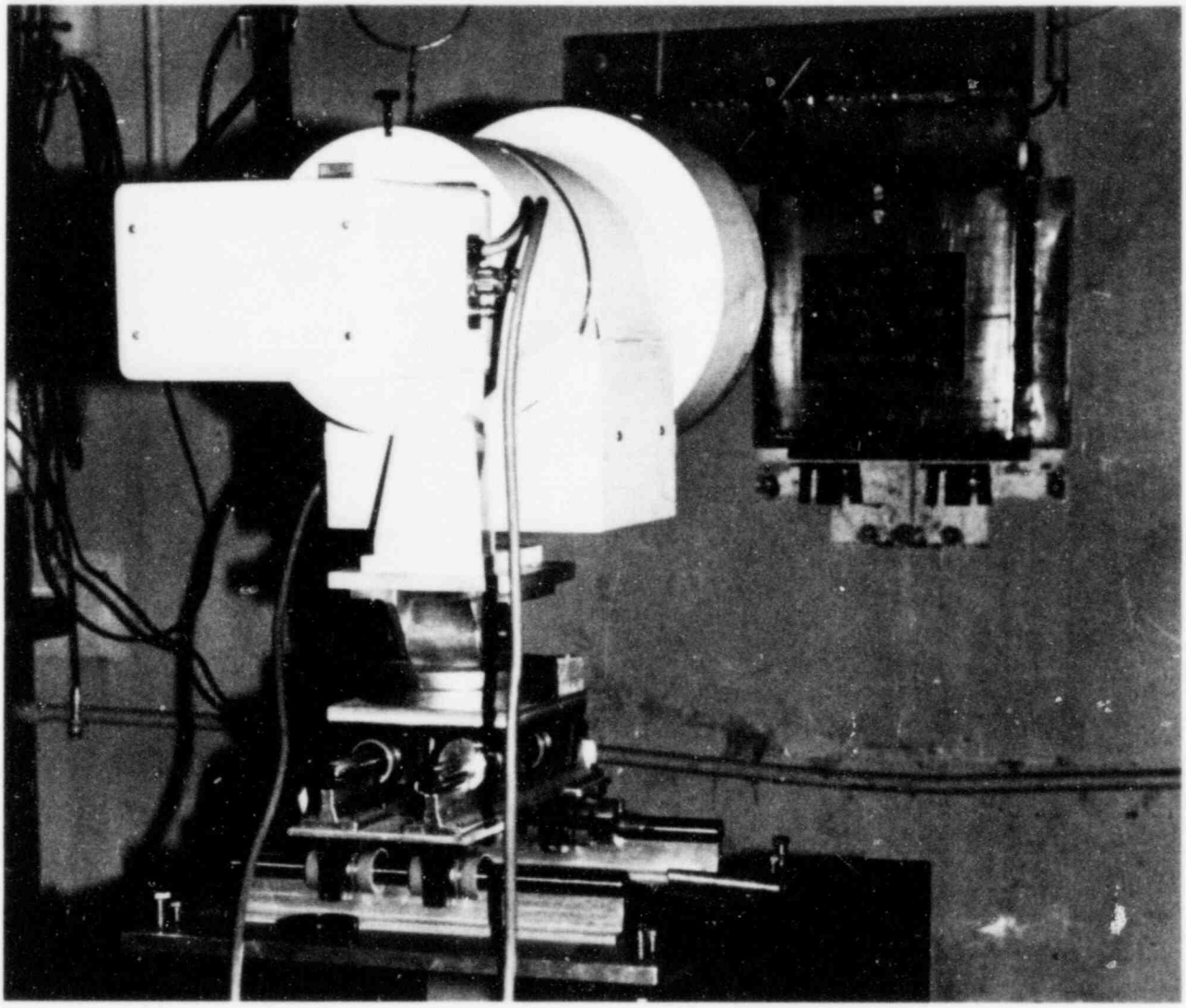
CONTRACT DE-AC02-76ER03409

THIRTIETH ANNUAL PROGRESS REPORT OF THE PENNSYLVANIA STATE UNIVERSITY BREAZEALE NUCLEAR REACTOR

July 1, 1984 to June 30, 1985



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

August 1985

PSBR 315-4985101

Contract DE-AC02-76ER03409

THIRTIETH ANNUAL PROGRESS REPORT OF THE PENNSYLVANIA STATE UNIVERSITY BREAZEALE NUCLEAR REACTOR

July 1, 1984 to June 30, 1985

Submitted to:

United States Department of Energy

and

The Pennsylvania State University

By:

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University Park, PA 16802

August 1985

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ACKNOWLEDGMENTS

The editor wishes to express his appreciation to all contributors for their research and project reports. Special thanks is also extended to those responsible for the various sections of this report as listed in the Table of Contents. Let us not forget the invaluable assistance of several part-time secretarial staff members under the direction of S. Ripka.

ABOUT THE COVER

The cover photo shows a real-time neutron image intensifier outside Beam Port #4 prior to the installation of the collimator. The intensifier is being positioned in preparation for the next radiography exposure. This is part of the equipment purchased from Precise Optics to develop PSBR's real-time neutron radiography capability. Our readers will be interested to know that this equipment is capable of real-time video recording of neutron radiography - a large step compared to last year's cover picture. That picture required the exposure of a gadolinium foil behind the objecting being radiographed, exposure of a film by the foil, development of the film and finally printing of the negative.

TABLE OF CONTENTS

TABLES

FIGURES

>> hIGHLIGHTS <<

* Three unannounced NRC compliance inspections were made during the past year - no violations were found.

* Over $787,000 was given by 18 sponsors to support research for 15 investigators which, at least in part, involved the use of the PSBR facilities.

* Forty-six faculty/staff members and twenty-seven graduate students were involved in the twenty-four reported research projects.

* One bachelor, five masters, and six doctoral degrees resulted from the reported projects.

* Seven papers and eleven publications related to these projects are reported.

* Twenty persons from five industries made use of the PSBR facilities.

* Eighteen Nuclear Engineering Technology students logged 16 hours each at the controls of the PSBR.

* Sixty-three reactor operator trainees from three electrical utilities were involved in twelve training programs comprising 196 hours over thirteen weeks.

* Nineteen educators from six states attended the 15th Nuclear Concepts and Energy Resources Institute (NCERI) for four weeks.

* Fifty-two high school classes (975 students total) visited the PSBR for a day of experiments and/or a tour under the CURE program.

* Ten college groups totaling 93 students were involved in Reactor Sharing Projects at the PSBR.

* One hundred and twenty groups totaling more than 2,400 participants toured the PSBR on formal tours.

* Mr. Edward Wenzinger, of the NRC, presented newly created license certifications to 8 Senior Reactor Operators and 2 Reactor Operators at a special luncheon honoring the licensed recipients.

I. INTRODUCTION

The Thirtieth 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 utilization 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 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.

This is the second year for including the section "Highlights" in the progress report. Statistical information presented in the highlights will no longer be included in the Introduction except when making special comments regarding the Highlight.

In 1965 the MTR type core was converted to a TRIGA core. Twenty years has passed since that time with the consequence that the facility must now submit an application for relicensing the reactor facility to NRC. The requirements for obtaining a license today, far exceeds that required by NRC twenty years ago. Nevertheless, the license application was submitted on time and the facility expects to receive a new license during the next academic year.

Penn State continues to emphasize research which is evident as many faculty from different departments make use of the reactor facility. The wide range of research using the PSBR can be noted by reading Chapter VII "Facility Research Utilization". The research performed using the PSBR covers studies on the dietary patterns of the prehistoric population of the Maya Center at Copan, Honduras and the physiological effects of low pH water on the survival of larval amphibians to noise analysis of the TRIGA core. Many departments have used the research reactor this past year.

They are: Anthropology, Biology, Chemical Engineering, Dairy, Ecology, Nuclear Engineering, Physics, Polymer Science and Solid State Science.

Of importance to the facility is the research performed by Dr. Ed Kenney in trying to understand reactor instrumentation and control interfaced microcomputers. Hopefully this research will lead to improved reactor instrumentation for both operation and research performance. The reactor staff is pleased to support all researchers who wish to use the reactor, however, it should be mentioned that the research involving the reactor has allowed the university to receive approximately $787,000 in support.

Two laboratories of the facility continue to provide important service in support of research. The Radionuclear Applications Laboratory continues to assist the faculty and students performing research using activation analysis and in understanding the radiation environment in which the samples are irradiated. The Low Level Radiation Monitoring Laboratory continues to expand. Research performed to measure the natural radiation in the environment, for example radon in water, is important to the health of the citizens of the state. Support by the Pennsylvania Power and Light Co. in determining radiation environment in the vicinity of their nuclear power plants continues to be an important program for both Penn State and PP&L. Special note should be made to Dr. W.A. Jester for his entrepreneurship in instrumenting the facility and expanding the use of this equipment.

The neutron radiography facility continues to be improved. It is expected that this facility will, in the future, utilize a significant portion of reactor time because of the unique and invaluable information it provides researchers. Mr. D.E. Hughes has made valuable contributions in the construction and expansion of this facility.

The large number of training programs, 12, offered to various nuclear utilities is a unique achievement for the facility this year. A special training program was provided to GPU for training the senior reactor operators of the TMI-2 damaged reactor. These experiments were complex and difficult to perform. They required simulating various conditions of the damaged TMI-2 reactor. A few experiments simulated attaining critical with 3000 parts per million boron in water and studying the shutdown capability when increasing the parts per million boron to 5000. In addition, the

draining of the TMI-2 pressure vessel was simulated as well as the reactivity effect of loading fuel into a canister for transportion.

Services provided by the Education Group is an important factor in the use of the Breazeale Reactor. The reactor sharing program allowed 10 colleges and universities to use the facility and the Nuclear Concepts and Energy Resources Institute (NCERI) was offered as NucE 497 for the fifteenth consectutive year during the summer of 1984. Seventeen high school science teachers and two continuing education people from five states in addition to Pennsylvania attended this course. The importance of this work to the NucE Department, the University and the State can not be underestimated.

