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

July 1, 1981 to June 30, 1982

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

July 1982

PSBR 315-498296

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July 1, 1981 to June 30, 1982

Submitted to

United States Department of Energy

and

The Pennsylvania State University

by

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University Park, Pennsylvania

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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. J. Bonner for the Co-60 Facility 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 wihtout the help of the nimble fingers of M. Beward and R. Murgas.

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INTRODUCTION

I. INTRODUCTION

The Twenty-seventh Annual Progress Report of the operation of The Pennsylvania State University Breazeale Reactor is submitted in accordance with the requirements of Contract DE-AC02-76ER0349 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.

One of the concepts that resulted from observing the neutron detector response of the Three Mile Island Unit-2 (TMI-2) accident is the Non-Invasive Liquid Level Density Gauge for nuclear power reactors. To date there is no satisfactory way of determining the water height in the pressure vessel of a Light Water Reactor. As described in Section VII, Facility Research Utilization, this technique shows promise for solving the water height measurement problem. There are many other interesting research problems being studied using the PSBR facility. Among them are determining the non-homogeneities in a soil system, the archeological study of prehistoric trade relationships in the Eastern United States, study of reptiles, and the study of digestive processes in ruminants, to name a few. This report lists researchers covering a wide range of technical disciplines that use the PSBR to advance knowledge in their field of expertise.

The Radionuclear Applications Laboratory is continuing to provide excellent analytical capability. Utilization of the laboratory has increased during the past year. This can be partially explained by the new equipment and facilities placed into operation during the past year. This includes an automatic sample changer, a multichannel analyzer-computer system, and a 20% efficient High Purity Germanium Coaxial Detector with shield. The Low-Level

Radiation Monitoring Laboratory (LLRML) has received an Interim Certification for monitoring radioactivity in water as required by the National Safe Drinking Water Act. Of particular importance to the PSBR is the awarding of a radiation monitoring contract to this laboratory by Pennsylvania Power & Light Company. The activities of the Radionuclear Applications Laboratory are making a major contribution to the PSBR.

Education and Training has become a most important factor in the use of the Breazeale Reactor. The number of courses taught using the reactor, the Nuclear Concepts and Energy Resources Institute (NCERI) in educating high school science teachers, high school student experiments, and the industrial training of reactor operators for nuclear power plants continues to grow impressively. During this period, four industrial training programs were offered to 51 operations personnel providing needed income to the facility and the Nuclear Engineering Department. There were 137 groups totaling more than 2,125 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 year, 39 Penn State University faculty and staff and 21 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, to review operational records, and to consult on special operational problems. No NRC inspections were conducted during the period covered by this report.

Messrs. J. J. Bonner, D. R. Shaulis, and A. R. Carusone successfully passed the NRC reactor operator examination; J. J. Bonner is now a Senior Reactor Operator and the other two are Reactor Operators.

An independent audit of the Breazeale Reactor operation was conducted by Mr. P. M. Orlosky of the State University of New York at Buffalo, on April 16 & 19, 1982. The purpose of the audit was to determine the University's ability to meet the licensing requirement as required by technical specifications, government regulations and established procedures. A formal written report of this audit was received and will be reviewed by the Nuclear Reactor Safeguards Committee. No violations of compliance were found; however, the audit will probably result in constructive changes in the operation of the facility. Dr. S. H. Levine conducted a similar audit of the Buffalo reactor facility on a reciprocal agreement.

Last, but not least, is the recognition of a member of the facility who has worked and served The Pennsylvania State University for twenty-five years with loyalty and distinction. Mr. Robert E. Totenbier was recognized by the University for having attained this landmark. During the next year two other members of the staff will receive recognition for their twenty-five years of service.

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.

PERSONNEL

II. PERSONNEL

There have been no changes in reactor operating staff during the year.

Licensing activities during the year have included the successful completion of Reactor Operators Examination and the licensing of both D. R. Shaulis and A. R. Carusone. Their additional assistance to the operation is most welcome. Mr. J. J. Bonner successfully completed a Senior Operators Examination during the year, but because of administrative delays within the NRC, has not yet received his license.

