continues to serve as Chairman of the Committee.

Table 1 lists the personnel associated with the reactor facility. The organization chart, Figure 1, reflects the present area of responsibilities of the permanent staff.

Table 1

PERSONNEL

Faculty and Staff

J. B. Bonner	- Reactor Supervisor/Auxiliary Operations Specialist
** T. L. Flinchbaugh	- Reactor Supervisor/Nuclear Education Specialist
** R. C. Houtz	- Reactor Supervisor/Nuclear Education Specialist
W. A. Jester	- Associate Professor
** S. H. Levine	- Professor/Director
J. R. McKee	- Coordinator, Energy Education Programs
** I. B. McMaster	- Research Assistant/Deputy Director
** J. L. Penkala	- Research Assistant
K. K. S. Pillay	- Associate Professor
** D. C. Raupach	- Reactor Supervisor/Reactor Utilization Specialist
* K. E. Rudy	- Senior Engineering Aide-Mechanical Services
J. K. Shillenn	- Energy Education Specialist/ Technology Transfer
** R. E. Totenbier	- Research Assistant/Operations Supervisor
* D. S. Vonada	- Electronics Designer

Technical Service Staff

P. P. Carier (Resigned 12/14/79)	- Reactor Operator
W. A. Davy	- Custodian/Driver
F. G. LeWando (Resigned 1/1/80)	- Maintenance Worker
R. O. Lowery (Resigned 2/11/80)	- Experimental and Maintenance Mechanic
D. R. Shaulis	- Maintenance Worker

Clerical

M. D. Beward	- Facility Worker
R. M. Fasick	- Secretary and Receptionist

* Licensed Operator
** Licensed Senior Operator

Table 1 (Continued)

Graduate Assistants

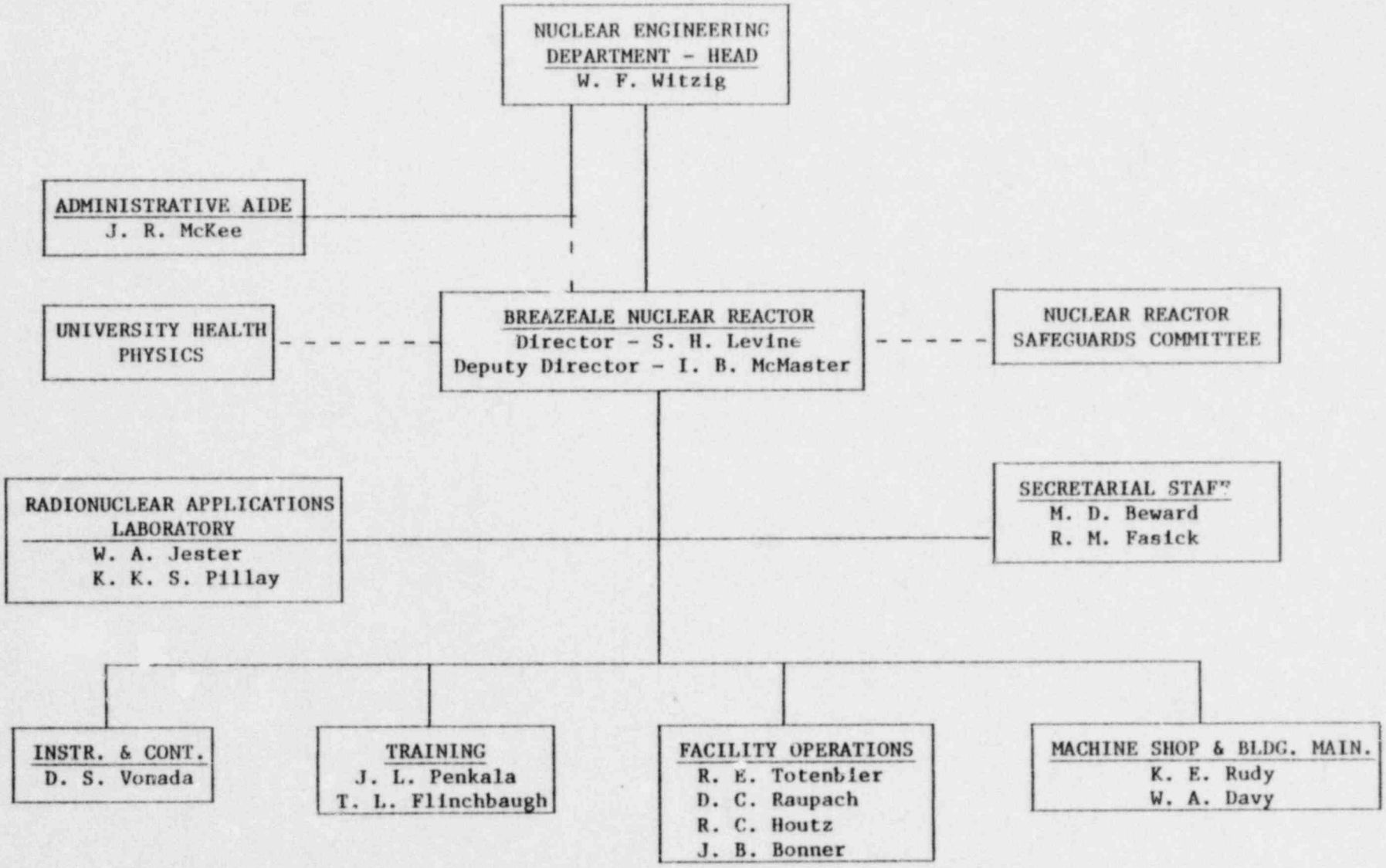
J. S. Brenizer	- Graduate Assistant
J. P. Colletti	- Graduate Assistant
G. M. Comparetto	- Graduate Assistant
D. S. Croft	- Graduate Assistant
M. Forsaty	- Graduate Assistant
H. Y. Huang	- Graduate Assistant
C. J. Jarvis	- Graduate Assistant
M. Y. Khalil	- Graduate Assistant
J. H. Wallace	- Graduate Assistant

Health Physics

E. C. Augustine	- Health Physics Assistant
N. M. Dougherty	- Associate Health Physicist
R. W. Granlund	- University Health Physicist
D. H. Hollenbach	- Health Physics Assistant

Nuclear Reactor Safeguards Committee

P. Barton, Assistant Professor, Chemical Engineering
G. M. Faeth, Professor, Mechanical Engineering (Present Chairman)
R. W. Granlund, Health Physicist, Intercollege Research Programs and Facilities
R. E. Henderson, Associate Professor, Mechanical Engineering
E. H. Klevans, Professor, Nuclear Engineering
W. P. Kovacik, Westinghouse Research Laboratories
S. H. Levine, Professor and Director, Breazeale Nuclear Reactor
J. R. McKee, Coordinator, Energy Education Programs, Nuclear Engineering (Secretary)
I. B. McMaster, Research Assistant and Deputy Director, Breazeale Nuclear Reactor
W. M. Miller, Professor Emeritus of Chemistry
K. K. S. Pillay, Associate Professor, Nuclear Engineering



ORGANIZATION CHART

Figure 1

FACILITY OPERATIONS

III. REACTOR FACILITY

Research reactor operation began at Penn State in 1955. In December of 1965 the original reactor core, which operated at a maximum power level of 200 KW, was replaced by a more advanced TRIGA core, capable of operation at 1000 KW. The present core may also be operated in a pulse fashion in which the power level is suddenly increased from less than 1 KW to up to 2000 MW for short (milliseconds) periods of time. TRIGA stands for Training, Research, Isotope production, built by General Atomic company.

Utilization of the Reactor falls into three major categories:

Educational utilization is primarily in the form of laboratory classes conducted for graduate, undergraduate, associate degree candidates, and numerous high school science groups. These classes will vary from the irradiation and analysis of a sample to the calibration of a reactor control rod.

Training programs for Reactor Operators and Reactor Supervisors are continuously offered and can be tailored to meet the needs of the participants. Individuals taking part in these programs fall into such categories as foreign trainees, graduate students, and power plant operating personnel.

Research occupies much of the remaining reactor time for Radionuclear Applications and faculty and graduate students throughout the University who utilize the Reactor in a myriad of research programs.

The PSBR core, containing about 7½ pounds of Uranium-235, is operated at a depth of approximately 18 feet in a pool of demineralized water. The water provides the needed shielding and cooling for the operation of the reactor. It is relatively simple to expose a sample by merely positioning it in the vicinity of the reactor at a point where it will receive the desired radiation dose. A variety of fixtures and jigs are available for such positioning. Various containers and irradiation tubes can be used to keep samples dry.

Three pneumatic transfer systems with different neutron levels offer additional possibilities.

In normal steady state operation at 1000 kilowatts, the thermal neutron flux available varies from approximately 1 x 10^{13} $n/cm^2/sec$ at the edge of the core to approximately 3 x 10^{13} $n/cm^2/sec$ in the central region of the core.

When considering the pulse mode of operation, the peak flux for a maximum pulse is approximately 6 x 10^{16} $n/cm^2/sec$ with a pulse width of 15 msec at ½ maximum.

Support facilities include a machine shop, electronic shop, laboratory space, and fume hoods.

A comparison of the operation and utilization data for the past two years, as listed in Tables 2 and 3, indicates relatively small changes except in two areas. The hours spent in adjusting fuel was lower in 1980 because the annual fuel inspection was delayed until July. The entire month of June was occupied with a utility training program. A substantial increase in sample hours per shift was due both to increased utilization of the "Merry-Go-Round," a rotating sample holder designed to uniformly irradiate up to 24 samples simultaneously, and to scheduling two or more experiments during the same period whenever possible.

Table 2

Reactor Operation Data

July 1, 1978 - June 30, 1980

		78-79	79-80
A.	Hours of Critical Time		
	1. Hours Critical	734	739
	2. Approaching Critical	162	167
	3. Adjusting Fuel	101	18
B.	Number of Pulses	183	176
C.	Number of Square Waves	62	73
D.	Energy Release (MWh,	510	529
E.	Grams U-235 Consumed	26	27
F.	Number of Scrams		
	1. Planned as part of experiments	107	91
	2. Unplanned - resulting from		
	a) Personnel action*	15	19
	b) Abnormal system operation	7	7

*The majority of these resulted from operation by trainees.