The reactor staff and the Nuclear Reactor Safeguards Committee continue to review the operation of the facility in an effort to maintain the safety, improve the efficiency of its operation and to provide conditions conducive to its utilization. The Nuclear Reactor Safeguards Committee met four times under the able chairmanship of R. E. Bland to confer with the staff on unusual experiments, to review operational records and to consult on special operational problems. The Reactor Safeguards Committee continues to provide important input for the safe operation of the facility.

Special mention should be made of Martha Beward's retirement. For over 22 years, Martha has been a loyal, diligent and effective secretary to the facility. She is loved by all and everyone wishes her a long, healthy and happy retirement.

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

One significant change in personnel at the PSBR became effective on the last day of this reporting year. Mrs. Martha Beward's retirement was effective on June 30, 1985. She has served the PSBR and Penn State University faithfully for 22½ years. Her presence will be missed by the operating staff.

In other personnel matters, David Ryan has accepted a one-year extension to his fixed-term appointment as Research Technologist at the Low Level Radiation Monitoring Laboratory (LLRML).

Dennis Shaulis completed his studies at Penn State and accepted a position with The Philadelphia Electric Company at their Peach Bottom Plant.

Carol Rudy and Scott Nicely have been hired on wage payroll to assist the operating staff for the summer.

Patrick Boyle has been placed on wage payroll at the LLRML in an attempt to clear-out a backlog of environmental monitoring samples.

D. Hughes received his NRC Senior Reactor Operators license effective July 29, 1984, after a very brief training period.

Edward Wenzinger, representing the NRC, presented formal Operator License Certificates to the 10 licensed operators at the facility at a cerememony held in the PSBR classroom on June 21, 1985.

R. Bland of the Applied Research Laboratory continues to serve as Chairman of the PSBR Reactor Safeguards Committee. Table 1 lists the current members of this committee. The changes in committee membership reflected in this table are: R. H. Jacobs of the PSU Mechanical Engineering Department and D. White of the PSU Chemical Engineering Department were appointed to the committee effective January 1985. These appointments were made to replace F. Helfferich whose appointment expired December 31, 1984 and to fill a vacant position on the committee. These appointments bring the committee membership to ten, the maximum permitted by the operating procedure.

TABLE 1

PERSONNEL

Faculty and Staff

** J. J. Bonner	- Senior Nuclear Education Specialist/ Affiliate Instructor
G. L. Catchen	- Assistant Professor
** T. L. Flinchbaugh	- Reactor Supervisor/Nuclear Education Specialist/In-House Training Coordinator
B. C. Ford	- Environmental Analyst
** D. E. Hughes	- Reactor Supervisor/Nuclear Education Specialist
W. A. Jester	- Associate Professor
** S. H. Levine	- Professor/Director
A. F. Marino	- Energy Education Specialist
** I. B. McMaster	- Research Assistant/Deputy Director
D. C. Nicely	- Administrative Aide
** J. L. Penkala	- Research Assistant/Utility Training Coordinator
** D. C. Raupach	- Reactor Supervisor/Reactor Utilization Specialist
* K. E. Rudy	- Senior Engineering Aide - Mechanical Services
D. F. Ryan	- Research Technologist
** R. E. Totenbier	- Research Assistant/Operations Supervisor
* D. S. Vonada	- Research Technologist

Technical Service Staff

W. A. Davy	- Custodian/Driver
R. L. Eaken	- Experimental and Maintenance Mechanic

Clerical

M. D. Beward	- Facility Secretary
S. K. Ripka	- Secretary and Receptionist

* Licensed Operator
** Licensed Senior Operator

Graduate Assistants

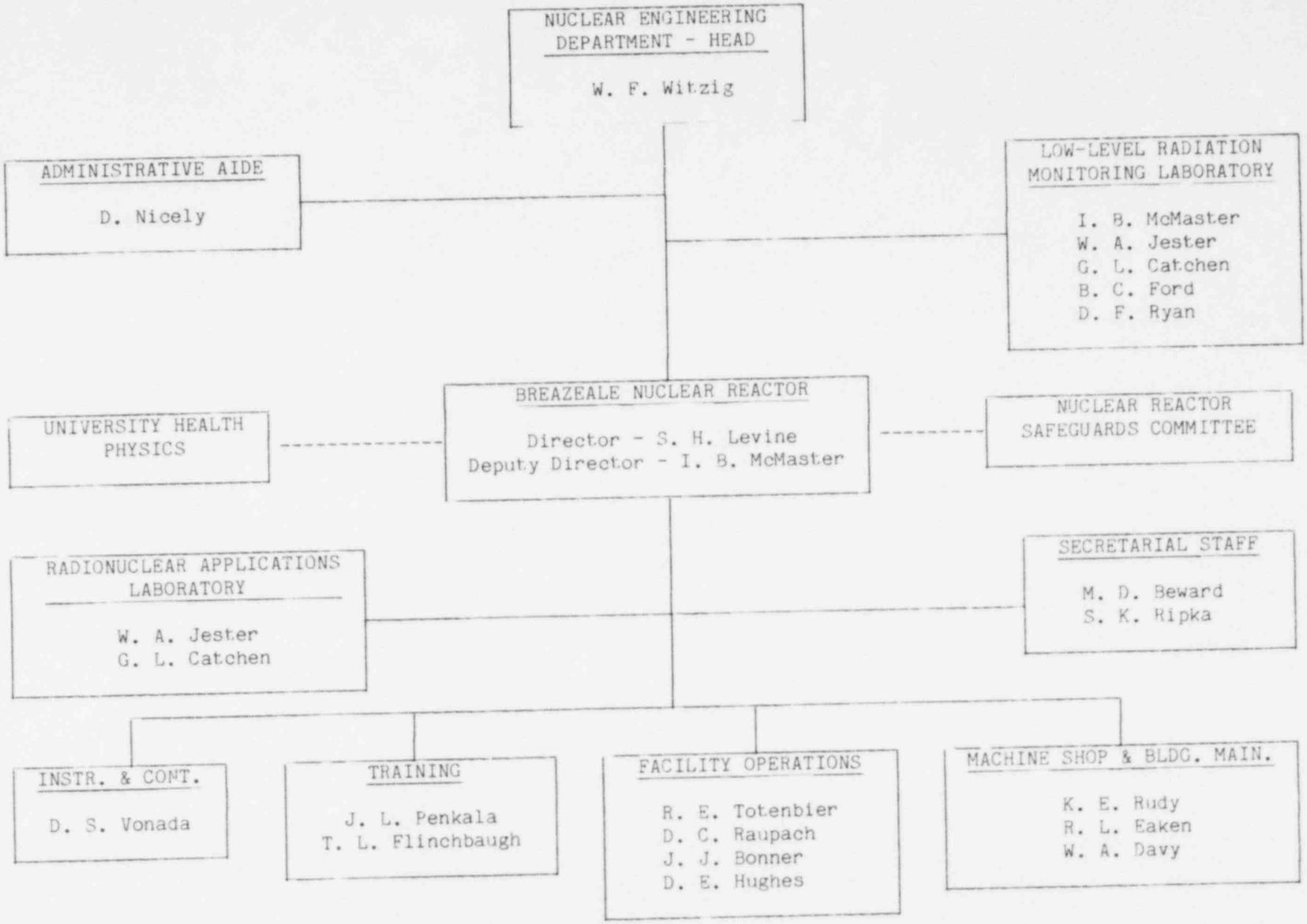
R. Rama	- Graduate Assistant
L. Shen	- Graduate Assistant
J. Siu Lam	- Graduate Assistant
W. Sutton	- Graduate Assistant
T. Tseng	- Graduate Assistant
C. Yu	- Graduate Assistant

Health Physics

E. C. Augustine	- Health Physics Assistant
W. T. Ford	- Health Physics Assistant
R. W. Granlund	- University Health Physicist
D. H. Hollenbach	- Health Physics Assistant

Nuclear Reactor Safeguards Committee

A. J. Baratta, Assistant Professor, Nuclear Engineering
J. A. Blakeslee, Health Physics/Chemistry Supervisor, PP&L Susquehanna Steam Electric Station
R. E. Bland, Associate Professor, Engineering Research, ARL (Chairman)
T. L. Flinchbaugh, Reactor Supervisor, Breazeale Nuclear Reactor (Acting Secretary)
R. W. Granlund, Health Physicist, Intercollege Research Programs and Facilities
H. R. Jacobs, Professor and Department Head, Mechanical Engineering
E. S. Kenney, Professor, Nuclear Engineering
S. S. Lestz, Professor, Mechanical Engineering
S. H. Levine, Professor and Director, Breazeale Nuclear Reactor (Ex-officio)
W. W. Miller, Professor Emeritus of Chemistry (Ex-officio)
D. A. Ross, Special Projects Director, General Public Utilities
R. E. Totenbier, Operations Supervisor, Breazeale Nuclear Reactor
D. White, Assistant Professor, Chemical Engineering



ORGANIZATION CHART
Figure 1

III. REACTOR FACILITY

Research reactor operation began at Penn State in 1955. In December of 1965 the original 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.

Research accounts for a large portion of reactor time which involves Radionuclear Applications, a myriad of research program by faculty and graduate students throughout the University, and various applications by the industrial sector.

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.

The PSBR core, containing about 7½ pounds of Uranium-235, in a form not applicable to nuclear weapons, 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 neutrol 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.

STATISTICAL ANALYSIS

Tables 2 and 3 list reactor operation and utilization data for the two year period from July 1, 1983 through June 30, 1985. Although there has been an increase in recent years in the use of the PSBR facility for industrial research, the categories of data collected in the past do not reflect such changes. Items like Hours Critical, and Energy Release have remained relatively stable because of the number of hours available rather than the ways in which the reactor was used. As of January 1, 1984, the method of collecting operation and utilization data was revised in order to provide more meaningful data, especially for review by the Penn State Reactor Safeguards Committee (PSRSC). Usage of the reactor while shut down, and while subcritical will be tabulated. Also, usage will be categorized into hours of use for Research and Service, Instruction and In-House Training, Utility Training Programs, Calibrations and Maintenance, and Fuel Adjustments. Since this data has been collected for only 18 months, no fair comparison of data with former years' is possible until two full years of data are collected under the revised method.