Ms. B. C. Ford's fixed-term appointment as a Project Assistant to assist W. A. Jester in the Water Analysis Laboratory and Neutron Activation Laboratory has been extended for an additional year.

We had the pleasure this year of honoring another staff member for 25 years of service at the facility. R. E. Totenbier received his 25-year service award from the University through the College of Engineering.

The Reactor Safeguards Committee was under the chairmanship of Dr. Robert Bland this year. As with each passing year, some members' terms expire and new members were appointed to replace them. The complete listing of the present committee membership is found in Table 1.

Dr. K. K. S. Pillay, a member of the PSBR staff and Nuclear Engineering faculty for 11 years, resigned to accept a position at Los Alamos National Laboratory. His academic talents and friendship will be missed. He has, however, agreed to remain "as active as 2000 miles [illegible]it" by accepting an Adjunct Associate Professor appointment.

In February 1982, Gary L. Catchen joined the Nuclear Engineering faculty as an Assistant Professor to fill the position vacated by K. K. S. Pillay.

Mr. J. J. Bonner has assumed the dual role of Reactor Supervisor and Faculty Associate. He is the first in the College to receive such an appointment. In this role he will continue to be a PSBR staff member but will also be able to teach and do research as a principal investigator.

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

Table 1

PERSONNEL

Faculty and Staff

*	J. J. Bonner	Reactor Supervisor/Auxiliary Operations Specialist
	B. C. Ford	Project Assistant
**	T. L. Flinchbaugh	Reactor Supervisor/Nuclear Education Specialist
*	A. R. Carusone	Reactor Supervisor/Nuclear Education Specialist
	G. L. Catchen	Assistant Professor
	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 (Resigned 8/31/82)	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

	W. A. Davy	Custodian/Driver
	R. L. Eaken	Experimental and Maintenance Mechanic
*	D. R. Shaulis	Maintenance Worker/Reactor Operator

Clerical

	M. D. Beward	Facility Secretary
	R. E. Murgas	Secretary and Receptionist

* Licensed Operator
** Licensed Senior Operator

Table 1 (continued)