Table 3

Reactor Utilization Data
(average per shift)

July 1, 1978 - June 30, 1980

		78-79	79-80
A.	Number of Users	2.4	2.8
B.	Samples or Experiments		
	1. Pneumatic transfer samples	12.0	8.5
	2. Total number of samples	16.3	15.3
	3. Sample hours	18.8	31.5
C.	Reactor Usage (hours)		
	1. Total operation	2.9	2.9
	2. Shutdown in stand-by condition	1.2	1.3
	3. Total usage	4.0	4.2
	4. Subtotals		
	a) Full power operation	1.6	1.3
	b) Educational usage	2.3	2.7
	c) Reactor operator training	1.4	1.9
	d) Calibration and maintenance	.9	.5
D	Number of 8 hour shifts	258	252

IV. COBALT-60 FACILITY

The University, in March of 1965, purchased 23,600 curies of Cobalt-60 to provide a pure source of gamma rays. In November of 1971, the University obtained, from the Natick Laboratories, 63,537 curies of Cobalt-60 in the form of aluminum clad source rods. These source rods have decayed through several half lives leaving a February 1, 1980 total of 25,000 curies.

In this facility, the sources are stored and used in a pool 16 feet x 10 feet, filled with 16 feet of demineralized water. The water provides a shield which is readily worked through and allows great flexibility in using the sources. Due to the number of rods and size of the pool, it is possible to set up several irradiators at a time to vary the size of the sample that can be irradiated, or vary the dose rate. Experiments in a dry environment are possible by use of either a vertical tube or by diving bell type apparatus.

Radiation levels up to approximately 4×10^5 R/hr are available depending on the number of rods and source geometry used.

The Cobalt-60 facility is designed with a large amount of working space around the pool and has two laboratory rooms equipped with work benches, fume hoods, and the usual utilities. Additional facilities include a Hot Laboratory consisting of two identical "Hot Cells." The two feet thick high density concrete walls provide sufficient shielding to allow up to 400 curies of radioactive materials to be safely handled through the use of remote manipulators.

Table 4 compares the past two years utilization of the Cobalt-60 facility in terms of time, numbers and daily averages. Again this past year, most of the exposures were for experimenters interested in biological effects. Although these exposures are usually of short duration, there were enough long term irradiations to almost equal both the hours of facility use and the total sample hours used for the previous year.

Table 4

Cobalt-60 Utilization Data

June 1, 1978 - May 31, 1980

		1978-1979	1979-1980
A.	Time involved (hours)		
	1. Set-up time	56	10 hrs
	2. Total facility use	1,141	985
	3. Total sample hours	2,586	2,113
B.	Numbers involved		
	1. Samples run	633	725
	2. Different experimenters	25	16
	3. Configurations used	3	3
C.	Per day averages		
	1. Experimenters	0.6	0.6
	2. Samples	1.9	2.0

Most of the long term irradiation periods extend overnight and over weekends which, in effect, makes the facility available for use 365 days a year even though it is not staffed during these times.

V. EDUCATION AND TRAINING

The training and educational ability and adaptability of the Penn State Breazeale Reactor (PSBR) operating staff and the TRIGA Mark III reactor were manifest in the variety of formal laboratory courses, industrial training programs, inhouse training, and continuing education functions which were provided during this past reporting period.

Typical of the cooperative effort provided by the PSBR operating staff was the guidance and supervision given to the 13 Nuclear Engineering Technology (NET) students as part of their Reactor Technology Laboratory course, NucE 814. Under the surveillance of senior operators, I. B. McMaster, R. E. Totenbier, D. C. Raupach, R. C. Houtz, T. L. Flinchbaugh, and J. L. Penkala, each of the NET students logged in a minimum of 12 safe and informative operating hours at the controls of the PSBR where they participated in all the routine operations which the reactor is capable of performing. The experimentation portion of the NucE 814 course was taught by J. L. Penkala, assisted by T. L. Flinchbaugh in the laboratory.

Rounding out the offerings of formal courses at the PSBR in the NET program, K. K. S. Pillay taught the Nuclear Technology Laboratory course, NucE 812, in which the reactor was used to generate radioisotopes.

The inhouse training this past year consisted of a complete license requalification program that was completed in early 1980 and a reactor operator licensing program which is currently in progress. The annual requalification program consisted of oral examinations on abnormal and emergency procedures and facility design (walk-around) which were conducted by R. E. Totenbier and I. B. McMaster, respectively. The written portion of the requalification examination was administered by J. L. Penkala and T. L. Flinchbaugh. As in past

years, the PSBR operating staff successfully requalified for their NRC operating licenses.

The inhouse reactor operator licensing program is currently being conducted for J. J. Bonner who joined the staff in mid-1979. It is anticipated that Bonner will take an NRC operator license examination during the Fall of 1980.

The Nuclear Concepts and Energy Resources Institute (NCERI) was offered as NucE 497 for the tenth consecutive year during the Summer of 1979. The NCERI, a four week institute, was attended by 44 high school teachers from nine states, in addition to Pennsylvania. As a result of their four weeks of intensive study, the participating teachers will return to their respective school districts and offer an elective course in Nuclear Concepts. The major portion of the NCERI laboratory experiments was supervised by T. L. Flinchbaugh and J. J. Bonner. D. H. Hollenbach, E. Augustine, and J. L. Penkala assisted in the laboratory exercises.

As in previous institutes, the participants in the NCERI were encouraged to return with their high school classes for a one-day field trip to the PSBR. This past year, as a result of previous NCERI's, 26 groups totalling 327 students participated in a full day of experimentation, observation, and touring at the PSBR. J. J. Bonner and J. K. Shillenn handled the scheduling of and lecturing to the high school tour groups with assistance from J. L. Penkala and T. L. Flinchbaugh. Table 5 summarizes the participation in the high school tour program.

The laboratory course NucE 440 was taught in the Fall 1979 and Spring 1980 terms by M. A. Schultz with valuable assistance from A. J. Baratta. Three of the more important experiments were conducted at the PSBR with major assistance from the reactor operating crew.

Table 5

High School Nuclear Science Program

1979-80

High School	Instructor	No. of Students
Altoona	Mr. Beach	10
Bedford	Mr. Turner	22
Bellefonte	Mr. Young	13
Berwick	Mr. Foster	9
Conrad Weiser	Mr. Noll	3
Chestnut Ridge	Mr. Popp	6
Daniel Boone	Mr. Tobias	24
Delone Catholic	Sister Aimee	15
Derry	Mr. Feeny	14
Exeter	Mr. Murray	13
Harbor Creek	Mr. Peterson	11
Jersey Shore	Mr. Allen	7
Keystone Oaks	Mr. Popovich	12
Lower Dauphin	Mr. Lyter	18
Marion Center	Mr. Petrosky	8
Mt. Penn	Mr. Markley	5
Mt. Union	Mr. Schatawie	10
N. Schulkill	Mr. Welker	10
Penncrest	Mr. Goode	9
Penns Valley	Mr. Fuller	8
Redland	Mr. England	11
Ringgold	Ms. Zober	14
Thomas Jefferson	Ms. Bogdan	13
Union City	Mr. Obert	9
Warren	Mr. Szul	43
Wyomissing	Mr. Bell	10
Group Total 26	Participants Total	327

During the Fall 1979 and Winter 1980 terms, E. S. Kenney taught the NucE 441 course with the assistance of the reactor staff. Thirty-three students were registered for the NucE 441 course. In the fall term, W. A. Jester conducted the graduate course NucE 502a utilizing the radioactivity measuring facilities of the reactor.

The TRIGA reactor was used extensively when S. H. Levine taught NucE 502b, a graduate laboratory course, for five students the past Winter term. E. S. Kenney followed up with the NucE 502c laboratory course during the Spring Term 1980 for five students. These latter two courses received extensive cooperation from the PSBR operating staff.

An elective nuclear engineering course which was designed to give the student an opportunity to correlate classroom theory with actual reactor operation situations controlled by the student was offered a number of times this past year. The NucE 444 course, Nuclear Reactor Operations Laboratory, was offered during Summer 1979, Fall 1979, Winter 1980 and Spring 1980 Terms for 27 students by J. L. Penkala. Each student performed a minimum of ten reactor startups while logging approximately 30 hours of operating experience at the PSBR control console.

Two industrial training programs were provided for 20 reactor operator license candidates of the Philadelphia Electric Company and the Cincinnati Gas and Electric Company. The entire reactor operating staff, E. S. Kenney, and Health Physics personnel, participated in these industrial training programs.

Through funding provided by DOE, the PSBR is cooperating with other colleges and universities in a reactor sharing program. This past reporting period, groups of students from Bucknell University, the University of Pittsburgh, Villanova University, Mercyhurst College, and the Hazleton and Altoona Campuses of Penn State University were allowed to use the PSBR for experiments after appropriate background material was presented. Sixty-one students and their instructors were schooled in some of the basic reactor experiments in nuclear

engineering. J. L. Penkala administered the reactor sharing program and executed the pedagogical duties with the six university groups this past year.