There are, however, a few items that have changed enough to warrent an explanation. The hours the reactor was critical dropped last year in roughly the same proportion that the hours approaching critical increased. These changes were due primarily to the types of utility training programs offered. More time was spent with the reactor in standby condition, than critical for the past year.

There was also a drop in the number of samples irradiated, but these samples were irradiated for longer periods as indicated by the rise in sample hours.

TABLE 2

Reactor Operation Data

January 1, 1983 - June 30, 1985

		83-84	84-85
A.	Hours of Critical Time		
	1. Hours Critical	575	492
	2. Approaching Critical	383	556
	3. Adjusting Fuel	41	67
B.	Number of Pulses	200	227
C.	Number of Square Waves	140	103
D.	Energy Release (MWH)	223	188
E.	Grams U-235 Consumed	11	10
F.	Number of Scrams		
	1. Planned as part of experiments	110	141
	2. Unplanned - resulting from		
	a) Personnel action*	14	15
	b) Abnormal system operation	6	2

* The majority of these resulted from operation by trainees

TABLE 3

Reactor Utilization Data
(average per shift)
July 1, 1983 - June 30, 1985

		83-84	84-85
A.	Number of Users	2.7	2.9
B.	Samples of Experiments		
	1. Pneumatic transfer samples	1.2	1.2
	2. Total number of samples	4.3	3.3
	3. Samples hours	1.2	1.6
C.	Reactor Usage (hours)		
	1. Total operation	2.2	1.9
	2. Shutdown in stand-by condition	2.1	2.2
	3. Total usage	4.3	4.1
	4. Subtotals		
	a) Educational usage	1.9	1.5
	b) Reactor operator training	1.2	1.4
	c) Calibration and maintenance	0.7	0.7
D.	Number of 8 hour shifts	267	256

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 July 1, 1985 total of 12,009 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 saple 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.

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 usual utilities.

Maximum exposure rates of 456 KR/Hr in a 3" ID Tube and 263 KR/Hr in a 6" ID tube are available as of July 1, 1985.

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.

Hot cells were used by 5 experimentors for a total of 65 hours.

Hot cell source #1/72 has an activity of 150 Ci as of July 1, 1985.

Table 4 compares the past two years utilization of the Cobalt-60 facility in terms of time, numbers and daily averages.

TABLE 4

COBALT-60 UTILIZATION DATA

July 1, 1983 - June 30, 1985

		83-84	84-85
A.	Time Involved (hours)		
	1. Set-up time	20	23
	2. Total sample hours	8,336	4,598
B.	Numbers Involved		
	1. Samples run	905	892
	2. Different experimenters	22	25
	3. Configurations used	3	3
C.	Per Day Averages		
	1. Experimenters	0.8	0.5
	2. Samples	2.2	3.4

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 manifested 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 were the guidance and supervision given to 18 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, T. L. Flinchbaugh, J. J. Bonner and D. E. Hughes, each of the NET students logged in a minimum of 16 safe and informative operating hours at the controls of the PSBR where they participated in all the routine operations which can be performed with the reactor. The lecture and experimentation portion of the NucE 814 course was taught by J. L. Penkala.

Rounding out the offerings of formal courses at the PSBR in the NET program, J. J. Bonner offered the lectures and conducted the laboratories in the Nuclear Technology Laboratory course, NucE 812, in which the reactor was used to generate radioisotopes.

During this past reporting period, the PSBR operating staff completed a total of twelve training programs lasting thirteen weeks involving sixty-three utility trainees.

A further accounting of the industrial training programs follows:

Seven one-week Start-up Experience and Subcriticality Programs for forty-two people from G.P.U. Nuclear. Labs were supervised by S. H. Levine and T. L. Flinchbaugh.

Two Research Reactor Training Programs and one Start-Up Experience Program for fourteen people from The Boston Edison Company. Special lectures and labs were offered in Water Chemistry and Radiological Safety by F. C. Helffrich, D. C. Raupach and R. W. Granlund. Additional Start-Up Experience Programs were offered for three people

from Philadelphia Electric Company and four people from Public Service Electric & Gas of New Jersey.

The Senior reactor operators on the PSBR staff, namely I. B. McMaster, R. E. Totenbier, D. C. Raupach, J. L. Penkala, T. L. Flinchbaugh, J. J. Bonner, and D. E. Hughes provided the start-up experience in all programs and the coordination of all programs was done by J. L. Penkala.

The inhouse training this past year consisted of a partial license requalification program and a reactor operator licensing program which culminated with D. E. Hughes receiving an instant Senior Reactor Operator's Liscense. The annual requalification program consisted of oral examinations on abnormal and emergency procedures which was conducted by T. L. Flinchbaugh.

The Nuclear Concepts and Energy Resources Institute (NCERI) was offered as NucE 497 for the fifteenth consecutive year during the Summer of 1984. The NCERI, a four-week institute, was attended by 17 high school science teachers and two continuing education people from five 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.

Dr. W. F. Witzig and C. Rusnak were co-directors of the institute. The major portion of the NCERI laboratory experiments was supervised by C. Rusnak assisted by J. J. Bonner. Messrs. D. H. Hollenbach and E. C. Augustine also helped in the laboratory exercises.

The institute is designed to prepare secondary science teachers to meet the academic needs of students in the fundamentals of nuclear physics, radiological health, and radionuclide applications in the physical and life sciences. Laboratory experience is an important aspect of the Institute as teaches are able to have hands-on experience working with radioactive material. Discussion and problem solving sessions along with a field trip to fossil and nuclear fueled electric generating stations are included in the program schedule. Over the fifteen years, a total of 456 teachers have participated in the institute.

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, 52

groups totaling 975 students participated in a full day of experimentation, observation, and touring at the PSBR. Ms. C. Hodes handled the scheduling of the lecturing to the high school tour groups with assistance from J. J. Bonner, D. Showers, and C. Rusnak. Table 5 summarizes the participation of the high school tour program.

The laboratory course NucE 451 was taught in the Fall 1984 semester by E. S. Kenney and W. A. Jester. The reactor was used for 100 hours by forty-five students with major assistance from the reactor operating crew. Also during Spring Semester 1985, E. S. Kenney taught NucE 445 for twelve students in which the reactor was used for twenty hours for various projects.

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 1984 Semester for 8 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.

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:

A small group of W. W. Pratt's Physics 559 students utilized the PSBR for several hours for their respective projects this past year.

A 15-minute Health Physics Orientation slide presentation was given to well over 300 people to familiarize visitors to the PSBR with some simple radiation concepts and the alarm and evacuation systems.

Eight students from the University of Pittsburgh enrolled in a Radiation Chemistry course used the PSBR for a demonstration of neutron activation analysis.

The Reactor Sharing Project sponsored by the Department of Energy entertained 10 college and university groups consisting of 93 students during the past reporting period (see Table 6 for a summary).

Approximately 40 University Police Services personnel were given training/retraining sessions by J. J. Bonner at the PSBR to ensure

familiarity with the facilities. Combined with this training was an orientation lecture by the Health Physics staff.

When the electronic experimentation equipment and the console instrumentation are always in operable condition, it is too easy to forget that it is D. S. Vonada who maintains the hardware and makes the hundreds of student instruction hours at the PSBR possible.

With well over 200 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 don'ts, the how's and how not's of reactor operations, irradiation services, and understanding of nuclear engineering in general and nuclear applications in particular through the spectrum of educational and training vehicles described in this report.

TABLE 5

High School Groups
CURE Projects at the Breazeale Nuclear Reactor
Sponsored by the United States Department of Energy
and the American Nuclear Society
1984-1985 Academic Year

Date	School & Teacher	Class Type & Number	Activities & BNR Instructor
11-5	Chartiers-Houston H. Wicker	Physics 12	ATC & Ag Decay Bonner
11-9	Keystone Oaks R. Tillack	Physics 8	ATC Bonner/Hodes
11-16	Danville M. McDevitt	Chemistry 12	ATC & Ag Decay Bonner/Hodes
11-21	Lower Dauphin V. Lyter	Nuclear Science 14	ATC & Ag Decay Hodes
11-29	Wyomissing Area C. Bell	Nuclear Science 14	ATC & Ag Decay Hodes
1-31	Curwensville Mr. Barnes	Chemistry 9	ATC & Ag Decay Hodes
2-4	Jersey Shore J. Allen	Nuclear Science 12	ATC & Ag Decay Hodes
2-11	Eastern Lebanon Mr. English	Nuclear Science 25	ATC & Ag Decay Hodes
2-21	Penns Valley D. Fineberg	Chemistry II 24	ATC & Tour Hodes
2-27	Shamokin Mr. Williams	Chemistry II 48	ATC & Ag Decay Hodes
2-28	Punxsutawney Mr. Stuchell	Chemistry II 18	ATC & Ag Decay Hodes
3-1	Farrell Mr. Foreman	Chemistry 15	ATC & Ag Decay Hodes
3-13	Bedford Mr. Turner	Nuclear Science 11	ATC & Ag Decay Hodes