Graduate Assistants

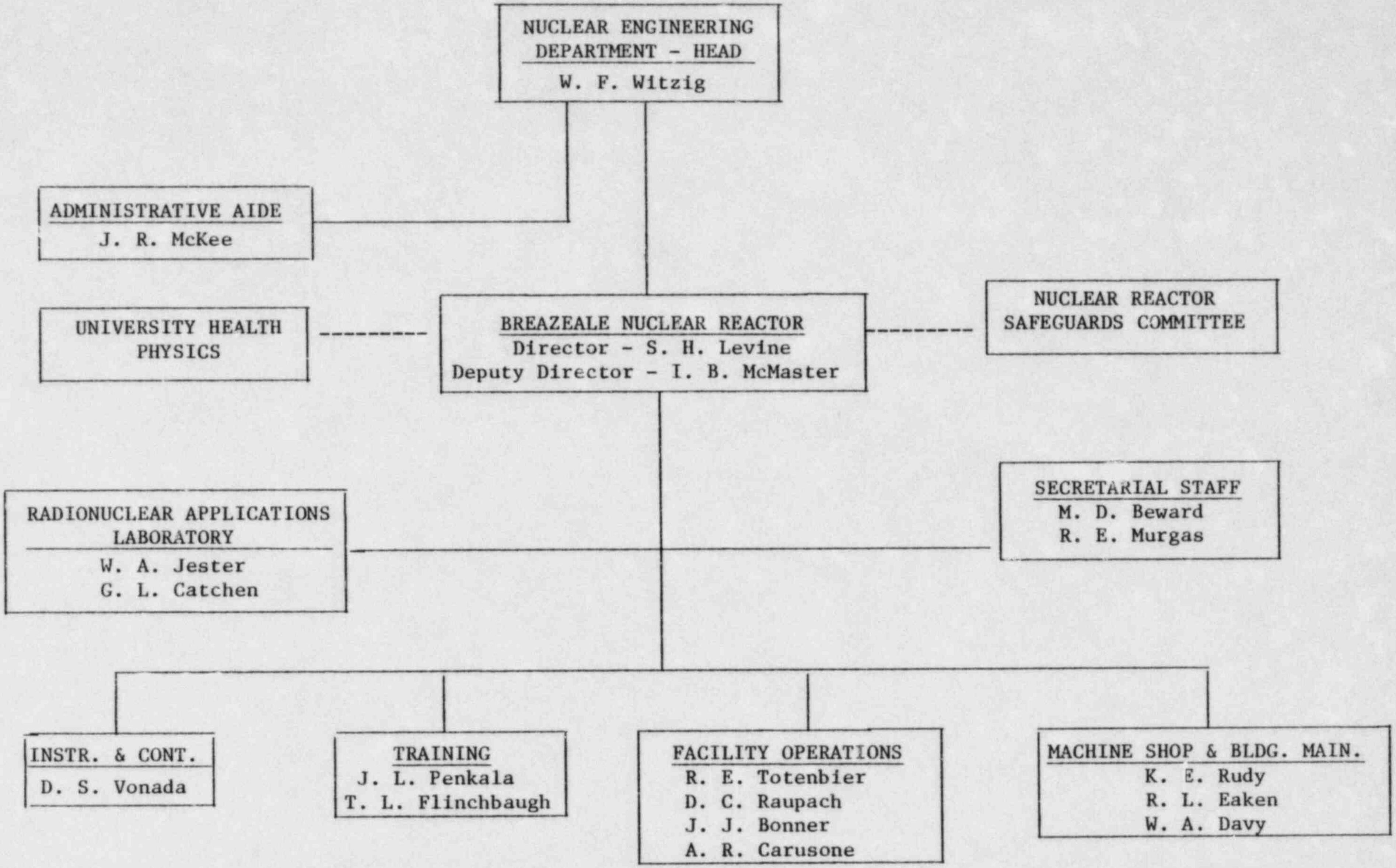
D. Chang	- Graduate Assistant
M. A. Gibbs	- Graduate Assistant
H. Y. Hwang	- Graduate Assistant
M. Y. Khalil	- Graduate Assistant
S. S. Kim	- Graduate Assistant
E. W. Okyere	- Graduate Assistant
C. R. Savage	- Graduate Assistant/DOE Fellow
T. T. Tseng	- Graduate Assistant
C. Yu	- Graduate Assistant

Health Physics

E. C. Augustine	- Health Physics Assistant
N. M. Dougherty (resigned 12/31/81)	- Associate Health Physicist
R. W. Granlund	- University Health Physicist
D. H. Hollenbach	- Health Physics Assistant

Nuclear Reactor Safeguards Committee

A. J. Baratta, Assistant Professor, Nuclear Engineering
R. E. Bland, Associate Professor, Engineering Research, ARL (Chairman)
R. W. Granlund, Health Physicist, Intercollege Research Programs and Facilities
F. Helfferich, Professor, Chemical Engineering
W. P. Kovacik, Westinghouse Research Laboratories
S. S. Lestz, Professor, Mechanical Engineering
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. W. Miller, Professor Emeritus of Chemistry
R. T. Perry, Assistant Professor, General Engineering, Altoona Campus



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, in a form not applicable to 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 neutron flux available varies from approximately 1×10^{13} n/cm^2/sec at the edge of the core to approximately 3×10^{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 6×10^{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 a few areas. The hours spent in adjusting fuel was higher in 80-81 because two annual fuel inspections were performed during this period. The hours critical and consequently the energy releases were higher during 81-82 as a result of an increase in demand for long-term irradiations. Although the number of samples more than doubled, most of the increase was for pneumatic transfer system samples which are short duration runs. Thus the overall sample hours total actually decreased slightly. Variations in the remaining data are relatively insignificant.