The PSBR and its operating staff continued to serve the nuclear engineering department in addition to other university departments and colleges in the following manner:

- Sixty-eight of A. M. Jacob's NucE 401 students were given a tour of the PSBR and a start-up and pulse demonstration.
- A full day of lecture and laboratory sessions was held at the PSBR for 12 journalists by W. A. Jester and A. J. Baratta. The subject of the seminar was Nuclear Radiation Concepts and the Three Mile Island purging.
- The reactor was used for irradiation services and preparation of material for the eight students in K. K. S. Pillay's NucE 405 course.
- J. B. Nesbitt's CE 574 class used Mn-56 tracer material to determine the hydraulic characteristics of a model settling basin. Ten students were involved in this study.
- Seven groups totaling approximately 42 University Police Services personnel were given training/retraining sessions by R. C. Houtz at the PSBR to ensure familiarity with the facilities.
- W. A. Jester and A. J. Baratta organized and conducted a Citizen's Radiation Monitoring program for 48 residents living within a seven mile radius of Three Mile Island. A day of touring and experimentation at the PSBR was provided by the reactor staff as well as support for the program in the Harrisburg area.
- K. K. S. Pillay and W. A. Jester used the PSBR for demonstration and isotope production for 24 students in Chem 526 and NucE 496 during the Fall 1979 and Spring 1980 terms.

With well over 125 man years of safe, reliable reactor operating experience, the staff of the PSBR is obviously fulfilling its obligation to "the general public" to disseminate information concerning the pros and cons, the do's and dont's, the how's and how not's of

reactor operations, irradiation services, and understanding of nuclear energy in general and nuclear applications in particular through the spectrum of educational and training vehicles described in this report.

VI. RADIONUCLEAR APPLICATIONS LABORATORY

The staff of the Radionuclear Applications Laboratory during this year consisted of A. Jester, K. K. S. Pillay, and D. C. Raupach. Several of Jester's and Pillay's graduate students assisted in conducting one or more of the projects associated with the laboratory. The purpose of the laboratory is to provide consulting and technical assistance to University research personnel who wish to utilize some type of radionuclear technique in their work. While the bulk of these projects involve some type of neutron activation analysis procedure, the staff is prepared to provide services in such areas as nuclear medicine, radioactive tracer techniques, radiation gauging and radiation processing; in fact, they have provided services in these and other fields in the past.

This year the laboratory has had a continued growth in industrial projects and in industrial sponsored research that included a variety of activation analysis projects for GTE Sylvania, water tracing services for E. I. DuPont DeNemours and Company, irradiation services for Raytheon Company and the analysis of arsenic in fish for the Pennsylvania Power and Light Company.

The two-day annual activation analysis workshop held on March 4, 5, 1980 was organized by D. C. Raupach. The purpose of this workshop is to instruct University research personnel in the use of activation analysis and nonradioactive but neutron activatable tracers as research tools. S. H. Levine and W. A. Jester, of the Nuclear Engineering Department, and R. W. Granlund, University Health Physicist, assisted by D. C. Raupach, conducted the workshop. A total of 10 researchers were in attendance.

A new laboratory is being equipped in the adjacent Academic Projects Building. This laboratory will be used for the detection of low levels of radioactivity in drinking water. When completed and certified by the Environmental Protection Agency (EPA), this will be one of only three facilities throughout the State that will be able to provide these services, which are now required by all municipal water companies under the Safe Drinking Water Act (P 673-523). It is anticipated that the

laboratory will be made operational and receive EPA certification during this coming year. A new staff member, Mrs. Bonnie C. Ford, is to begin work on July 1. Part of her duties will be to set up this laboratory.

VII. FACILITY RESEARCH UTILIZATION

Research continues to utilize the major portion of the available operation time of the reactor and the Cobalt-60 Facility. A wide variety of research projects are currently in progress as indicated on the following pages. For convenience, the University oriented research projects are arranged alphabetically by departments under the various colleges. Theses, publications and papers follow the research descriptions to which they pertain. In addition, a section is provided with examples of industrial research utilizing the facility.

The facility continues to serve as a research tool available to all faculty staff and graduate students of the various departments and colleges within the University. Fifty-one faculty and staff members and twenty-eight graduate students have used the facility in the past year for research. This represents a usage by nineteen different departments or sections in seven colleges of the University. Names of the individual users are arranged alphabetically under their departmental and college affiliations in Appendix A.

The following list of current research projects (arranged in alphabetical order using author's names) indicates the broad utilization enjoyed by the Breazeale Reactor Facility. The forty-three projects described involve eight master's theses, six doctoral theses, fifteen publications and seven papers. The examples cited are not to be construed as publications or announcements of research. The publication of research utilizing the facility is the prerogative of the researcher.

A. University Research Utilizing the Facilities of the Penn State Breazeale Nuclear Reactor

COLLEGE OF AGRICULTURE

Food Science Department

Removal of Chlorinated Hydrocarbon Residues from Brown Trout

M. Kroger
D. A. Cin

The Co-60 facility was used to test the hypothesis that gamma irradiation reduces the concentration of chlorinated hydrocarbons (one tentatively identified as the insecticide mirex) in brown trout from Spring Creek, Centre County, PA.

M.S. Thesis

"Mirex in Brown Trout (Salmo Trutta) - The Effect of Food Processing and Preservation Methods in Attempts to Remove this Chlorinated Hydrocarbon Insecticide," D. A. Cin, 1980, M. Kroger, advisor.

Plant Pathology Department

The Use of Neutron Activation Analysis to Separate the Xanthomonads from Other Yellow Pigmented Bacteria

F. L. Lukezic

A group of plant pathogenic bacteria belonging to the genus Zenthomonas has a yellow pigmented compound that contains bromine. The current technique used for extraction and detection is slow and somewhat difficult.

We proposed that by using neutron activation analysis we could separate these bacteria from other closely related bacteria.

We have completed the analysis of three different Zanthomonas species and two closely related species. Thus far our information supports the use of this technique as a taxonomic tool.

Biology and Taxonomy of the Genus Fusarium

P. E. Nelson
N. L. Fisher
J. Burgoon
B. Stuehling
R. Kaiser

Fusarium species grow well in artificial culture on a medium consisting of 2% water agar and small pieces of carnation leaves (3-6 mm^2). In order to get the best possible growth of the fungi the carnation leaf pieces must be sterilized by a method that leaves the nutrients in the leaf intact. This can be done by cold sterilization with propylene oxide or with gamma radiation from Co-60. The latter method is by far the most satisfactory. Irradiated carnation leaf pieces serve as an important ingredient in the medium used in all of our research on Fusarium species.

Doctoral Thesis

"Initial Stages of Infection of Zea mays L. by Fusarium moniliforme Sheldon emend. Snyd. & Hans. Causing Stalk Rot," R. P. Kaiser, 1980, P. E. Nelson, advisor.

Master's Thesis

"Host Range of the Formae Speciales of Fusarium oxysporum Causing Wilt of Chrysanthemem," J. S. Burgoon, 1980, T. A. Toussoun, advisor.

Publications

"Histology of a resistant chrysanthemem infected with Fusarium oxysporum f. sp. chrysanthemi." Paper presented at the 38th Annual Meeting, Northeastern Div., Amer. Phytopathol. Soc., Chicopee, Mass. Oct. 31-Nov. 2, 1979. B. Stuehling, and P. E. Nelson.

"A histological study of the initial stages of infection of Zea mays by Fusarium moniliforme." Paper presented at the 38th Annual Meeting, Northeastern Div., Amer. Phytopathol. Soc., Chicopee, Mass. Oct. 31-Nov. 2, 1979. R. P. Kaiser, and P. E. Nelson.

"The use of carnation leaves as a substrate for Fusarium species." Paper presented at the 38th Annual Meeting, Northeastern Div., Amer. Phytopathol. Soc., Chicopee, Mass. Oct. 31-Nov. 2, 1979. N. L. Fisher, T. A. Toussoun, and L. W. Burgess.

"Host range and races of the pathogen causing Fusarium wilt of chrysanthemem." Paper presented at the 38th Annual Meeting, Northeastern Div., Amer. Phytopathol. Soc., Chicopee, Mass. Oct. 31-Nov. 2, 1979. J. Burgoon, and T. A. Toussoun.

School of Forest Resources

Sludge Utilization/Strip Mine Reclamation Project

W. Sopper

The reactor was used to analyze soil samples for total cadmium concentration. Results are to be used to determine the effect of municipal sludge applications on the land with particular attention to cadmium accumulation in the surface soil.

Veterinary Science Department

Immune Response of Swine During Pregnancy and Lactation

A. Zarkower
J. M. Ritchie

Pig white blood cells from a Duroc boar and a Yorkshire sow are mixed in culture. The immunological reaction of the sow's white blood cells to the foreign boar's cells is measured. In order to prevent the boar's reaction against the foreign sow's cells, the boar's cells are exposed to 3×10^3 rads from a Co-60 source so that the cells are living but can no longer proliferate.

This procedure is to be done during the sow's estrus cycle, pregnancy, and the beginning of lactation. We are currently studying the sow's cell reactions during her estrus cycle.

COLLEGE OF EARTH AND MINERAL SCIENCES

Geoscience Department

Uranium and Thorium in Sandstones and Shales

A. W. Rose
M. L. Keith
C. A. Bell

Shales and sandstones near uranium deposits in Pennsylvania and Colorado are being analyzed for U and Th to determine the extent and levels of abnormal values. In both areas, rocks in the ore horizon are distinctly anomalous in U for distances up to a mile from ore deposits. Weak regional effects are recognized in Pennsylvania. About 500 samples of rock have been analyzed for U and Th with the delayed neutron facility over the last several years; about 200 of these have been completed in the past year.

Geoscience Department

Uranium in Zircons Near Uranium Deposits

A. W. Rose
L. C. Pilione
M. P. Tole

The J content of zircons has been determined by fission track techniques in order to determine whether the sand and silt of the host rocks were derived by erosion of a U-rich source area. The results for 60 samples from Pennsylvania show a positive relationship; results for 25 samples from Colorado do not. Further comparisons of the two sets of samples are in progress.

Volcanic Stratigraphy in Hokvrokn District NE Honshu, Japan

L. M. Cathles
H. Ohmoto
F. O. Dudas

Basalt flows may be distinguished from one another by their major and minor and trace element signatures. In the Hokvrokn district of Japan, valuable ore deposits were formed, it is thought, at one time, approximately 11 million years before present. The purpose of this study is to determine if basalt flows can be distinguished in this area of Japan and to see if an identified lava flow stratigraphy would be useful in interpreting the volcanic history of that area of Japan to aid in exploration for mineral deposits in that region.