3-13	Dover Mr. Lieb	Physics 9	ATC & Ag Decay Hodes
3-14	Ligonier Valley Mr. Mannion	Physics II 42	ATC & Ag Decay Hodes
3-19	Elkland Mr. Deats	Chemistry/Physics 41	ATC & Ag Decay Hodes/Rusnak
3-20	Salisbury(Allentown) Mr. Kirkendale/Porter	Chemistry/Physics 31	ATC & Ag Decay Hodes
3-26	Schuylkill Haven Mr. Porrino	Physics 15	ATC & Ag Decay Hodes
3-26	North Schuylkill Mr.Welker	Physics 15	ATC & Ag Decay Hodes
3-29	Valley Mr. Haser	Chemistry/Physics 37	ATC & Ag Decay Bonner/Hodes
4-3	Greater Johnstown Ms. Solarzyk	Chemistry 20	ATC & Ag Decay Hodes
4-4	NE Bradford Mr. Davis	Physics 9	ATC & Ag Decay Hodes
4-4	Clarion Mr.George	Chemistry 10	ATC & Ag Decay Hodes
4-9	Wellsboro Ms. Puskar/ Mr. Barty	Chemistry 30	LLRW & Ag Decay Hodes/Vincenti
4-10	Forbes Road Mr. Sprowl	Chemistry 18	LLRW & Tour Hodes/Vincenti
4-11	State College Mrs. Coilkosz	Chemistry 30	ATC & Ag Decay Hodes
4-12	St. Marys Mr. Scilingo	Chemistry 15	ATC & Ag Decay Hodes
4-12	Ridgeway Mr. Koos	Physics 15	ATC & Ag Decay Hodes
4-15	Belleville Mr. Bender	Chemistry 20	Tour Bonner
4-16	Bald-Eagle Nittany Mr. Laird	Chemistry 38	Ag Decay & Tour Hodes
4-17	Loyalsock Mr. German	Adv. Chem/Phys. 14	Ag Decay & Tour Hodes/Bonner

4-17	Shade Central Mr. Buben	Physics 4	ATC & Ag Decay Hodes/Bonner
4-18	Berwick Mr. Foster	Nuclear Science 8	ATC & Ag Decay Hodes
4-19	Blue Mt. Middle Ms. Cane	Gifted Program 6	Ag Decay & Tour Hodes
4-22	Harbor Creek	Nuclear Science 10	ATC & Ag Decay Bonner
4-23	Daniel Boone Mr. Tobias	Nuclear Science 9	ATC & Ag Decay Hodes
4-23	Palmyra Mr. Priebe	REM group 15	ATC & Ag Decay Hodes
4-24	Warren Area Mr. Szul	Nuclear Science 12	ATC & Ag Decay Hodes
4-26	Marion Center Mr. Petrosky	Nuclear Science 11	ATC & Ag Decay Hodes
4-26	Dallastown Mr. Landis	Nuclear Science 4	ATC & Ag Decay Hodes
4-29	Lackawanna Trail Ms. Yatco	Chemistry 34	Ag Decay & Tour Hodes
4-29	Bellefonte Mr. Tobias	Nuclear Science 8	ATC & Ag Decay Bonner
4-30	West Middlesex Mr. Ross	Chemistry 24	ATC & Ag Decay Hodes
5-1	George Washington Mr.Ettinger	Adv. Chemistry 45	Ag Decay & Tour Hodes
5-7	Greencastle/Antrim Mr. Monn	Nuclear Science 9	Ag Decay & Tour Hodes
5-14	Leechburg Mr. DePhillipi	Honor Society 18	Tour Hodes
5-20	North Hills Mr. Mikach	Chemistry/Physics 30	Ag Decay & Tour Hodes
5-22	Grier School	Chemistry/Physics 22	Tour Bonner
5-24	Muncy Mr.Grieco/Mr. Shrimp	Physics/Adv. Chemistry 12/8	Ag Decay & Tour Hodes

5-29	Salisbury Mr. Thomas	Physics 25	Ag Decay & Tour Hodes
5-30	Shippensburg Mr. Rebuck	Physics 8	ATC & Ag Decay Hodes
5-30	Olde Mill D. Householder	Nuclear Science 12	ATC & Ag Decay Bonner
Total	52 Schools	975 Students	

CURE: College Undergraduate Recruiting Effort
ATC: Approach to Critical Experiment
LLRW: Low-Level Radioactive Waste

VI. RADIONUCLEAR APPLICATIONS LABORATORY

The staff of the Radionuclear Applications Laboratory has continued to provide consulting and technical assistance to University research personnel who wish to utilize some type of radionuclear technique in their research. The majority of these research projects involve some sort of neutron activation procedure but the staff is also prepared, as they have been in the past, to provide services in such areas as radioactive tracer techniques, radiation gauging, radiation processing, and to provide radio isotopes for nuclear medical use.

Utilization of the laboratory has remained about the same as for the previous year. Some of the research projects which had been started the previous year are still in progress. A considerable portion of the services provided during the past year had to do with the identification and quantification of radio-isotopes in samples prior to their shipment from the facility.

Irradiation sciences and analytical procedures have continued to be performed for faculty and students. In many instances the researcher may have only a few samples a month to be analyzed and does not have the time or expertise to perform the analysis. These services are performed on a time-available basis. Examples of the types of sample analyses performed follow: quantification of rhodium, palladium iron, and cobalt on a carbon base; bromine, chlorine, and rhodium on polyethylene; platinum and palladium on silicon droxide; trace element identification and quantification in water samples.

Laboratory personnel have continued to provide technical assistance and to perform analyses of samples provided by several industries and research laboratories. The majority of these analyses involved some type of electronic components, i.e., diodes, transistors, integrated circuits, and silicon or germanium wafers.

A one-day workshop was conducted for members of a Health Physics class from the University of Pittsburgh. The workshop primarily demonstrated the analytical capability of neutron activation analysis and the safe handling of radioactive samples produced by the reactor.

Laboratory personnel continue to supply support for the operation of the reactor facility. Thermal and fast-neutron dosimetry is performed on

an as-needed basis, and flux mapping is performed for various irradiation facilities used for irradiating samples. Rad-waste water is analyzed for gamma-emitting radio-isotopes and air monitor filters are analyzed to determine the radio-isotopes deposited on them.

New laboratory equipment has just been received which will enhance the research capabilities and provide back-up instrumentation. A new large volume, high resolution, portable, intrinsic germanium detector has arrived which will be used in conjunction with a portable multi-channel analyzer and will make gamma-ray spectrum analysis possible outside the laboratory. New electronics have also been received to build another beta-particle counter to assist in flux monitoring and monitoring for radioactive contamination.

Laboratory personnel have developed a new laboratory experiment which has been used in conjunction with some of the nuclear utility training programs that are conducted at the facility. The experiment uses radio-isotopes produced at the facility to demonstrate the effectiveness of different types of ion exchange resins for removing cations and/or anions from radioactive feed water. The laboratory's multi-channel analyzer-computer-Ge(Li) detector system is used to peform the analytical work involved.

VII. LOW LEVEL RADIATION MONITORING LABORATORY

The Low Level Radiation Monitoring Laboratory (LLRML) has continued its expansion and growth in terms of staff, facilities, research and services performed.

Our staff has recently been expanded by the addition of a part-time analyst trainee, Patrick Boyle, who was a 1985 graduate of the Nuclear Engineering Department.

The analytical capacity of the LLRML has significantly increased this year through several major equipment purchases. A third High-Purity Germanium detector is on its way from ORTEC. And our existing Nuclear Data Model 66 Multi-Channel Analyzer system is being expanded by the addition of a Nuclear Data 680 computer and two more analog-to-digital converters, thereby doubling our existing gamma spectroscopy capabilities. When complete, this system will be interchangeable with the system currently in use at the Radionuclear Applications Laboratory.

Research projects this year have involved the investigation of a technique for the detection of radon-222 dissolved in water. This is a major concern to home owners in Pennsylvania, and there is no established procedure for the accurate detection of this naturally-occurring radioactive gas to date. Using the facilities of the LLRML, Eileen Supko, a Nuclear Engineering undergraduate student, chose to work on this topic as part of her senior project. Work is also underway to develop homogeneous gamma spectroscopy standards with densities both less than and greater than water. This will aid in the precise quantitating of radionuclides found in various types of environmental samples.

The LLRML continued its work for the Pennsylvania Power and Light Company (PP&L). For four years now we have been analyzing approximately 10 percent of the environmental samples collected from the vicinity of PP&L's Susquehanna Steam Electric Station at Berwick, Pennsylvania. This year, though, has seen an expansion in our range of services to PP&L. We are now preparing and analyzing spiked samples, using various media, that are then submitted to PP&L's principle analytical laboratory for analysis.

Related to this work is the gamma spectroscopy analyses we performed for the Academy of Natural Sciences of Philadelphia in cooperation with Emory University of Atlanta, Georgia. During the year, we have analyzed

139 environmental samples (mainly soil, vegetables and tree leaves) that were collected by the Academy at several garden locations around PP&L's Berwick plant. In order to plan this coming year's work for the Academy, and to view their facilities for the first time, two members of our staff along with PP&L and Academy representatives, traveled to Emory University in May of this year.

Additional services performed by the LLRML this year have included the analysis of about 170 drinking water samples for gross alpha activity as part of the Safe Drinking Water Act, and the analysis of some 25 water samples for radium-226 and radium-228 activity, and several for strontium-89 and strontium-90 activities. We have also assisted Drs. Levine and Catchen in the irradiation of approximately 1300 thermal luminescent detectors (TLD's) using the Health Physics Department's Cs-137 irradiation facility.

The administration of the Safe Drinking Water Act is in the process of being transferred from the United States Environmental Protection Agency (EPA) to the Pennsylvania Department of Environmental Resources (PADER). As one of the six laboratories in the eastern United States certified to perform radiological analysis on drinking water, this has meant some major changes for the LLRML. The laboratory has to once again apply for certification and be inspected by field representatives from PADER. We also must now be certified for all radiological parameters instead of just those we have a commercial interest in, as was the case with the EPA. Two members of our staff attended a workshop in Harrisburg this past April sponsored by PADER to inform all laboratories of the transition and the new requirements.

VIII. 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 authors under the various departments. Theses, publications and papers follow the research description to which they pertain. In addition, a section is provided with examples of industrial research utilizing the facility.

The facility cotinues to serve as a research tool available to all faculty, staff and graduate students of the various departments and colleges within the university. Forty-six faculty and staff members and 27 graduate students have used the facility in the past year for research. This represents a usage by 16 different departments or sections in 7 colleges of the University. In addition, 1 person from one other university and 20 individuals from 4 industries were involved in the research projects listed in this section. Names of the personnel involved in research using the facilities of the PSBR are arranged alphabetically under their college or company and departmental affiliations in Appendix A.