Table 2

Reactor Operation Data

July 1, 1980 - June 30, 1982

	80-81	81-82
A. Hours of Critical Time		
1. Hours Critical	493	614
2. Approaching Critical	145	238
3. Adjusting Fuel	81	48
B. Number of Pulses	161	217
C. Number of Square Waves	81	142
D. Energy Release (MWH)	271	302
E. Grams U-235 Consumed	14	16
F. Number of Scrams		
1. Planned as part of experiments	113	173
2. Unplanned - resulting from		
a) Personnel action*	10	17
b) Abnormal system operation	2	5

*The majority of these resulted from operation by trainees.

Table 3

Reactor Utilization Data
(average per shift)

July 1, 1980 - June 30, 1982

	80-81	81-82
A. Number of Users	2.8	3.0
B. Samples or Experiments		
1. Pneumatic transfer samples	0.9	4.2
2. Total number of samples	4.3	9.7
3. Sample hours	17.9	15.9
C. Reactor Usage (hours)		
1. Total operation	1.9	2.3
2. Shutdown in stand-by condition	1.4	2.0
3. Total usage	3.3	4.3
4. Subtotals		
a) Full power operation	0.8	0.7
b) Educational usage	2.2	3.0
c) Reactor operator training	1.6	2.6
d) Calibration and maintenance	0.8	0.7
D. Number of 8 hour shifts	254	267

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, 1982 total of 19,000 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 [illegible] possible by use of either a vertical tube or by diving bell type apparatus.

Radiation levels up to approximately 7.0 x 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 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. A typical use of the Hot Cells during the past year was the irradiation of rats for biological studies of radiation damage.

Table 4 compares the past two years utilization of the Cobalt-60 facility in terms of time, numbers and daily averages. There have been no dramatic changes in the facility utilization partly as a result of the relatively low dose rates available. Efforts are under way to obtain more Co-60 in order to increase the dose rates so that high exposures can be made over a shorter, more reasonable length of time.

Table 4

Cobalt-60 Utilization Data

July 1, 1980 - June 30, 1982

	80-81	81-82
A. Time involved (hours)		
1. Set-up time	33	30
2. Total sample hours	13,511	10,900
B. Numbers involved		
1. Samples run	499	566
2. Different experimenters	21	30
3. Configurations used	3	3
C. Per day averages		
1. Experimenters	0.8	0.7
2. Samples	1.9	2.3

EDUCATION AND TRAINING

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 the 11 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, 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 can be performed with the reactor. The 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, W. S. Diethorn, W. A. Jester, and G. L. Catchen joined efforts to teach the Nuclear Technology Laboratory course, Nuc812, in which the reactor was used to generate radioisotopes, and NucE 804 was taught by J. J. Bonner of the reactor staff who also was appointed to the Nuc E faculty as an affiliate instructor.

The inhouse training this past year consisted of a complete license requalification program that was completed in early 1982 and a reactor operator licensing program. The annual requalification program included 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 operator licensing program resulted in D. R. Shaulis and A. R. Carusone receiving NRC reactor operator's licenses and J. J. Bonner being upgraded to a Senior Reactor Operator.

The Nuclear Concepts and Energy Resources Institute (NCERI) was offered as NucE 497 for the twelfth consecutive year during the Summer of 1981. The NCERI, a four week institute, was attended by 45 high school science 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.

Drs. W. A. Jester and A. J. Baratta were co-directors of the institute which was sponsored by D.O.E., EG&G Idaho, the Edison Electric Institute, and a number of electric utilities. The major portion of the NCERI laboratory experiments was supervised by J. J. Bonner assisted by C. Yu. Messrs. D. H. Hollenbach, E. C. Augustine, and J. L. Penkala also helped 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, 19 groups totaling 287 students participated in a full day of experimentation, observation, and touring at the PSBR. Mr. J. J. Bonner handled the scheduling of and lecturing to the high school tour groups with assistance from D. R. Shaulis and A. R. Carusone. Table 5 summarizes the participation of the high school tour program.

The laboratory course NucE 440 was taught in the Fall 1981 and Spring 1982 terms by A. J. Baratta with valuable assistance from W. A. Jester. Three of the more important experiments were conducted for forty-two students at the PSBR with major assistance from the reactor operating crew.