Material Sciences Department

Preliminary Studies of Radiation Effects in Wood Species

D. Kline

The Co-60 facility was used to better establish the degradation gamma dose for cellulose in wood.

Material Sciences Department

The Effect of Fold Surface Modification on the Thermal Properties of Polyethylene Crystals

I. R. Harrison
J. P. Runt
J. Butler

The goal of this investigation is to determine the effect of bulky surface species on the properties of fold chain polyethylene crystals. Previous work has shown that the addition of bromine atoms to the surfaces of these cyrstals produces changes in the melting and annealing behavior but no change in the percentage crystallinity. The bromine therefore reacts only on the surface and not in the crystalline core. Considering the overall chain structure, one now possesses a novel block copolymer with possible unique properties.

The current study involves attachment of bromine atoms to the crystal surface and subsequent substitution of the bromine by aromatic rings through a Friedel-Crafts reaction. Neutron Activation Analysis is employed to determine the initial surface bromine concentration as well as the percentage aromatic substitution. Characterization of the substituted materials by differential scanning calorimetry and Raman spectroscopy is currently underway.

Doctoral Thesis

"On the Structure and Properties of Polyethylene Single Crystals," J. P. Runt, 1970, Polymer Science, I. R. Harrison, advisor.

Paper

"The Effect of Surface Modification on the LA Mode of Polyethylene Crystals," J. Runt and I. R. Harrison, Paper delivered at the March 1979 APS Meeting, Chicago, IL.

Publication

"The Effect of Mass Perturbations on the LA Mode of Polymers: Surface Bromination of Polyethylene Crystals," J. Runt and I. R. Harrison, accepted for publication, J. Macromol. Sci. Phys. Ed.

COLLEGE OF ENGINEERING

Chemical Engineering Department

The Adsorption Behavior and Crystallite Size Distribution of Ni/TiO_2

M. A. Vannice
J. S. Smith

The Facility was used to determine Ni wt. % in supported catalysts.

Behavior of Pt Methanation Catalysts

M. A. Vannice
F. Twu

The facility was used to determine Pt weight loading on various supports.

Master's Thesis

"The Adsorption Behavior and Crystallite Size Distribution of Ni/TiO_2, J. S. Smith, 1980, M. A. Vannice, advisor.

Publications

"An IR/Kinetic Study of Pt Methanation Catalysis, ACS Preprints, Div. Petr. Chem. 25, 303 (1980). M. A. Vannice, S. H. Moon, F. Twu.

Behavior of Pd Methanation Atalysts

M. A. Vannice
S. Y. Wang

The facility was used to determine Pd wt. % in supported catalyst systems.

Civil Engineering Department

Flowing Through Time Experiment on a Model Settling Basin

J. B. Nesbitt

Mm-56 was used as a tracer to evaluate the flow characteristics of a model mixing basin for Civil Engineering 514 laboratory classes.

COLLEGE OF ENGINEERING

Mineral Engineering Department

Minimization of Groundwater Contamination in Surface Mine Backfills

L. W. Saperstein
L. B. Phelps
J. S. Brenizer, Jr.
D. Yeung

Ammonium bromide is used to quantify the amount of flow in a specially designed zone in surface mine backfill simulated in the laboratory. Water samples are taken of the outflow from the model. These samples are irradiated in the reactor using techniques developed by W. A. Jester and the quantity of tracer can then be calculated. Using this technique, it is hoped to be able to monitor water flow in differential permeable soils. Knowing this, it is desired to be able to predict the size, shape, and relative density of a zone constructed in surface mine backfill in which potentially toxic-producing material can be placed.

Doctoral Thesis

A thesis by L. B. Phelps of the Mining Engineering Section is expected to be completed in 1981.

Master's Thesis

Expected to be completed early in 1981 by D. Yeung of the Mining Engineering Section.

Publications

Two semi-annual technical progress reports prepared for the U.S. Bureau of Mines.

Nuclear Engineering Department

A Comparison of Bromide and Chloride Ion Movement Through Soil Columns

W. A. Jester
A. R. Jarrett
J. S. Brenizer, Jr.
S. Morrison

In a recent article in "Groundwater" the author stated that his soil column test indicated that the bromide ion would be retarded with

respect to the chloride ion as the water in which these tracers were added was percolated through soil columns. We repeated his experiments and found that only when deionized water was employed did such retardation take place. When groundwater was utilized, other ions filled up the ion exchange sites in the soil and there was no significant retardation of the bromide ions.

Papers

"Soil Homogeneity Evaluation for Radionuclide Tracer Breakthrough Curve Interpretation." International Conference on Nuclear Methods in Environmental and Energy Research, April 1980, J. S. Brenizer, Jr., A. R. Jarrett, and W. A. Jester.

"Breakthrough Curves Reflect Hydraulic Properties of Soil." Transactions ASME. Paper No. NA-79-208, August 1979, J. S. Brenizer, Jr., A. R. Jarrett (Ag. E.) and W. A. Jester.

"Soil Homogeneity Evaluation by Radionuclide Breakthrough Curve Interpretation." Transactions of 26th Annual Meeting of ANS, June 1980, J. S. Brenizer, Jr., W. A. Jester, and A. R. Jarrett (Ag. E.).

Determination of Arsenic Concentration in Fresh Water Fish Samples

W. A. Jester
D. C. Raupach
G. M. Comparetto

The purpose of this work is to develop a new activation analysis method for determining the arsenic concentration in fish samples. The activation analysis of low levels of arsenic in fish is complicated because of the interference of sodium-24 and bromine-82 produced in the irradiation of tissue samples. Thus radiochemical separation is required in order to determine trace element levels of arsenic. Previous techniques required lengthy procedures taking many hours per sample. The new procedure developed takes much less time and can handle more samples during the analysis steps.

Publications

"Arsenic in Fresh Water Fish Traced to Fly Ash Leachate Using Neutron Activation Analysis," Abstract presented at ANS Meeting in Las Vegas, Nevada, June 1980. W. A. Jester, G. M. Comparetto, and W. F. Skinner.

"Arsenic in Fresh Water Fish Traced to Fly Ash Leachate Using Neutron Activation Analysis," Transactions 26th Annual Meeting of ANS, June 1980. W. A. Jester, G. M. Comparetto, and W. F. Skinner.

"The Evolution of a D_2O Irradiation Facility," Transactions of ANS, 9th Biennial Conference on Reactor Operating Experience, p. 53, August 1979, I. B. McMaster, W. A. Jester, and D. C. Raupach

Evaluation of Eberline PING-2 Iodine Monitor

W. A. Jester
J. H. Wallace

The ability of commercial airborne radioiodine detectors varies with the chemical form of the iodine and the humidity of the air being sampled. Iodine-128 labeled I_2 and CH_3I were prepared from reactor-irradiated ammonium iodide crystals. Amounts of I-128 were determined by counting as a point source in a calibrated Ge(Li) multichannel analyzer system. The I_2 or CH_3I thus prepared was introduced into a controlled humidity air sample stream of the commercial detector. Variations in detector efficiency and filter breakthrough were then determined as a function of chemical form and air humidity.

Paper

"Evaluation of Airborne Radioactive Iodine and Noble Gas Environmental Monitors Using Short-Lived Research Reactor Radionuclides," International Conference on Nuclear Methods in Environmental and Energy Research, April 1980, W. A. Jester and J. H. Wallace.

Publication

"Evaluation of Airborne Radioactive Iodine and Noble Gas Environmental Monitors Using Short-lived Research Reactor-produced Radionuclides," Transactions 26th Annual Meeting of ANS, June 1980, W. A. Jester and J. H. Wallace.

An Independent Overview of DOE's Technology Development for Nuclear Waste Management

K.K.S. Pillay

The major tasks undertaken during this year's effort were: (1) An examination of the status of lead site programs for the management of transuranic high-level, low-level and airborne nuclear wastes; (2) An independent examination of the assay instrumentation

opment projects associated with transuranic waste management
(3) The development of a mechanism for the independent evaluation
individual projects funded by the transuranic waste management
ad office at Rocky Flats, Colorado.

As a result of this review and recommendations, a process to objectively evaluate technology development for waste management has been initiated and a select committee consisting of experts from universities and industries are examining the transuranic waste process technologies. If this evaluation technique is found valuable, the Division of Waste Products of the Office of Nuclear Waste Management plans to institute similar evaluation programs in other areas of nuclear waste management.

Publications

"An Overview of DOE's Technology Development Program for Nuclear Waste Management," NE/ET-79-02, pp. 25, 1979, K.K.S. Pillay.

"An Independent Overview of Technology Development for Nuclear Waste Processing," Transactions of the American Nuclear Society, 34, 421-22, 1980, K.K.S. Pillay.

Establishment of Baseline Levels of Wastes from Uranium Mill Tailings

K. K. S. Pillay
R. C. Baldwin
J. Shillenn

A feasibility study was undertaken to determine the potentials of activation and radiochemical analysis for the establishment of baseline levels of selected radioactive and nonradioactive uranium mill tailings. A combination of dendrochronology and neutron activation analysis was used in this study of tree ring samples collected from a selected area of Salt Lake City, Utah.

Thirty-seven separate sampling sites were established and a total of fifty-one increment core borings and/or full cross-sectional specimens were collected. The activation analysis of a few samples have been completed and additional work is in progress at the present time. It is hoped that the trace element profiles of the tree rings from this region could be identified with some of the unique constituents of uranium mill tailings.

Development of a Preconcentration Method for Monitoring Water-borne Radionuclides

K. K. S. Pillay
D. Croft
M. F. Sulcoski

The research efforts to develop an on-line monitoring system for the secondary effluents from nuclear reactor facilities continued during this period. An electrolyte coagulation technique, using a combination of anodic dissolution and hydrolysis, is being examined to optimize the preconcentration of activation and fission products that are likely to be present in extremely low levels in water systems.