The following list of current research projects indicates the broad utilization enjoyed by the Breazeale Reactor Facility. The 24 projects described involve one bachelor's thesis, 5 master's thesis, 6 doctoral thesis, 11 publications, and 7 papers or reports. 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

Anthrolpology Department

PALEONUTRITION AT COPAN, HONDURAS

J. W. Hatch
R. A. Geidel

This research involves the nuetron activation analysis of nutritionally sensitive trace elements in human bone. Variations in the concentrations of these elements in skeletons representing members of various sub-groups within the prehistoric population of the Maya center at Copan, Honduras are expected to indicate dietary patterns which reflect the demographic structure and complex social order of the Maya.

Both the Rabbit pneumatic transfer system and the central thimble oscillator are used to conduct irradiations for this research. Soil samples associated with the burials will also be analyzed for evidence of the effects of diagenetic contamination and/or leaching of trace elements between the buried skeletons and their soil matrix.

Doctoral Thesis

"Paleonutrition and Social Organization at Copan, Honduras," Geidel, Richard A., Ph.D. dissertation, expected date of completion, 1986, Department of Anthropology, J. W. Hatch, advisor.

Publication

"Status-specific Dietary Variation in Two New World Cultures," J. W. Hatch and R. A. Geidel, J. of Human Evol., 1985, in press.

Paper

"Paleonutrition and Social Stratification," R. A. Geidel and J. W. Hatch, paper delivered at the annual meeting of the American Anthropological Association, Chicago, Illinois, 1983.

Biology Department

THE EFFECT OF ACIDIC PRECIPITATION ON TEMPORARY POND BREEDING AMPHIBIANS IN PENNSYLVANIA

W. A. Dunson
J. Freda

We have used Na-24 generated at the reactor to investigate the physiological effects of low pH water on larval amphibians. We have found that acidic water inhibits active uptake of sodium and causes a massive

acceleration in sodium efflux. Animals die when 50% of the total body sodium pool is lost and differences in the rate of loss account for inter- and intra-specific variation in tolerance to low pH water.

Doctoral Thesis

"The Effect of Low pH Water on Amphibians," Freda, J., Ph.D. thesis, Fall 1985, Ecology Program, Biology Department, W. A. Dunson, advisor.

Paper

"Field and Laboratory Studies of Ion Balance and Growth Rates of Ranid Tadpoles Chronically Exposed to Low pH," J. Freda and W. A. Dunson, Copeia, 1985, 415-423.

Biology Department

THE EFFECTS OF LOW pH AND WATER HARDNESS ON SODIUM INFLUX AND EFFLUX, AND ON BODY AND PLASMA SODIUM CONCENTRATIONS OF AN ACID TOLERANT SUNFISH

W. Dunson
R. Gonzalez

The effects of low pH and water hardness on sodium influx and efflux, and on body and plasma sodium concentrations of an acid tolerant sunfish (Enneacanthus obesus) were examined. The effects of humic compounds on body sodium concentration were also studied. 1) Sodium influx in E. obesus showed no less inhibition by low pH than in the low pH intolerant salmonids. 2) Sodium efflux, in contrast, underwent less stimulation at low pH's. It remained at control levels of pH 3.5 and above. After prolonged exposure to pH 3.5, sodium efflux even declined below control levels. 3) Sodium efflux of sunfish in hard State College tap water (TW) was accelerated less at pH 3.0 than when they were placed in artificial soft water (ASW). 4) Plasma sodium concentrations remained unchanged during chronic exposure to pH 3.5 while body sodium concentration showed a transitory depression. 5) After two weeks of exposure to TW, body sodium concentration was elevated, and no significant body sodium depression resulted during subsequent chronic exposure to pH 3.25 bog water (BW). 6) The presence of humic acids in Webb's Mill BW had no additional effect on body sodium concentration at pH 3.5 other than that observed in ASW at the same pH.

Biology Department

IONIC REGULATION IN THE PREDACEOUS DIVING BEETLE, DYTISCUS VERTICALIS (SAY) (COLEOPTERA: DYTISCIDAE)

W. A. Dunson
M. P. Frisbie

Relatively little research has been conducted investigating the ion regulatory capabilities of air-breathing aquatic insects. Sytiscus verticalis adults and larvae are abundant predators in many small and temporary pond habitats in central Pennsylvania. Indeed, they may often be the most important top carnivore in these ponds. Adults live several years and remain active in the water throughout the winter. Because the major food source in these small ponds is larval amphibians, dytiscid adults face a huge variation in available food resources: abundant in the spring and diminished in the fall and winter after most amphibians have metamorphosed.

This project seeks to (1) characterize the basic ion regulatory capabilities of both D. verticalis adults and larvae, with particular emphasis on the major hemolymph cation, sodium, (2) study the relationship between feeding rate and body sodium levels, and (3) investigate the ionic and energetic response of field individuals to fluctuating food resources.

The Breazeale Reactor has provided ^{24}Na which has been used in the lab to determine sodium influx and efflux rates of larvae and adults under various environmental conditions.

Biology-Chemistry Department

EQUILIBRIUM ISOTOPE EXCHANGE STUDIES ON ASPARTATE TRANSCARBAMYLASE

F. C. Wedler
G. K. Farrington

In this study, an attempt was made to synthesize P^{32} labeled carbamyl-phosphate. However, the reaction failed to give the desired product.

Chemical Engineering Department

CO OXIDATION CATALYSTS

M. A. Vannice
K. I. Choi

This study was conducted to measure the contents of Pd and Cn weights in Aqua Rega solutions by Nuclear Activation Analysis.

Chemical Engineering Department

IONIC DIFFUSION IN CONCENTRATED ELECTROLYTES

E. E. Graham
F. Helfferich
N. de Gouvea Pinto

Radionuclides are used to measure the rate of diffusion of ions within ion-exchange resin. The total ionic concentration in the ion-exchange resin is 3-4M. At these high concentration ion-ion interactions are important and affect the diffusion process. The use of radioactive tracers will allow one to measure the diffusion coefficient as a function of ionic concentration and ionic species. From this data the ion-ion interaction effects can be determined and related to the Stefan-Maxwell coefficients. The Stefan-Maxwell coefficients can then be used to provide a general correlation for the diffusion of ionic species at high electrolytes concentrations.

Doctoral Thesis

"Ionic Diffusion in Concentrated Electrolytes," de Gouvea Pinto, Neville, Ph.D. Thesis, 1985, Chemical Engineering Department, E. E. Graham, advisor.

Dairy & Animal Science Department

DETERMINATION OF PARTICULATE DIGESTA FLOW AND NUTRIENT DIGESTIBILITY IN RUMINANT ANIMALS

L. D. Muller
T. F. Sweeney

The use of rare earth elements as digesta markers attached to feedstuffs has been receiving attention as a means of estimating feedstuff retention time and rate of passage in the digestive tract of ruminants. Rare-earths are desirable as ingesta markers because they are not absorbed from the gastrointestinal tract and possess strong binding properties for particulate matter. The required analytical sensitivity for measuring these rare-earths is available through neutron activation analysis.

Several markers have been used including La, Sm, Ce, Yb, and Co-EDTA. These markers have been attached to fibrous, grain, and liquid fractions and placed into the digestive tract. Subsequent fecal samples taken at time intervals are then analyzed at the Penn State Breazeale Reactor facility. The Neutron Activation Analysis allows us to obtain various measurements in large ruminant animals using nonradioactive elements, and has the advantages of sensitivity, ease of sample preparation, and simultaneous analysis of several rare-earth markers. The use of these techniques and the data obtained from these studies will provide us with a better understanding of the digestive processes in ruminants. Ultimately, we can then modify the digestion and nutrient utilization to improve animal performance and productivity.

Analyses are completed from four studies and will be continued on a fifth study.

Master Thesis

"Effects of Dietary Synthetic Zeolite A on Performance of Lactating Dairy Cows," Johnson, Melanie A., Master Thesis, 1985, Dairy & Animal Science Department, T. F. Sweeney, advisor.

Publications

"Digesta Passage Measured by Markers in Dairy Cows Fed Two Ratios of Corn Silage: Grain with 0 or 1.2% Sodium Bicarbonate," T. J. Snyder, L. D. Muller, J. A. Rogers, and S. M. Abrams, J. Dairy Sci., 67:1953-64, 1984.

"Milk Production, Nutrient Digestion, and Rate of Digestion Passage in Dairy Cows Fed Long or Chopped Alfalfa Hay Supplemented with Sodium Bicarbonate," J.A. Rogers, L.D. Muller, T.J. Snyder, and T.L. Maddox, J. Dairy Sci., 68:868-880, 1985.

Ecology Department

ECOLOGY OF THE PINE BARRENS TREEFROG (*HYLA ANDERSONI*)

J. Freda
W. A. Dunson
R. Gonzalez

The reactor was used to make Cr-51 which was used to follow the movements of the endangered pine barrens treefrog. I found that treefrogs were capable of daily movements greater than the area currently provided around ponds as a buffer zone against disturbance.

Technical Report

"Adult Home Range of the Pine Barrens Treefrog (*Hyla andersoni*) and the Physical, Chemical, and Ecological Characteristics of its Preferred Breeding Ponds," J. Freda and P. J. Morin, Division of Pinelands Research, Rutgers University, New Brunswick, N.J. 08903.

Nuclear Engineering Department

ANALYSIS OF ARGENTINE URANIUM SAMPLES

W. A. Jester
D. Raupach

Three samples sent from Dr. Pepe Lolich of the Instituto Balseiro, Centro Atomico Bariloche, Argentina were analyzed for their uranium content

using the reactor facilities, pool-side rabbit, and delayed neutron counting system. An olivine blank and two uranium standards, G-2 and SV-1, obtained from the Geo-Chemistry Department were used to obtain quantative information on these samples.

Publications

"Technique for Preparing a Continuous Interference-Free Stream of Argon-41 in Air," W. A. Jester and T. Tseng, Nuc. Tech., 65-2:350-353,1984.

"Utilization of a TRIGA Reactor as a Test Facility for a Pressure Vessel Water Level Gauge," W. A. Jester, E. W. Okyere, and A. J. Baratta, Atom Kernenergie-Kerntechmik, 44:467-473, 1984.