During the Fall 1981 and Winter 1982 terms, E. S. Kenney taught the NucE 441 course with the assistance of the reactor staff. Thirty-five students were registerd for the NucE 441 course.

Table 5

High School Nuclear Science Program

1981 - 1982

School	No. of Students	Instructor
Bedford	12	Emery Turner
Bellefonte	35	Walter Young
Berwick	15	Robert Foster
Chestnut Ridge	6	Dave Popp
Daniel Boone	31	Larry Tobias
Delone Catholic	11	Marie Aimee
Harbor Creek	11	John Peterson
Horseheads	36	Larry Josbeno
Jersey Shore	12	James Allen
Marion Center	16	John Petrosky
North Schuylkill	12	Dan Welker
Penns Valley	8	John Thompsen
Red Land	10	George Farley
Ridgeway	18	Ernest Koos
State College	8	Maragrete Ciolkosz
Villa Maria	10	Helen Ackerman
Warren	12	Eugene Szul
West Perry	14	Donald Stoops
Wyomissing	10	Charles Bell
19 Groups	287 Participants	

The TRIGA reactor was used extensively when S. H. Levine taught NucE 502b, a graduate laboratory course, for five graduate students the past Winter term and E. S. Kenney taught 502c for six graduate students in the Spring term.

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 1981, Fall 1981, Winter 1982 and Spring 1982 terms for 28 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.

Three industrial training programs were provided for 15 reactor operator license candidates of the Cincinnati Gas and Electric Company. The senior reactor operating staff participated in these industrial training programs.

A fourth industrial training program was offered for 36 operations personnel from GPU Nuclear's Three Mile Island Unit-2. The GPU program was conducted during a six-week period with S. H. Levine, F. G. Helfferich, and G. B. Gockley providing the lecture sessions while G. L. Catchen and D. C. Raupach instructed the laboratory sessions.

The entire senior operating staff provided the start-up experience and the program was coordinated by J. L. Penkala.

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 496 and 559 students utilized the PSBR for their respective projects this past year.

A group of 19 of G. E. Robinson's NucE 401 students were given a tour of the PSBR and a start-up and pulse demonstration.

An introductory course in Nuclear Engineering, NucE 200 was offered by J. L. Penkala to 42 sophomore students during the Winter 1982 term. This course used the PSBR facilities for two experiments. Assistance was given by J. J. Bonner in the lab.

Approximately 30 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 150 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 energy in general and nuclear applications in particular through the spectrum of educational and training vehicles described in this report.

RADIONUCLEAR APPLICATIONS

LABORATORY

VI. RADIONUCLEAR APPLICATIONS LABORATORY

The staff of the Radionuclear Applications Laboratory during this year consisted of W. A. Jester, G. L. Catchen, D. C. Raupach, and B. C. Ford. Gary L. Catchen joined the Nuclear Engineering faculty in February 1982, as an Assistant Professor, to fill the position vacated by K. K. S. Pillay. Several of Dr. Jester'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 involves 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.

Utilization of the laboratory has increased during the past year. In part, this increase in utilization can be attributed to the ease of use of the new multichannel analyzer and the use of the automatic sample changer which was developed and constructed by members of the reactor staff during the past year. The automatic sample changer, in conjunction with the multichannel analyzer-computer system, can be loaded with up to 100 samples which can be analyzed over night or over a weekend, without the experimenter having to be present. The new analyzer processes the data and prints out the results while the next sample is being analyzed. Prior to getting the new analyzer, the results would not be available until the day after the last sample was analyzed.

In addition to the analyzer and the automatic sample changer, a new 20% efficient High Purity Germanium Coaxial Detector and shield have been added to the laboratory. The new detector is at least twice as efficient as any of the other detectors in the laboratory. This detector is being used primarily for counting environmental samples or other samples which contain very small amounts of radioactivity.