Systematic investigations of the process parameters are being conducted to develop the prototype of a process which could be incorporated into the effluent monitoring systems of nuclear reactor facilities.

Master's Theses

"Preconcentration Methods for Water-borne Radionuclides," M. F. Sulcoski, Nov. 1979, K. K. S. Pillay, advisor.

"Development of an On-line Monitoring System for Water-borne Radionuclides," D. Croft, 1980, K. K. S. Pillay, advisor.

Trace Element Profiles of a California Redwood Tree

K. K. S. Pillay
J. Jempson

Activation analysis and dendrochronology for the study of pollution histories of geographical regions were originally developed at Penn State. This technique was extended to a study of the environmental history of the Humbolt Redwood State Park in California using a 1250 year old Coast Redwood (Sequoia Sempervirens) with the assistance of the Department of Parks and Recreation of the State of California. Selected samples of several redwood trees were obtained for the use of this investigation. The analytical work on one of the specimens completed shows rather interesting results.

The profiles of thirty trace elements present in the tree were developed using multiple neutron activation and high resolution gamma-ray spectrometry. The results indicate that the Humbolt Redwood State Park has escaped the industrial pollution because of its unique location near the Pacific coast. However, a global nature of pollution

due to mercury is identifiable in the Redwood samples and parallels the results obtained from tree samples collected from central regions of Pennsylvania.

Some of the unique findings of this investigation were the identification of changes in tree rings during flood seasons in the early 1900's. There were also data relating to the early 1400's which were not yet explained because of the limited knowledge of the history of that region during that period.

Master's Thesis

"Neutron Activation Analysis and Dendrochronology in Environmental Pollution Studies," J. R. Jempson, 1980, K. K. S. Pillay, advisor.

Publications

"Trace Element Profile of a California Redwood Tree," Trans. Amer. Nucl. Soc. 34, 111-112 (1980), J. R. Jempson and K. K. S. Pillay.

Radiation and Transmutation Effects on Nuclear Waste Forms

K. K. S. Pillay
E. R. Vance
M. Y. Khalil

Fundamental studies on the development of a generation of new materials - tailored ceramics - has been an on-going effort at Penn State for several years. With the newly-found political emphasis on nuclear waste management, a variety of generic studies have been initiated at Penn State by Rockwell International as a subcontract to DOE's technology development efforts for waste management. As part of this effort, radiation stabilities and radioactive decay induced transmutation effects are being studied extensively using the nuclear facilities at Penn State.

The nuclear reactor at Penn State is used as an irradiation source of combined fission products during shut-down mode. In addition, a variety of experiments incorporate the use of the reactor as a neutron source to induce nuclear fission in waste matrices to study the effects of damages induced within crystalline materials.

Various polycrystalline single-phase materials which are possible candidates for inclusion in multiphanic ceramics for solid nuclear waste formulation have been studied. Some of the typical materials were alumina, perovskite, monazite, and zirconalite, all doped with either depleted or enriched uranium. In these cases, the main radiation damage effect was via fission fragments. In other cases, only fast neutron and gamma-irradiation effects occurred. The irradiated materials are

being characterized by X-ray diffraction, gamma-ray spectrometry, leach tests, and hydrothermal tests.

Paper

"Fission Fragment Damage in Candidate Ceramic Waste Forms," Paper presented at the American Ceramic Society meeting, Chicago, Illinois, April, 1980, E. R. Vance and K. K. S. Pillay.

A Conceptual Design of Pathfinder-TRIGA(PATR) Fuel Elements for Use in the Penn State University Breazeale Reactor

S. H. Levine
A. A. Gui

A PATR fuel element containing 17 Pathfinder fuel rods (UO_2 fuel, 6.95w% enriched in U-235) of 15" fuel length has been conceptually designed for use in the Penn State Breazeale Reactor (PSBR). The steady state physics performance of PSBR containing 90 fuel elements, with some of its TRIGA fuel elements replaced by the PATR fuel elements, and operating at 1 KW is analyzed using the PSU LEOPARD and MCRAC computer codes. Although the above analysis excludes the xenon effect and the temperature defect, the minimum cold, zero power end-of-cycle (EOC) k-effective is set to be 1.025 to override both the xenon effect and the temperature defect so that the reactor can maintain operation at full power. When the k-effective drops to 1.025, the TRIGA core is refueled with new fuel elements. The study demonstrates that the reactivity and normalized power limits imposed on the reactor are all satisfied and considerable cost savings can be made if PATR fuel elements are fabricated for less than $1000 each.

Master's Paper

"A Conceptual Design of Pathfinder-TRIGA(PATR) Fuel Elements for Use in the Penn State Breazeale Reactor, A. A. Gui, 1979, S. H. Levine, advisor.

Paper

"Fuel Management for TRIGA Reactor Operators," Presented at the Seventh Biannual U.S. TRIGA Users Conference, San Diego, California, March 2-5, 1980, R. E. Totenbier and S. H. Levine.

Dose Rates in Air and Water from PSBR TRIGA Fuel

S. H. Levine
A. H. Foderaro
M. Y. Ali

Dosimetry measurements are being performed to determine the dose rates in air and water from PSBR TRIGA fuel elements. Various methods were used to measure the dose rate in water at specified distances from TRIGA fuel elements having different histories of power-energy production. Calculations were made to compare experimental data with theory for the water medium and then theoretical calculations were used to extrapolate the experimental data to corresponding dose rates in air.

K-Infinity Measurement Meter

M. A. Schultz
S. H. Levine
W. F. Witzig
H. Ocampo
D. Chang

Studies are being conducted to develop subcritical reactivity measuring systems for monitoring the safe storage of spent fuel elements in closely packed arrays. An analytical model has been developed to determine the k_∞ of a fuel assembly in a subcritical assembly ($k_{eff} < .95$) by measuring the change in the core multiplication it produces when substituted for another fuel assembly. Measurements have been performed to verify the analytical model using the TRIGA core. Experiments are now being developed to determine a simple method for measuring the k_{eff} of the initial subcritical assembly used in these measurements.

Publication

"A k_∞ Meter for Spent Nuclear Fuel Storage Pools," ANS TRANS., Vol. 33, p. 378, Nov. 1979, S. H. Levine, M. A. Schultz, and D. Chang.

Shutdown Reactivity Measurements for Spent Fuel Element Storage Pools

M. A. Schultz
S. H. Levine
H. Ocampo

Because nuclear fuel reprocessing is currently not permitted in this country, it is necessary for the utilities to store spent fuel in racks placed in large pools of water at the site of the nuclear power plant.

As these racks fill up, many utilities are "reracking" using new high density packing configurations. The problem is the obvious one that the racks must not go critical as more and more fuel is added. Currently, criticality is determined by elaborate calculations. Yet as the density of fuel packing becomes higher, it appears highly desirable to measure the degree of subcriticality in the pool. A survey has been made of all the known methods of measuring subcriticality and promising methods for further detailed exploration have been selected. Preliminary measurements have been made using the Breazeale Reactor in known and calculable configurations. Currently, an assymetrical source method has been selected as the most promising system and apparatus is being built up to form a subcriticality meter. The electronics involved utilize a microprocessor based system that will have a direct output reading of the multiplication factor. This system will be evaluated at the Breazeale Reactor facility.

Doctoral Thesis

"A Subcriticality Meter for Spent Fuel Pools," H. Ocampo, 1981, M. A. Schultz, advisor.

COLLEGE OF SCIENCE

Biology Department

Adaptations of Nymphs of a Marine Dragonfly, Erythrodiplax berenice, to Wide Variations in Salinity

W. A. Dunson

Nymphs of the dragonfly, Erythrodiplax berenice, are common on rocky mangrove flats in the lower Florida Keys at salinities of 36 to 48 ppt. E. berenice appears to be the only truly marine odonate and the nymphs are able to tolerate wide variations in salinity. Hemolymph osmotic pressures for nymphs freshly captured in sea water or held in artificial sea water were 358-412 mOsm. There was little further variation at salinities between fresh water and 260% sea water (2612 mOsm). In 300% sea water, hemolymph osmotic pressure rapidly increases to about 1000 mOsm, and death ensues. The transition point between hyper and hypo-osmotic regulation occurred at approximately 350 mOsm sea water. Fresh water and sea water acclimated nymphs differ little in body water content (about 80%), but Na content is elevated from 50 to 89 µmoles/g wet wt respectively. In 35 ppt sea water Na influx and efflux were approximately balanced near 400 µmoles/100 g h. In fresh water (1 mM Na), these fluxes decline to about 10 µmoles/100 g h. The time for complete turnover of body Na increases from 0.9 day in sea water to 21 days in fresh water. On rapid transfer from water of 470 mM Na to water of 1 mM Na, the Na efflux of 1 mM was only slightly higher than expected for fresh water acclimated nymphs. At a water Na level of 0.25 mM, Na efflux increases greatly, and there is a large net loss of Na. Water influxes of nymphs in distilled water or 35 ppt sea water were similar (33 and 40 µl/g·h respectively); complete turnover of body water occurs in about 0.8 day. Nymphs of E. berenice rival the better known dipterans in osmoregulatory abilities and should be studied further to compare mechanisms of hypo-osmotic regulation that have presumably evolved independently in these two orders.

Behavioral and Physiological Osmoregulation in the Key Mud Turtle, Kinosteron b. bavrius

W. A. Dunson

K. b. baurii, listed as threatened by the state of Florida, is still relatively common in favorable habitats in the Lower Florida Keys. 137 turtles were captured on the southern portion of Summerland Key, which is extensively man-altered; only 26 were trapped on uninhabited Johnston Key. Mark recapture rates indicate that total populations in these areas may be 1.6 - 2 times higher. K. b. baurii requires ponds that are less than 15 ppt salinity for aquatic activity. Turtles given a choice preferred land when water salinity was above 50% sea water (17.5 ppt). Water was preferred when the salinity was

25% sea water (8.5 ppt) or below. In the field, long periods may be spent on land in terrestrial retreats during times when unfavorable conditions exist in the ponds. Evaporative water loss was quite low (about 0.5% wt/day) when measured in the laboratory under conditions that simulate aestivation. Individual turtles are extremely faithful to their "home" ponds and only rarely move to adjacent ones. The greatest density of turtles (59) was found in a small series of artificial ditches cut through the surface rock into the underlying fresh water lens. Density in natural ponds containing a minimum of two animals was related to the log of pond surface area. K. b. baurii are more tolerant of immersion in 100% sea water than other kinosternids studied, but are not capable of long term survival. Their success in colonizing Lower Keys habitats is largely due to their ability to use terrestrial retreats when pond conditions are adverse.