"Identification of Inadequate Core Cooling Utilization," W. A. Jester, A. J. Baratta, M. Gundy, E. W. Okyere, and T. Gillen, NUREG/CP-0058, 1:274-281, October 1984.

"Water Level Measurement Using Fast Neutron Detectors," W, A. Jester, A. J. Baratta, E. W. Okyere, G. Imel, and M. Gundy, Proceedings of Nuclear Thermal Hydraulics, 1983 Winter Meeting, 1:263-268, 1984.

Paper

"Identification of Inadequate Core Cooling Utilizing Existing Ex-core Neutron Detectors," W. A. Jester, A. J. Baratta, M. Gundy, E. W. Okyere, and T. Gillen, Twelfth Water Reactor Safety Research Meeting, Gaithersburg, MD, October 23, 1984.

Nuclear Engineering Department

COOLANT VOID FRACTION DETERMINATION, AN ULTRASOUND TECHNIQUE

G. Robinson
A. J. Baratta
T. Hughes
M. Murphy

This project examines the use of a pulsed ultrasonic system for the detection of void fraction in two phase flow. The device used was developed by Micro Pure Systems, Inc. as a means of detecting microparticles and microbubbles in blood and plasma during flow through an extracorporeal system. It has been successfully adapted to several industrial applications.

To date, flow regime identification and some quantification of the flow field have been successfully completed. The project is proceeding on schedule.

Reactor facilities being used for the experiment include the lab (Room 1-B) and the machine shop. There is no plan to use the reactor in this experiment.

Nuclear Engineering Department

THE DEVELOPMENT AND EVALUATION OF A SWEEP GAS PRODUCTION AND RADIOASSAY SYSTEM FOR IN-PILE GENERATED TRITIUM

W. S. Diethorn
S. K. Skiles

In the evaluation of fusion reactor concepts, the importance of information on tritium release from lithium compounds is generally recognized. This thesis reports the development and evaluation of a sweep gas and radioassay system for in-pile generated tritium, an essential tool in the study of tritium release from lithium compounds during irradiation.

The system, consisting of two parts,an in-pile apparatus and a pool-side radioassay system, was designed, built, and operated at the PSBR facility. Tritium produced by the $^{6}Li(n,d)^{3}H$ reaction in powdered lithium oxalate is deposited in a sweep gas and carried to the pool-side radioassay system where it is measured by a flow-through ionization chamber with electrometer. The sweep gas is then passed through two catalytic oxidizers, and tritium is removed from the gas by a tritium recovery system.

Experiments were performed with the PSBR reactor operating in the steady-state mode or the pulse mode. The results of these experiments indicate that the sweep gas and radioassay system performs satisfactorily and encourages its use in an investigation of in-pile tritium release from lithium compounds.

Master Thesis

"The Development and Evaluation of a Sweep Gas Production and Radioassay System for In-Pile Generated Tritium," Skiles, S. K., Master, Thesis, 1985, Nuclear Engineering Department, W. S. Diethorn, advisor.

Talk/Paper

"Radioassay of Sweep Gas Tritium During In-Pile Generation," S. K. Skiles and W. S. Diethorn, Amer. Nuc. Society - Second National Topical Meeting; Tritium Tech. in Fission, Fusion and Isotopic Applications, April 1985.

Publication

"Radioassay of Sweep Gas Tritium During In-Pile Generation," S. K. Skiles and W. S. Diethorn, Fusion Tech., 1985, in press.

Nuclear Engineering Department

BETA DOSIMETRY

S. H. Levine
G. L. Catchen
L. Shen

Research on beta-ray dosimetry in a background of gamma radiation is being performed in support of PP&L's health physics program at the Susquehanna BWR in Berwick, Pennsylvania. A beta dosimetry laboratory has been established and used to provide accurate calibrated doses for different beta spectra. A special vacuum chamber was constructed for performing the beta measurements and an extrapolation chamber is used to determine the skin dose. A new method is being developed to determine the skin dose and depth dose distribution due to beta rays. This method uses a standard packet of four TLD's in a dosimeter badge, each TLD covered with a shield of a different thickness to give the basic dose measurement. The data is then fitted with two component beta spectra based on Monte Carlo calculations. An optimization program chooses the correct component data. Experimental verification for the skin dose is performed with the extrapolation chamber.

Doctoral Thesis

"Optimization Method in Beta Dose Measurement with TLD," L. Shen, Ph.D. Thesis, 1985, Nuclear Engineering Department. S. H. Levine, G. Catchen, advisors.

Nuclear Engineering Department

RELATING TRIGA FUEL TEMPERATURE MEASUREMETNS TO TRIGA PHYSICAL PARAMETERS

S. H. Levine
D. E. Hughes

A series of experiments have been performed at PSBR with an unused instrumented 12 wt% U TRIGA fuel element to provide fuel temperature data at various power levels during steady state and pulse operation. These data were used to develop a relationship between the fuel temperature distribution and the power density during full power steady state and pulse operation. The results provide a calibrated instrumented 12 wt% fuel element that can be used in the future to determine the maximum power density at any core position during steady state operation. Once the power density is determined, the maximum fuel temperature during a pulse, the most critical operational parameter, can be predicted for any core configuration and core position. This ensures that the maximum fuel temperature will be within technical specifications for any configuration that is used.

During the next year, we will be continuing to collect data to improve our results.

Paper

"Relating TRIGA Fuel Temperature Measurements to TRIGA Physical Parameters," S. H. Levine and D. E. Hughes. Invited paper to the 1985 ANS Winter meeting in San Francisco.

Nuclear Engineering Department

NEUTRON RADIOGRAPHY

S. H. Levine
D. E. Hughes
K. E. Rudy
R. L. Eaken
L. Pilione
A. Siu
P. Hartley
R. Meyer

Neutron radiography, as a non-destructive testing method, can give valuable information which can not be obtained using gamma or X-ray radiogrpahy. We have been using the BNR as an intense thermal neutron source for neutron radiography.

During this year, the most significant activity has been with the R&D project entitled "Development of Real-Time Neutron Radiography for Improving the Design of the Gas Spring". This is a Ben Franklin Partnership with Gas Spring Company, Colmar, PA.

To date we have imrpoved our facilities in the beam hole laboratory with the addition of a Precise Optics neutron image intensifier which gives us real time capability. We have also purchased a video image processing system which is based on a Zenith 151 PC with a PC-Vision Frame Grabber peripherial. This equipment has greatly increased our marketability for industry and versitility for research and education.

We have continued to work wiht still neutron radiography. As a result, we have extended our capability to the direct film method using a gadolinium converter. Also with the help of Dr. L. Pilione, we are developing still neutron radiography using the nitro-celluolose etch track method. The latter technique has the advantage of high resolution while not being degaded with gamma background.

In order to attact more funding from industry, PSBR is having a three-day workshop on Real-Time Neutron Radiography in October. The speakers at this workshop will ɜe Dr. Harold Berger of Quality Inc.; Dr. S. H. Levine of PSBR, PSU; Dr. R. Kasturi of Electric Engineering, PSU; Dr. J. Sommer of Mechanical Engineering, PSU; Vijay Alreja of Precise Optics; and Daniel Hughes a PSBR Senior Operator.

Our emphasis in the coming year will be to further develop techniques in both real-time and still neutron radiography and video image processing. In addition, we are working to improve our neutron intensity and beam purity with design changes of the collimatory and D_2O.

Nuclear Engineering Department

DEVELOPMENT OF AN ASYMMETRIC MULTIPLE POSITION NEUTRON SOURCE (AMPNS) METHOD FOR MONITORING THE CRITICALITY OF THE DEGRADED CORE

S. H. Levine
S. S. Kim

An analytical/experimental method has been developed to monitor the subcritical reactivity and unfold the k_∞ distribution of a degraded reactor core. The method uses several fixed neutron detectors and a Cf-252 neutron source placed sequentially in multiple positions in the core. Therefore, it is called the Asymmetric Mutliple Position Neutron Source (AMPNS) method.

The AMPNS method employs the nucleonic codes to analyze the neutron multiplication of a Cf-252 neutron source. The method uses the tilt independent asymmetric count rate ratios of two neutron detectors positioned at opposite sides of the core to determine the core k_{eff}. An optimization program, GPM, has been utilized to unfold the k_∞ distribution of the degraded core, in which the desired performance measurement minimizes the error between the calculated and the measured count rates of the degraded reactor core. This latter technique will identify hot spots within the core.

The analytical/experimental approach has been validated by performing two dimensional experiments and calculations using the Penn State Breazeale TRIGA Reactor (PSBR). The experiments involved supercritical, critical and subcritical cores. A comparison of the experimental data with the analytical results showed good agreement, indicating the analytical model of the core used is valid.

Several test runs of optimization calculations have been made on the PSBR core assuming one of the subcritical configurations is a damaged core. Test runs of the AMPNS method revealed that when the core cell size and source position are correctly chosen, the solution converges to the correct k_{eff} and k_∞ distribution without any oscillations or instabilities.

A significant result of this study has been to provide a simpled, practical means to plan the source and detector placements and assign core cells to the damaged TMI-2 core as well as to monitor its k_{eff} during the recovery period.

Publications

"The Assymetric Multiple-Position Neutron Source (AMPNS) Method Using the TRIGA Reactor," S. S. Kim and S. H. Levine, Trans. Amer. Nucl. Soc., Y739, Vol. 46, June 1984.

"Development of An Asymmetric Multiple-Position Neutron Source (AMPNS) Method to Montor the Criticality of a Degraded Reactor Core," S. H. Levine and S. S. Kim, Amer. Nucl. Energy, 1985, in press.

Paper

"Development of An Asymmetric Multiple-Position Neutron Source (AMPNS) Method to Monitor the Criticality of a Degraded Reactor Core," S. H. Levine and S. S. Kim, Invited Paper Proceedings of the Workshop on Subcritical Measurements, Albuquerque, N.M., to be presented in August 1985.