During the last year, members of the radionuclear applications group have developed a technique for producing iodine-131 from NH_4Te. The iodine-131 is separated from the irradiated ammonium tellurate (in an aqueous form) and counted on one of the Ge(Li) detector systems. Quantification of the amount of iodine-131 produced is thereby possible because the detectors are calibrated using volumetric standards purchased from the National Bureau of Standards. Once the solution is quantified for iodine-131 concentration, samples of any size or shape can be produced. This is of significant importance because secondary standards can be made up to simulate different sample geometries. For example: air filters, activated charcoal filters, and liter volumetrics can be produced to simulate actual samples being analyzed for iodine-131.

A new set of calibration standards (one point source and one volumetric source) have been procurred from the National Bureau of Standards and a recalibration of all the detectors in the laboratory will be undertaken in the near future.

During this year, work has continued in the development of the capabilities of the Low-Level Radiation Monitoring Laboratory (LLRML). This Lab has been set up in rooms 103 and 116 of the Academic Projects Building which is located just east of the Breazeale Nuclear Reactor. The staff of this facility includes Dr. W. A. Jester, B. C. Ford and D. C. Raupach. During the Spring term, Dr. G. L. Catchen joined this group.

Some of the activities and accomplishments of the year are as follows:

In June 1981 there was a visit by an EPA inspection team which has led to the labs Interim Certification (July 1982) for monitoring radioactivity in water as required by the National Safe Drinking Water Act. This certification includes gross alpha and beta analysis of evaporated water residues, tritium in water analysis, and gamma-ray spectroscopy of water. Work has progressed during the year in the analysis of strontium-89 and strontium-90 in drinking water.

One of the most notable events of the year was the awarding of a radiation monitoring contract to the Laboratory by Pennsylvania Power & Light Company. Under this contract, the lab will monitor radioactivity in samples collected from the environment in and around PP&L's Susquehanna plant. Environmental radiation levels will also be measured using TLD dosimeters. As part of this program an extensive procedures and quality assurance manual has been written.

In addition to University researchers, the laboratory has continued to perform analyses f.. governmental agencies and for industry. During the past year, analyses have been performed for the Pennsylvania Department of Environmental Resources, Raytheon Company, Draper Laboratory, Kennedy Van Saun, Pennsylvania Power & Light, Gulf Oil Company, and others.

FACILITY RESEARCH UTILIZATION

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 authors under the various departments. 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. Thirty-nine faculty and staff members and twenty-one graduate students have used the facility in the past year for research. This represents a usage by eleven different departments or sections in six 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 indicates the broad utilization enjoyed by the Breazeale Reactor Facility. The nineteen projects described involve three master's theses, one doctoral thesis, four publications and one paper. 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

Agricultural Engineering Department

Tracer Breakthrough Curve Studies: The Effects of Soil Nonhomogeneities

A. Jarrett
W. A. Jester
D. A. Lehman

The reactor was used to irradiate samples of NH_4Br. This produced the radioisotope bromine-82. The bromine is being used as a tracer to study solute flow through a soil column. The hypothesis of this experiment is that the results of a tracer test (a breakthrough curve) can be used to identify the nonhomogeneities present in a soil system. This will be done quantitatively by relating the effects of dispersion coefficients to certain nonhomogeneities.

Anthropology Department

Source Analysis of Jasper, a Prehistoric Raw Material

J. W. Hatch
P. E. Miller

The goal of archaeology is the understanding of past human behaviors through the analysis of the material remains of prehistoric activities. One means of deriving behavioral data from such remains is by determining the geographic source of raw materials used by particular groups of individuals. The presence at an archaeological site of materials from distant sources is indicative of exchange or trade relationships between groups. The directionality and importance of such relationships can vary through time. Materials which have been analyzed for source data include ceramics, copper and obsidian.

A specific problem in Northeastern U.S. archaeology is the apparent widespread occurrence of Pennsylvania jasper, a crypto-crystalline quartz of high quality used throughout prehistory for stone tool manufacture. The assignment of this jasper to a Pennsylvania source has been made on the strength of macroscopic appearance, despite the existence of other desposits of similar jaspers in the Eastern U.S. In order to test hypotheses regarding trade relationships, it is necessary to assign jasper artifacts to a source using an accurate and replicable technique. Studies of other geological materials suggest that chemical analysis is a successful approach to sourcing problems. Neutron activation analysis was selected over techniques such as atomic absorption and emission spectroscopy because of its high sensitivity and because a number of elements could be analyzed simultaneously. Material from eight geological sources are being studied;

discriminant analysis will be applied to the resulting data in order to provide a means of assigning future unknowns to a source. At present, 130 of approximately 160 samples have been irradiated for one hour at 950 kilowatts. The samples have been analyzed for short half-lived elements after approximately 20 hours and for longer half-lived elements after approximately seven days. The automatic sample changer is now being used for the latter analysis. Projected completion data of the research is July 15.