Osmoregulation of Crocodiles

W. A. Dunson

It is possible that the survival rate of hatching C. acutus in Florida Bay is low and is associated with osmoregulatory problems caused by high salinities near nest sites. Crocodiles show few physiological specializations for life in saline waters in comparison with marine snakes and turtles. Wild C. acutus hatchlings have a plasma osmotic pressure of the cloacal fluid of wild caught C. acutus was equal to or less than that of the plasma. The solid portion of the cloacal fluid was mainly uric acid, and contained 1.3 to 450 times more K than Na. The highest levels of these ions were 1111 and 222 µmoles/g dry wt respectively, normal values for carnivorous reptiles. Thus it appears that K is excreted in both the fluid and solid portions of the "urine," whereas Na is conserved. The analysis of Na fluxes of small C. acutus submerged in sea water (35 ppt) is complicated by the presence of a sizeable compartment that turns over quite rapidly. There is a second compartment with a long turnover time ($T_{\frac{1}{2}}$ of efflux 29-156 days). I assume that the slow compartment represents the true long-term rate of exchange with sea water. Na influx (11.5 µmoles/100 g·h) and efflux (2.5 µmoles/100 g·h) were both quite low, although the influx did exceed the efflux. Thus a net uptake of about 10 µmoles Na/100 g·h may occur. No passage of Na across small pieces of keratin was observed after one day. It appears that the skin is virtually impermeable to Na, as is the case with most aquatic reptiles. In some plasma samples taken during the first two weeks of life, Na was atypically low, but in others it is near normal (about 150 mM). This discrepancy was not found in plasma samples from mangrove snakes (Nerodia fasciata compressicauda) taken and analyzed under identical conditions. The indications that there may be a Na deficiency of the extracellular fluid in some recent hatchlings is supported by the extremely low Na concentration of cloacal fluid (12-21 mM). In some, but not all cases, Cl and K were much higher than Na. The relationships between snout vent length (L), body weight (W), and surface area (A) are as follows: $A=1.1550L^{1.8947}$; $W=0.0263L^{2.9730}$. The head-neck, tail, legs and body regions each account for about one

fourth of the total area. After hatching, crocodiles seek out cool, moist, terrestrial microclimates by entering crab holes and wave-cut crevices, or by hiding in clusters of mangrove roots. It might appear that this behavior is advantageous for small crocodiles in avoiding the loss of body weight (about 1.7%/day) that occurs when fasting and immersed in 100% sea water. Such is not the case since a similar amount of evaporative water loss occurs in air at 30°C and 96.5% relative humidity. This is several times the loss of the mangrove snake living in the same habitat. It appears that this obligatory water loss is normally counterbalanced by feeding. When fed *ad lib.* and kept in an aquarium divided into land and water portions, small (100-480g) crocodiles maintain weight at salinities up to at least 17.5 ppt (50% sea water).

The Relation of Sodium and Water Balance to Survival in Sea Water of Estuarine and Freshwater Races of the Snakes *Nerodia fasciata*, *N. sipedon* and *N. valida*

W. A. Dunson

Subspecies of the Florida banded water snake (*Nerodia fasciata*) vary markedly in their tolerance to sea water. The freshwater race *N. f. picliventris* differs physiologically from the estuarine races *N. f. compressicauda* and *N. f. clarki* in several important ways. When placed in sea water it has a higher body water influx and efflux, a higher body sodium influx and its skin is more permeable to water and sodium. It is likely that the high rate of sodium influx, immediately after placement in sea water, is the primary factor leading to drinking of sea water and subsequent death. Thus the distinction between freshwater and estuarine races is not simply behavioral, as was previously believed, but is dependent also on physiological differences. Other freshwater snakes studied (*N. sipedon*, *Regina septemvittata*) also had greater rates of water influx than found in marine or estuarine species. The queen snake (*R. septemvittata*) has the highest rates of sodium influx and water exchange. Immediately after immersion in sea water, water exchange is primarily through the skin and sodium uptake through the mouth. Intergrades between *N. f. pictiventris* and *N. f. compressicauda* had the sea water tolerance of the estuarine race. It appears that these estuarine subspecies are in the process of evolving into true marine species. They may not have a salt gland, but they are capable of surviving long periods in saline habitats. A similar evolutionary development may be occurring among coastal populations of the Mexican water snake *N. valida*.

A Possible New Salt Gland in a Marine Homalopsid Snake (Cerberus thynchops)

W. A. Dunson
M. K. Dunson

The dog-faced water snake, Cerberus rhynchops, apparently has a small premaxillary salt gland, which is not homologous with previously known lachrymal (turtles), nasal (lizards) or posterior sublingual (sea and file snakes) salt glands. Cerberus is a mangrove-dwelling snake that has adapted to a marine existence independently of the hydrophiids and the acrochordids. The premaxillary salt gland of Cerberus is small (approximately 0.005% body wt) and excretes sodium at about 19 μmoles/100 g body wt.h. When salt adapted, the glandular fine structure of the principal cells is very similar to that of other ophidian salt glands. However in fresh water striking changes in ultrastructure take place, indicating that the gland is probably readapting to serve a different function. The salt gland in Cerberus probably functions only during periods of dehydration, as the plasma Na concentration rises above 150 mM. The skin of Cerberus is virtually impermeable to Na, and overall Na influx (all oral) is extremely low, about 10 μmoles/100 g h. Almost all water exchange with sea water is through the skin, and net loss is relatively low. Cerberus can hydrate by drinking fresh water when it is available, and survive many months of sea water immersion before gradual dehydration causes the activation of the premaxillary salt gland. Even when fully active the gland can excrete only very limited amounts of electrolytes in comparison with some other marine reptiles. However, the presence of even such a small source of extrarenal electrolyte excretion must be important to fasting snakes or those denied access to fresh or brackish drinking water for prolonged periods.

Osmoregulation in Sea Water of Hatchling Emydid Turtles, Callagur borneoensis, from a Malaysian Sea Beach

W. A. Dunson
E. O. Moll

The emydid turtle Callagur borneoensis nests on Malaysian ocean beaches with the true sea turtles. Adults were seen mainly in tidal upstream areas of the Perak and Setiu Rivers. It is likely that hatchlings must swim through the sea to reach the river mouths, yet they are intolerant of long term immersion in sea water when tested in the laboratory. Fasting turtles in the initial week of exposure undergo a net weight loss of 0.9 and 1.4% body weight/day in 50% and 100% sea water (35% salinity) respectively. In 25% sea water a net weight gain of 0.9% body weight/day was recorded. Turtles move to or remain in fresh water when given a choice between it and sea water in

a divided tank in 100% sea water, body water influx and efflux were 0.616 and 0.546 in 100 g·h respectively. This is equivalent to a turnover of 16-18% of the body water daily (81% weight is water). Influx must be mainly occurring through the skin and/or shell since turtles apparently do not drink 100% sea water. This is proven by the very low Na influx, 5.6 µmoles/100 g·h which could be accounted for if a 50g turtle "drank" only 10 µl/h of the radioactive bath. Na efflux is even lower (about 1 µmole/100 g·h) and does not increase after injection of salt loads. Less than 0.5% of the total body Na content (82 µmoles/g) is lost daily. Hatchling C. borneoensis are not physiologically specialized for a life in estuaries of high salinity, yet they can survive for at least two weeks in 100% sea water.

Keratin Membrane Permeability and Applications to Desalination

W. A. Dunson
G. D. Stokes

It has long been known that the proteins alpha and beta keratin create a strong, semipermeable covering for many animals. In the case of snakes, the nearly pure alpha-beta keratin covering that is shed has "channels" of varying size depending on the habitat of the species. These channels act as a sieve allowing particles of small enough size to pass but retaining particles of larger size. In recent work performed in our lab we have shown that the shed skin of some of these snakes allows the passage of water but not certain ions such as sodium and bromide. We propose to test the possibility that keratin might be used as a new type of reverse osmosis(RO) membrance. This might involve the dissolution of keratin in a proper solvent and its reconstitution into a configuration useful in RO applications. Extensive testing of the permeability of the native and reconstituted keratin will be carried out both at atmospheric pressure and in RO pressure cells. The potential application is the possible development of an entirely new material for RO desalination and waste water treatment which may be more efficient than the cellulose acetate or plastic membranes now in use. Isotopes such as Na-24, K-42, Br-81, and Ar-41 have been activated at the reactor and are used as tracers in determining the membrane channel size.

Chemistry Department

The Inclusion of Monomer Molecules in a Phosphazene Tunnel-Clathrate and Their Subsequent Polymetization

H. R. Allcock
M. L. Levin

Tris (o-phenylenedioxy) cyclotriphosphazene exists in the solid state as a tunnel-clathrate with a tunnel diameter of 5 Å. Unsaturated nonomer molecules (butadiene, isobutylene, divinylbenzene, styrene, p-bromostyrene, methyl methacrylate, isoprene, and acrylonitrile) have been included within the tunnels of this clathrate. The clathrate/monomer complexes were then exposed to Co-60 gamma-radiation at -78°C. By this technique, we have been successful in polymerizing the clathrated monomers in situ. The resultant polymers were isolated and characterized by a variety of techniques and compared to analogous polymers formed in bulk, i.e., in the absence of the clathrate.

We have found that in certain cases, this "template" polymerization initiated by gamma-radiation leads to stereoregular polymers, that is, polymers which have a highly symmetric structure relative to the random-type polymers formed in bulk.