Nuclear Engineering Department

DYNAMIC RADIOGRAPHY

E. S. Kenney
L. McDaniel

Characteristic X-rays from stable iodine produced by conventional X-ray generators has been proposed as a non-radioactive tracer in cardiac studies. The characteristic X-rays have energies of only about 30 keV. The k-α and k-β X-rays differ only slightly in energies. Because of the low energies involved, it was supposed that differential attenuation would allow quantitative estimates of deep deposits of iodine in the human heart. Results of our tests indicate that this would be a marginal technique, at best. Triangulation methods still look promising for localization of deposited iodine.

Bachelor Thesis

"A Quantitative Study of X-ray Fluorescence and Its Application to Cardiac Imaging," B.S., Thesis, 1985, Engineering Science and Mechanics Department, E. S. Kenney, advisor.

Nuclear Engineering Department

REACTOR INSTRUMENTATION AND CONTROL STUDIES

E. S. Kenney
C. Els

This project was directed towards understanding reactor instrumentation and control interfacing to microcomputers. An IBM PC at the PSBR was used to acquire data via a 23 bit A/D, D/A converter. Reactor signal analysis via statistical and frequency filters was performed. Interfacing problems to plotters and printers was done for data output. Graphing routines were developed for rod drive indication.

Master Thesis

"Survey of Control and Instrumentation Progress on PWR's," C. Els, Master of Engineering, expected date of completion 1985, Nuclear Engineering Department, E. S. Kenney, advisor.

Nuclear Engineering Department

REACTOR NOISE ANALYSIS USING ACOUSTICAL TECHNIQUES

E. S. Kenney
M. Geleshe

The behavior of reactor noise relative to space and time suggested a stronger integration of acoustical techniques and procedures to interpretation of this behavior. Reactor neutron noise has been heavily studied but is only lightly used in industry, in part because it appears to represent an overly complex subject. With a view towards providing insight from a parallel study area, we have begun a program of comparative analysis to transfer tools and techniques from acoustics to reactor noise analysis.

At the time, we are rewriting a noise analysis software program to incorporate standard procedures. The present program works in Compiled Basic but has very little versatility to handle new output devices or computer graphics.

When the software has been improved, a study will be made of the spatial dependence of noise about the PSBR core to provide a data base for testing acoustical field concepts.

Nuclear Engineering Department

SEMI-CONDUCTOR IRRADIATION AND TESTING

E. S. Kenney
A. J. Baratta
B. Palmer
M. Willis

Modern semi-conductors have been successfully hardened against high gamma-ray exposures. This technology has advanced to the point where high energy neutron effects may be very important for postulated service environments. Testing equipment has been assembled to actively evaluate static RAM's and FET's under irradiation. The equipment measures changing performance as the accumulated exposure occurs.

A major part of this work included neutron and gamma-ray dosimetry in enriched neutron fields. A major problem was found in trying to quantitate gamma fields in the presence of large high energy neutron fields. This was solved using a Xenon filled-ion chamber. Secondary reactions caused air and nitrogen chambers to over estimate the field. Similar problems occurred using Li-7 and normal TLD's.

Nuclear Engineering Department

TRITIUM TRANSPORT THROUGH NEUTRON-IRRADIATED INORGANIC LITHIUM COMPOUNDS

G. L. Catchen
B. Campbell

Tritium was bred in Li_2O via the reaction $^{6}Li(n,d)^{3}H$ at The PSBR. The subsequent removal of ^{3}H was studied at various temperatures for three different concentrations of an impurity phase (LiOH) from several different particle sizes (range 1.9 to 9μm in diameter). The release rates of ^{3}H were analyzed, yielding diffusion coefficients, activation energies, and other information consistent with previous literature on this subject. The results of this work shall be published.

Master Thesis

"A Study of ^{3}H Transport in Neutron-Irradiated Li_2O as a Function of Sample Purity, Particle Size, and Temperature," Campbell, B. C., Master, Thesis, 1985, Nuclear Engineering Department, G. L. Catchen, advisor.

Physics Department

ARGON CONTENT OF SPUTTERED AMORPHOUS GERMANIUM THIN FILMS

L. J. Pilione
J. S. Lannin
N. Maley

Thin films (≤10 microns) of amorphous germanium have been prepared by rf and dc sputtering at an argon pressure of 5m Torr. The incorporation of argon into the growing film during the deposition process could affect the optical properties (ε_1, ε_2) of the germanium. We have determined the argon to germanium ratio in several films by neutron activation analysis and have found the atomic concentration of argon to be ≤4%. The optical spectra for these films were determined from the ultraviolet to the infrared with no discernable difference observed with argon content.

Polymer Science

POLYMER-SUPPORTED CATALYSTS

I. R. Harrison
B. G. Gordon, III
J. S. Butler

In recent years polymers have been utilized as binding sites for transition metal catalysts (e.g., cross-linked polystyrene seeds). However, general problems exist with the above system. Recently a new

system has been developed whereby tris (trephenyl phosphine) chlororhodium (Wilkinson's catalyst) is bound to the surface of polyethylene single crystals. In order to prepare the polyethylene single crystals for catalyst support, several reactions must be carried out. For example, the sample must be (1) brominated (leaving bromine atoms on the surface), (2) phosphinated (substitutes diphenyl phosphine groups for the bromine atoms), and finally (3) catalyst additive step (whereby the catalyst is bound to the surface). In order to follow the progress of the reactions, samples from each reaction step are sent to the PSBR for neutron activation analysis of bromine and rhodium.

Currently we are involved in supporting Wilkinson's catalyst on other polyethylene supports such as polyethylene spectramesh and polyethylene hollow fibers.

Master Theses

"Surface Modification of PE Single Crystals," Butler, J. S., Master, Thesis, 1983, Polymer Science Department, I. R. Harrison and B. Gordon, III, advisors.

Doctoral Thesis

"Polymer-Supported Catalysts," J. Butler, expected date of completion 1985, Polymer Science Department, I. R. Harrison and B. Gordon, III, advisors.

Publication

"Preparation and Hydrogenation Studies of Rhodium (I) Catalyst Supported on Polymer Crystalline Surfaces," B. G. Gordon, III, J. S. Butler, and I. R. Harrison, J. Polymer Sci., Polymer Chem. Ed., 23:19-26, 1985.

Solid State Science Department

SWITCHING IN FERROIC CRYSTALS

R. E. Newnham
L. E. Cross
S. M. Shiau

This project involves the investigation of pinning of domain walls due to lattice defects caused by irradiation.

Induced Dauphine' twinning in Quartz is being studied as a function of coercive stress, temperature, and irradiation. Practical reasons for this study include:

1) Processing of quartz requires heating and stress; twins cause reversal of piezoelectric coefficient.
2) Oil well pressure and temperature changes can cause twinning.
3) It is hoped that irradiation will prevent twinning.

Doctoral Thesis

"Ferrobielastic Twinning in Quartz," Shiau, S. M., Ph.D., Solid State Science Department, R. E. Newnham, advisor.

B. INDUSTRIAL RESEARCH UTILIZING THE FACILITIES OF THE PENN STATE BREAZEALE NUCLEAR REACTOR

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

Gas Spring Company

Lawther O. Smith, President
Franz Kautz, Manager Product Engineering
Jim Snyder, Manager Reliability Assurance

Gas Spring Company makes pneumatic springs which considerably reduce the cost and weight and increase the fuel efficiency of vehicles into which they are engineered. They have stated the following:

"With the ever expanding applications for this product, our development efforts reached an impasse in trying to measure the location of oil inside permanently sealed steel components.

The Personnel at the Penn State Breazeale Reactor facility together with those listed above of Gas Spring Company, made some tests using neutron radiography. The results gave us information otherwise unavailable upon which we based modifications of our manufacturing processes. In fact, we hope to expand the capability with PSBR later this year to widen the applications appropriate to our use of this unique facility."

Lawrence Livermore National Laboratory

D. L. Redhead
D. E. Smith
M. J. Moran

Personnel of the Lawrence Livermore National Laboratory have made the following statement:

"We have been able to verify, through the use of your exceptionally clean beam of Thermal Neutrons, the sensitivity of our "Fission Foil Detectors". We use these detectors to determine the neutron spectral output and magnitude of the various nuclear devices tested at the Nevada Test Site. Our staff has applied these detectors with rather outstanding success."

Raytheon Company

R. N. Diette

Raytheon has made extensive use of the Penn State Breazeale Reactor facility over the past year. In the words of Mr. Diette, "The purpose of our studies is to predict the response of semiconductor devices and electronic circuits to neutron environments. Experiments to analyze the

resultant damage mechanisms are being required by an increasing number of programs. Nuclear vulnerability studies for radar, communications and missile systems applications utilize the reactor to establish the necessary damage coefficients."

Raytheon Company

D. F. Stransky, Jr.

Raytheon's use of the Breazeale Nuclear Reactor has consisted of the passive exposure of electronic devices (diodes, transistors, integrated circuits, etc.) to various neutron fluence levels. The purpose of these irradiations is to determine the response of these electronic devices to neutron environments. Nuclear vulnerability research such as this is used to establish damage constants for use in present and future designs of radiation tolerant electronic systems.

Raytheon Company

M. W. Worthington, Associate Engineer
J. Weckback, Section Manager
B. Schupp, Group Leader
M. Pieper
D. Lee
J. Izquierdo
M. Rearwin
R. Cotton

"Our testing is exclusively of electronic devices in support of various military communications systems programs, as part of our overall function of hardening these systems in the nuclear environments. Over the past year, we have tested numerous devices at several fluences; including: op amps, SCRs, DACs, line drivers and receivers, various custom ICs, comparators, voltage references, voltage regulators, voltage followers, pulse width modulators, optocouplers, discrete bipolar transistors, darlington pairs, and differential amplifiers. The bulk of our testing at Breazeale involves linear bipolar devices."

APPENDIX A

Personnel involved in research utilizing the facilities of the Penn State Breazeale Reactor.