This project is still in progress and it is anticipated that it will continue for the next several months.

Physics Department

Effect of Trapping Centers on Minority Carrier Injection in n-type Germanium

H. K. Henisch
G. Rieder
S. Rahimi

In the presence of minority carrier traps, minority carrier injection should lead to a resistance increase (as opposed to the familiar decrease ordinarily assumed). Neutron bombardment was used (in conjunction with subsequent annealing) to induce trapping centers in situ. It does so. The experiment was successful and an account of it is now being prepared for publication.

Doctoral Thesis

"Current-Controlled Non-equilibrium Processes at Metal-Semiconductor Contacts," S. Rahimi, 1981, H. K. Henisch, advisor.

Physics Department

Lithium and Lithium-6 Analysis in Solutions by the Nuclear Track Technique

L. C. Pilione
B. S. Carpenter

This study demonstrates that the nuclear track technique coupled with absorbers can be used to determine the concentration or isotopic abundance of solutions containing lithium. These measurements are made by registering in cellulose nitrate detectors, the triton particle produced in the $^{6}Li(n,\alpha)^{3}H$ nuclear reaction. In addition, this study illustrates that the use of the absorbers eliminates interferences from alpha particles produced from other nuclides during the irradiation of the samples.

Nuclear Track Determination of Lithium and Boron in Secondary Minerals of Deep Ocean Basalts

L. C. Pilione
B. S. Carpenter

In recent experiments we have demonstrated that trace amounts of Li and B can be determined uniquely by recording their thermal neutron-induced reaction products in nuclear track detectors.

In some rocks it may be difficult to isolate the source of alpha particle emissions, induced by thermal neutrons, because these reactions are common to a number of elements. Lithium and Boron will undergo a significantly larger number of alpha-producing nuclear reactions than equivalent amounts of these other elements, because of their large thermal neutron cross-sections and isotopic abundances. By careful chemical etching, the alpha particle tracks from neutron-boron reactions can be enlarged selectively to an easily discernable size. The boron distribution within the sample is determined by measuring these etched alpha particle tracks in the detector.

The boron-alpha detector also serves the role of a particle absorber, stopping all alpha particles produced at the sample surface from reaching a second detector positioned behind it. Tritons, generated by neutron-lithium reactions penetrate and produce etchable tracks within the second detector. A measurement of the etched triton track density yields the lithium distribution within the sample. Thus the neutron exposure is used to determine the Li and B content of the same area on the sample surface. A distinct advantage of this technique, as compared to whole sample analysis, is the ability to identify and map the distribution of Li and B non-destructively in small samples on a microscopic scale.

This multiple discriminating detector technique will be used to determine the in situ distribution and abundance of Li and B in alteration zones adjacent to small fractures and veins in layer 2 ocean floor basalts.

Low Intensity Gamma Rays in the Decay of Cd-115

W. W. Pratt

Recent studies of the gamma ray spectrum following the beta decay of Cd-115 have resulted in some disagreement concerning the low energy low intensity transitions between levels in In-115. Coincidence techniques are being used here to investigate the presence of uncertain gamma ray transitions of 371 and 384 keV.

R dioactive Decay of Cs-134

W. W. Pratt

In the course of measurements of the gamma ray spectrum of Cs-134, which were being carried out for instrument calibration purposes, some evidence was found for an unreported transition between known levels of Ba-1235 at 1424 and 2029 keV. A search for th s transition is currently in progress.

Resonance Activation of Nuclear Isomers

W. W. Pratt

It has been known for some time that nuclear isomeric states can be excited when nuclei are irradiated with gamma rays of suitable energy. A study is in progress to look for isomeric states which can be excited with Co-60 gamma rays. Positive results have been obtained to date in Sr-87, Cd-111, In-113, In-115, and Pt-195.

COLLEGE OF THE LIBERAL ARTS

Anthropology Department

J. W. Hatch
R. A. Geidel

Status in societies organized according to ranked kinship groupings (chiefdoms) is recognized through a series of behavioral, artifactual, and ritual attributes. One common feature of these societies is the greater availability of certain foodstuffs (especially animal protein) to higher status groups.

Some trace elements are found in higher concentrations in certain food sources. Specifically, Co, Cu, Mo, Se, and Zn are more abundant in animal foods than in plant foods. The reverse is true for Mn, Ni, Sr, and V. Thus, the concentrations of these elements in the human skeleton can be used to assess nutritional history. Levels of the former group of elements should correlate positively with rank while the latter elements can be expected to correlate negatively.

Bone samples from approximately 200 burials of the prehistoric Dallas culture of eastern Tennessee are being analyzed to determine the relative percentage of each of these elements. A two-step irradiation sequence is being employed to maximize elemental data. An initial one minute irradiation using the rabbit system has been completed for all samples. A second exposure of the samples in the central thimble oscillator for five hours is in progress. Preliminary results indicate a fluctuation in diet during episodes of social change and political consolidation.

HERSHEY MEDICAL CENTER

Surgery Department

Effect of Mucosal Na and Amphotericin on Serosal Transport of K in Necturus Gallbladder

R. C. Rose
D. L. Nahrwold

The isotope K-42, generated at the Breazeale Nuclear Reactor Facility, was used in an attempt to define the role of potassium in the Necturus gallbladder. In many epithelial tissue (e.g., ileum and gallbladder), it is known that the cell normally maintains low intracellular sodium. When sodium is transported into the cell interior from the mucosal bathing solution, the excess sodium is transported out on a coupled carrier that exchanges with potassium from the serosal bathing solution. The serosal uptake of potassium into the cell of Necturus gallbladder was assessed in the presence and absence of sodium in the mucosal bathing solution. In addition, Amphotericin-B, which increases the permeability of the mucosal cell wall to sodium, was added to evaluate its effect on the movement of serosal potassium.

B. Industrial Research Utilizing the Facilities of the Penn State Breazeale Nuclear Reactor

The facilities of the Penn State Breazeale Nuclear Reactor (PSBR) are made available to state, federal, and industrial organizations for use in their research and development programs. Some typical examples follow:

The Charles Stark Draper Laboratory, Inc.

R. G. Miller
G. F. Ostler

In the past year, the Draper Laboratory has used the Breazeale Nuclear Reactor Facility to investigate how neutron environments effect the functional and parametric characteristics of transistors and integrated circuits. The results of this research have provided greater insight in understanding neutron sensitive damage mechanisms in semiconductor circuits. In addition, the studies undertaken have provided data to determine damage coefficients which will be useful for predicting circuit responses to neutron environments.

Delaware Custom Materiel, Inc. (DCM)

G. Sagliocca

Activation Techniques to Determine Leachability of Uranium Sludges. Political and environmental concerns have compelled federal, state, and local agencies to scrutinize the ways low-level radioactive wastes are readied for burial.

Presently, the nuclear industry must meet the "free standing solid" criterion; however, there is no mention of the more important issue of reducing leachability rates once the solid waste is placed in the dynamic soil environment.

The methods used to achieve solids are numerous, but the one most promising in achieving low leachability is the DCM cement-aqueous silicate chemical process.

Since 1976, neutron activation and etched fission studies have been conducted at Penn State's Breazeale Nuclear Reactor to measure leach rates of chemically-fixed uranium sludges -- quintessent of fuel fabrication plants -- using the DCM process. These reactor studies proved superior to gamma ray spectroscopy results because the interference from other neutron isotopes is precluded.

E. I. Du Pont De Nemours and Company

N. W. Henry, II, M.S.

Aquatic Waste Water Facility Monitoring. Groundwater monitoring of the wells surrounding our aquatic waste lagoon is proceeding on schedule. Background levels of bromide anion in the wells have been determined this past year by neutron activation analysis at the Radionuclear Applications Laboratory of the Penn State Breazeale Nuclear Reactor. Results of these analyses indicate that it may be feasible to use bromide anion as a tracer in the lagoon because of its low background concentration in the wells and detectability by neutron activation analysis. Currently, a spiking experiment with chloride anion is being done to determine horizontal groundwater flow beneath the lagoon. Results of this experiment will establish direction and rate of flow without contaminating our original tracer experiment with bromide. The overall results of these experiments hopefully will provide us with a waste lagoon leak monitoring technique and also satisfy regulatory requirements for insuring lagoon liner integrity.

Raytheon Company

R. N. Diette

The services of The Pennsylvania State University Breazeale Reactor have been used at an increasing rate by Raytheon over the past year. In addition to other in-house projects, several tasks have been performed for Charles Stark Draper Laboratory.

The irradiations performed by the reactor facility staff have been utilized in assessing damage to electronic components. Electrical test, pre and post neutron exposure, identify functional and parametric changes used for analysis of the nuclear vulnerability of diverse electronic circuits and systems. This analytical approach is applied to land and sea based radar, communications and missile systems.

The dosimetry for our exposures and the accuracy in providing specific fluences have been most satisfactory. Continued and frequent use of the reactor is projected for the coming year. Many thanks for your valuable assistance to Raytheon.

Westinghouse Electric Corporation

J. Bartko
P. E. Felice
H. Troutman

Following our fission neutron irradiations of power devices at the Breazeale Reactor Facility, we performed anneal and deep level transient spectroscopy studies on the devices. Our analysis caused us to speculate about the influence that the neutron energy has on the results. We had additional irradiations made in a heavy water moderated area of the facility. The devices have not as yet been fully analyzed but it is expected that work along these lines will continue.

APPENDIX A

Faculty, staff and students utilizing the facilities of the Penn State Breazeale Reactor.

COLLEGE OF AGRICULTURE

Food Science

Cin, David A., BS
Graduate Student

Kroger, Manfred, BS, MS, PhD
Professor of Food Science

Plant Pathology

Burgoon, Janet, BS, MS
Graduate Student

Fisher, Nancy L., BS
Research Assistant

Kaiser, Roger, BS, MS, PhD
Graduate Student

Lukezic, Felix L., BS, MS, PhD
Professor of Plant Pathology

Nelson, Paul E., BS, PhD
Professor of Plant Pathology

Steuhling, Barbara, BS, MS
Graduate Student

School of Forest Resources

Baldwin, Robert C., BS, MS, PhD
Assistant Professor of Wood Science and Technology

Sopper, William E., MF, PhD
Professor of Forest Hydrology

Veterinary Science

Ritchie, Joan M., BS
Graduate Student

Zarkower, Arian, DVM, MS, PhD
Professor of Veterinary Science

COLLEGE OF EARTH AND MINERAL SCIENCES

Geochemistry Section

Bell, Christy, BS, MS, PhD
Graduate Student

Keith, MacKenzie L., BBc, MSc, PhD
Professor Emeritus of Geochemistry

Tole, Peter M., BS, MS
Graduate Student

Geosciences

Cathles, L. M, PhD
Associate Professor

Dudas, F., AB
Graduate Student

Ohmoto, H., PhD
Professor

Rose, Arthus W., BS, MS, PhD
Professor of Geochemistry

Materials Science

Butler, Jackie
Undergraduate Student

Harrison, an R., BS, MS, PhD
Associate Professor of Polymer Science

Kline, Donald E., BS, MS, PhD
Professor of Materials Science

Runt, James P., BS, MS, PhD
Instructor of Polymer Science

Vance, E. R., BSc, PhD
Research Associate

Mineral Engineering

Phelps, L. Barry, M.Eng
Instructor

Saperstein, Lee W., BS, DPhil, PE
Professor of Mining Engineering

Young, D., BS
Graduate Assistant

COLLEGE OF ENGINEERING

Agricultural Engineering

Jarrett, Albert R., BS, MS, PhD
Assistant Professor of Agricultural Engineering

Chemical Engineering

Smith, J. S., BS
Graduate Student

Twu, Fred, BS, MS
Graduate Student

Vannice, M. Albert, BS, MS, PhD
Associate Professor of Chemical Engineering

Wang, S. Y., BS, MS
Graduate Student

Civil Engineering

Nesbitt, John B., BS, SM, ScD
Professor of Civil Engineering

Nuclear Engineering

Ali, M. Y., BS
Malaysia Atomic Energy Department

Brenizer, Jack S., Jr., BS, MS
Graduate Asistant

Chang, D.
Graduate Student

Comparetto, Gary M., BS
Graduate Assistant

Croft, Duane, BS
Graduate Student

Diethorn, Ward S., BS, MS, PhD
Professor of Nuclear Engineering

Foderaro, Anthony, B, PhD
Professor of Nuclear Engineering

Flinchbaugh, Terry L.
Nuclear Education Specialist

Gui, A. A., BS, MS
Malaysia Atomic Energy Department

Houtz, Robert C.
Nuclear Education Specialist

Jacobs, Alan M., BS, MS, PhD
Professor of Nuclear Engineering

Jempson, James R., BS
Graduate Student

Jester, William A., BS, MS, PhD
Professor of Nuclear Engineering

Kenney, Edward S., BS, PhD
Professor of Nuclear Engineering

Khalil, M. Y., BS
Graduate Student

Klevans, Edward H., B, MS, PhD
Professor of Nuclear Engineering

Levine, Samuel H., BS, MS, PhD
Professor of Nuclear Engineering

Manson, Steve
Undergraduate Student

McKee, John R., BS
Coordinator, Energy Education Programs

McMaster, Ina B., BS
Research Assistant

Ocampo, Hector, BS, MS
Graduate Student

Penkala, John L., BS
Research Assistant

Pillay, K. K. Sivasankara, BSc, MSc, PhD
Associate Professor of Nuclear Engineering

Raupach, Dale C.,
Reactor Utilization Specialist

Remick, Forrest J., B, MS, PhD
Professor of Nuclear Engineering

Robinson, Gordon E., BS, MS, PhD
Associate Professor of Nuclear Engineering

Schultz, Mortimer A., BS
Professor of Nuclear Engineering

Shillenn, James K.
Energy Education Specialist

Sulcoski, Mark, BS, MS
Graduate Student

Totenbier, Robert E., BS
Research Assistant

Wallace, Johathan
Graduate Assistant

Witzig, Warren F., B, MS, PhD, PE
Professor of Nuclear Engineering

COLLEGE OF THE LIBERAL ARTS

Anthropology

Geidel, Richard, BA
Graduate Student

Hatch, James W., BA, MA, PhD
Assistant Professor of Anthropology

COLLEGE OF SCIENCE

Biology

Dunson, William A., BS, MS, PhD
Professor of Biology

Stokes, Glenn, BS
Graduate Student

Chemistry

Allcock, Harry R., BSc, PhD
Professor of Chemistry

Levin, Michael L., BS
Graduate Student

Physics

Henisch, Heinz K., PhD, DSc
Professor of Physics

Pilione, Lawrence J., BS, MS, PhD.
Associate Professor of Physics - Altoona

Pratt, William W., BS, PhD
Professor of Physics

Rahimi, Saeid, BS, MS
Graduate Student

INTERCOLLEGE RESEARCH PROGRAMS AND FACILITIES

Health Physics Office

Granlund, Rodger W., BS
University Health Physicist

Hollenbach, Donald H.
Health Physics Assistant

Materials Research Laboratory

Reider, Gerhard, PhD
Senior Research Associate

THE MILTON S. HERSHEY MEDICAL CENTER

Surgery Department

Rose, Richard C., BS, MS, PhD
Associate Professor

Nahrwold, David L., AB, MD
Professor

APPENDIX B

FORMAL TOUR GROUPS

1979		Participants
Jun 1	Park Forest Jr. H S	36
29	Executive Management Group	21
Jul 5	Conservation Leadership School	39
9	Young Executive Program	8
18	Conservation Leadership School	47
25	Alumni Association	19
25	University of Pittsburgh	7
Aug 6	Utility Representatives	14
6	Ohio Visitors	6
7	Philadelphia Electric Company	12
10	Harrisburg Hospital	17
10	Exeter H S	6
14	Visitors	9
25	B S Graduates	11
30	Student and Guests	4
31	Executive Management Group	32
Sep 4	Nuclear Engineering 441	13
6	Nuclear Engineering 440	21
8	Altoona Naval Reserve	83
14	Nuclear Engineering 441	6
28	Chemistry 526	24
Oct 2	Physics	12
3	Food Sciences	11
10	Rad Waste Seminar	12
18	Industrial Professional Advisory Council	4
26	Altoona Campus	10
25	Physics 101	43
25	Slippery Rock H S	9
26	Army War College	24

FORMAL TOUR GROUPS

1979		Participants
Nov 1	Cooperative Extension Services	36
1	Geological Sciences 303	34
1	Engineering 5	23
2	Metallurgy 412	12
5	Science Class	11
8	Redland H S	11
8	Intercollegiate Academic Interest House	11
9	Bradford H S	23
9	Association for General & Liberal Studies	4
12	Park Forest United Methodist Church Group	7
19	Lower Dauphin H S	18
28	Wyomissing H S	10
29	Nuclear Engineering 441	15
29	Nuclear Engineering 405	13
30	St. Francis H S	7
Dec 3	Altoona H S	10
11	Penn Cambria H S	19
19	Jersey Shore H S	7
19	Conrad Weiser H S	3
1980		
Jan 9	Police Services Orientation	45
11	Robb School	28
23	Nuclear Engineering 200	25
23	Entomology	34
29	Engineering 5	39
31	Geological Science 303	33
Feb 6	Delone H S	15
7	Penns Valley H S	8
12	Women Engineers	15
15	Nuclear Engineering 200	16

FORMAL TOUR GROUPS

1980			Participants
Feb	18	Jr. ROTC	24
	19	Westerly Parkway Jr. H S	9
	21	English (Intensive Communication)	20
	26	Bellefonte Middle School	31
	27	Bedford H S	22
Mar	3	Brownies Troop	11
	4	Neutron Activation Analysis Seminar	10
	11	Nuclear Engineering 812	24
	18	Westerly Parkway Jr. H S	11
	19	Derry H S	14
	20	Villanova University	20
	21	Shamokin H S	17
	24	Johnstown Boy Scouts	36
	25	Physics 101 (2)	24
	26	Physics 101	16
	27	Physics 101	16
	28	Physics 101	22
	28	Ringgold H S	14
	31	Engineering 50	12
Apr	1	Geological Sciences	25
	3	Mt. Union H S	10
	8	Bellefonte Middle School	26
	9	Bellefonte Area H S	13
	10	Berwick H S	9
	10	Mt. Penn H S	5
	11	REDEDICATION SERVICE	50
	12	Open House	454
	15	Nuclear Engineering 401	8
	15	Harrisburg Hospital	15
	16	Selingsgrove H S (2)	47
	17	State College Jr. H S	23

FORMAL TOUR GROUPS

1980			Participants
Apr	17	Gifted Jr. H S Class	23
	17	Mercyhurst College	6
	18	Marion H S	8
	21	Bald Eagle Nittany H S	28
	23	Pennsylvania Electric Association (3)	77
	24	Philipsburg-Osceola H S	24
	24	Bucknell University	18
	25	Penn Crest H S	9
	25	Rotary Club	26
	29	Nuclear Engineering 401	7
	29	Bishop Newman H S	10
	30	Exeter	7
May	1	Plant Pathology	10
	1	South Park H S	17
	2	Chestnut Ridge H S	6
	6	Nuclear Engineering 401	8
	6	Geological Sciences 303	14
	7	Nuclear Engineering 401	8
	8	Harbor Creek H S	11
	8	West Branch H S	22
	9	Alternative School	9
	9	Keystone Oaks	12
	12	Physics 406	10
	13	Nuclear Engineering 401	4
	14	Daniel Boone H S	24
	15	Warren H S (2)	43
	16	N. Schuylkill H S	10
	20	Porter Township (2)	45
	21	Union City H S	9
	28	Thomas Jefferson H S	13
122		Groups	Total 2,648