COLLEGE OF AGRICULTURE

Dairy & Animal Science

Abrams, Stephen M.
Research Animal Scientist

Johnson, Melaine A., B.S.
Graduate Assistant

Leslie, Lu A., B.S.
Research Technician

Muller, Lawrence D., Ph.D.
Professor

Sweeney, Thomas F., Ph.D.
Assistant Professor

COLLEGE OF EARTH & MINERAL SCIENCE

Materials Science

Gordon, Bernard G., Ph.D.
Asst. Prof. of Polymer Science

Harrison, Ian R., Ph.D.
Prof. of Polymer Science

Polymer Science

Butler, Jacquelin, M.S.
Research Assistant

COLLEGE OF ENGINEERING

Chemical Engineering

Choi, K.I., M.S.
Graduate Student

Graham, E. Earl, Ph.D.
Associate Professor

Helfferich, Friedrich G., Ph.D.
Professor

Pinto, NeVille de Gouvea, M.S.
Graduate Student

Vannice, M. Albert, Ph.D.
Professor

Electrical Engineering

Cross, L.E., Ph.D.
Professor

Engineering Sciences

McDoniel, Lisa
Undergraduate Student

Nuclear Engineering

Baratta, Anthony J., Ph.S.
Associate Professor

Bonner, Joseph Jr., M.S.
Affiliate Instructor

Campbell, Brian, M.S.
Graduate Student

Catchen, Gary L., Ph.D.
Assistant Professor

Diethorn, Ward S., Ph.D
Professor

Eaken, Ronald L.
Experimental & Maintenance
Mechanic

Els, Chrisstian, B.S.
Graduate Student

Flinchbaugh, Terry L.
Nuclear Education Specialist

Foderaro, Anthony H., Ph.D.
Professor

Ford, Bonnie C., B.S.
Environmental Analyst

Gillen, Thomas J., M.S.
Graduate Student

Gundy, L.M., M.S.
Graduate Student

Hartley, Paula
Undergraduate Student

Huegel, David S., B.S.
Graduate Student

Hughes, Dan S., B.S.
Education Specialist

Imel, George R., Ph.D.
Assistant Professor

Kenney, Edward S., Ph.D.
Professor

Maley, N., B.S.
Graduate Student

McMaster, Ira B., B.S.
Research Asst. and Deputy Director
Breazeale Nuclear Reactor

Murphy, Michael, B.S.
Graduate Student

Okyere, Ebenezer W., M.S.
Graduate Assistant

Palmer, Brian, B.S.
Graduate Student

Penkala, John L., B.S.
Research Assistant
Training Coordinator

Raupach, Dale C., B.S.
Reactor Utility Specialist

Robinson, Gordon, E., Ph.D.
Associate Professor

Rudy, Kenneth E.
Senior Engineering Aide

Shen, Li, B.S.
Graduate Student

Shillenn, James K., B.S.
Coordinator, Energy Tech Projects

Siu, Alberto, B.S.
Graduate Student

Skiles, Samuel K., M.S.
Graduate Student

Totenbier, Robert E., B.S.
Research Asst. and Operator Super.
Breazeale Nuclear Reactor

Tseng, Tung-Tse, M.S.
Graduate Assistant

Voth, Marcus H., M.S.
Instructor

Kim, Soon S., M.S.
Graduate Assistant

Levine, Samuel H., Ph.D.
Professor and Director
Breazeale Nuclear Reactor

Willis, Michael
Undergraduate Student

Witzig, Warren F., Ph.D.
Professor and Department Head

INTERCOLLEGIATE RESEARCH PROGRAMS AND FACILITIES

Health Physics

Grandlund, Roger W., B.S.
University Health Physicist

Hollenbach, Donald
University Health Physicist

INTERDISIPLINARY

Applied Research Lab

Geleshi, Mark, B.S.
Research Assistant

Hughes, Thomas, Ph.D.
Research Associate

Materials Research Lab

Newman, Robert E., Ph.D.
Professor of Solid State Science

Solid State Sciences

Shiau, Shoiw-Meer, Ph.D.
Graduate Student

COLLEGE OF LIBERAL ARTS

Anthropology

Geidel, Richard A., M.A.
Graduate Student

Hatch, James W., Ph.D.
Assistant Professor

COLLEGE OF SCIENCE

Biochemistry

Farrington, Graham K., Ph.D.
Graduate Student

Wedler, F.C., Ph.D.
Professor

Biology

Dunson, William A., Ph.D.
Professor

Frisbie, Malcolm P., B.A.
Graduate Student

Freda, Joseph, B.S.
Research Assistant

Gonzolez, Richard, B.S.
Graduate Student

Chemistry

Kaminsky, Mark, M.S.
Graduate Student

Physics

Briceno, Marcos, B.S.
Graduate Student

Lannin, J.S., Ph.D.
Associate Professor

Pilione, Lawrence J., Ph.D.
Associate Professor

Pratt, William W., Ph.D.
Professor

UNIVERSITY OF PITTSBURGH

Radiation Health

Schell, W.R., Ph.D.
Professor of Radiation Chemistry

INDUSTRIES

CHARLES STARK DRAPER LAB

Leonard, Linda

GAS SPRING COMPANY

Smith, Lawther O.
Snyder, James

LAWRENCE LIVERMORE NATIONAL LAB

Moran, Michael J.
Redhead, David L.
Smith, Donald E.

RCA CORPORATION

Goodman, Alvin M.
Russel, John
McAllister, Joann

RAYTHEON COMPANY

Baron, S.R.
Diette, Robert N.
Hazeltine, M.
Herbert, Robert
Izquierdo, Jose G.
McInnis, W.
Mikulsky, Chris
Morris, Jake R.
Mulford, Steward G.
Rearwin, Matt T.
Worthington, Mark W.

APPENDIX B

FORMAL GROUP TOURS

1984			Participants
July	3	Nuclear Engineering 420	6
	5	Faculty Guests	9
	6	Renaissance Interest Group	8
	10	Upward Bound	19
	13	University of Pittsburgh	7
	14	Penn State Alumni	8
	17	Alumni Vacation College	12
	20	PP&L/High School Teachers (2)	27
	24	Harrisburg Hospital Technicians	13
	25	Peer Program	9
	26	PSU Tour Guides	25
	30	Nuclear Concepts	6
Aug	3	Nuclear Engineering 420	18
	10	PP&L/High School Teachers	31
	13	Police Services	7
	14	Middletown High School	9
	15	Police Services	7
	25	UPCLOSE	10
	28	Nuclear Engineering 451	43
Sept	4	Nuclear Engineering 451	45
	6	Renaissance Interest House	7
	26	Penn State Physical Plant Retirees	16
	28	Non-Radiological Risks Conference	17
Oct	16	Hazleton Nuclear Engineering students	8
	21	Open House (8)	276
	25	Engineering Graphics 50 (2)	10
	26	Nuclear Engineering 401 (2)	36
	30	Boiling Springs High School	12
	30	GPU Nuclear	11

	30	Nittany Chemical Society	2
	31	Society of Physics Students	6
Nov	5	PA Jr. Science Group	28
	5	Chartiers Houston High School	16
	8	Human Development Interest House	15
	9	Keystone Oaks High School (2)	6
	9	Biology 498 and 544	24
	16	Danville High School	12
	20	Physics 406	27
	21	Lower Dauphin High School	15
	26	Science Interest House	13
	29	Wyomissing Area High School	12
	30	Bellefonte Middle School	16
Dec	4	Physical Science 11	3

1985

Jan	9	PSU Interest Group	4
	14	Police Services	20
	14	Nuclear Engineering 814	17
	21	Nuclear Engineering 814	3
	21	Police Services	24
	22	Nuclear Engineering 812	13
	24	Nuclear Engineering 812	3
	31	PA Well Water Contractors Assoc.	15
	31	Curwensville High School	11
Feb	4	Jersey Shore High School	12
	7	Society of American Military Engineers	20
	11	Eastern Lebanon County High School	26
	14	Allegheny College	10
	18	Engineering Graphics 50	10
	19	Entomology 416	14
	20	Williamsport Community College	6
	21	Penns Valley High School	24
	27	Shamokin High School (2)	31
	28	Food Science 521	9

	28	Punxsutawney High School	18
Mar	1	Farrell High School	12
	11	Cub Scout Pack	10
	13	Bedford High School	9
	14	Ligonier Valley High School (2)	43
	14	Nuclear Engineering 307 (2)	23
	15	Higher Education 101	8
	19	Elkland High School (2)	39
	20	Salisburg High School	28
	21	Wilkes/Westminster Colleges	13
	22	Horseheads High School	33
	26	Schuylkill Haven/North Schuylkill High School	23
	29	Valley High School	36
	30	Engineering Open House	235
Apr	3	Greater Johnstown High School	20
	4	Northeast Bradford High School	9
	4	Clarion High School	10
	5	Ogontz Campus	11
	9	Wellsboro High School	32
	10	Forbes Road High School	21
	11	State College High School	28
	12	St. Marys/Ridgeway High Schools	35
	15	Belleville High School	19
	15	University of Pittsburgh	9
	16	Bald Eagle Nittany and Loyalsock High Schools	38
	17	Shade Central High School	20
	18	Berwick High School	9
	18	Industrial Professional Advising Council	5
	19	Blue Mountain Middle School	7
	22	Harbor Creek High School	9
	23	Daniel Boone High School	7
	23	Palmyra High School	8
	24	Warren High School	47
	25	Grove City College	4
	26	Dallastown Area High School	5
	26	Marion Center High School	12

	29	Lackawanna Trail High School	36
	29	Bellefonte High School	8
	30	West Middlesex High School	27
May	1	George Washington High School	49
	6	Juniata College	15
	7	Greencastle/Antrim High School	7
	14	Leechburg High School	20
	20	North Hills High School (2)	30
	21	Harrisburg Hospital Tech.	17
	21	Cub Scout Pack 44	9
	22	Grier School	21
	23	Harrisburg Hospital Tech.	12
	24	Muncy High School	24
	29	Salisbury High School	24
	29	Olde Mill High School	13
	30	Olde Mill High School	13
	30	Shippensburg High School	4
June	11	Mifflin County Teachers	19
	25	4-H Group (2)	23
	26	4-H Group (2)	20
Total		120 Groups	2,482