Biology Department

Sodium Loss in Amphibian Larvae Exposed to Low pH

W. A. Dunson
J. Freda

Ambystomatid and ranid larvae placed in sulfuric acid solutions, at pH's between 3.0 and 4.0, were unable to regulate their body sodium content. Body sodium influx ceased and sodium efflux increased markedly. This resulted in a 50% or greater drop in body sodium content/gram dry mass, at the time of death. The rate of net sodium loss was inversely related to survival time. A 20 fold increase in water calcium concentration significantly slowed the rates of sodium loss, and increased survival times. This specific inhibitory effect of low pH on amphibian body sodium regulation is quite similar to that previously reported for fish. Thus a major cause of death in aquatic amphibians living in situations polluted by acid rain or acid mine wastes is depletion of body sodium.

Publication

"Specific Inhibition of Hatching in Amphibian Embryos by Low pH." W. A. Dunson and J. Connell, Journal of Herpetology: in press, 1982.

Biology Department

Asymmetrical Diffusion of Sodium and Water Through the Skin of Sea Snakes

W. A. Dunson
G. D. Stokes

Diffusion of water, Na, Cl, and ethanol were studied *in vitro* across whole, fresh skins of six species of sea snakes placed between 1 M solute solutions and distilled water. Water influxes varied from 60 μmoles/cm^2-h in *Pelamis* to 240 μmoles/cm^2-h in *Aipysurus laevis*. In four species, including *Pelamis* and *Aipysurus*, influx exceeded efflux. This is a reversal of flux asymmetry as found in fresh-water snakes, measured under identical circumstances. Na and Cl fluxes across whole skins were low, with effluxes exceeding influxes in *A. laevis*. In shed skins of *A. laevis*, Na fluxes were considerably higher than in whole skins, but the same asymmetry in direction of movement was observed, efflux exceeding influx by a factor of 2-16. This

represents a reversal of the ion flux asymmetry seen in fresh-water snakes. The directions of asymmetrical diffusion of water and Na are appropriate for regulating these materials in the respective marine or fresh-water environments. A model for snake skin is proposed in which observed asymmetries in fluxes are accounted for by the presence of lipid-lined channels of two sizes which change in diameter depending on different water and ion concentrations of the bathing fluids on the two sides.

Publication

"Asymmetrical Diffusion of Sodium and Water Through the Skin of Sea Snakes," W. A. Dunson and G. D. Stokes, Physiol. Zool., In press.

Biology Department

Passage of Water and Electrolytes Through Natural and Artificial Keratin Membranes

W. A. Dunson
G. D. Stokes

The feasibility of reconstituting dissolved α-keratin was tested by rekeratinizing bovine hoof into sheets through electrodialysis. At voltage densities of 10, 15, and 25 V/cm we were successful in forming thin, fragile membranes on the surface of a dialysis membrane. Mean Na diffusion rates across these membranes between 0 and 1M NaCl at atmospheric pressure were 121-291 μmole/cm^2-h. The rate dropped to 3 μmole/cm^2-h. after topical addition of linoleic acid to the membrane. Permeability characteristics of shed snake skin (Constrictor constrictor, Nerodia cyclopion floridana), sea turtle scutes (Chelonia mydas, Caretta caretta), bovine hoof slices, and tarpon scales (Megalops atlantica) were tested at pressures up to 300 lb/in^2 and compared to the commercial reverse osmosis membrane, SEPA 97. The first three membranes are composed of keratin and the latter two of collagen and cellulose, respectively. Shed snake skin and fish scale allowed passage of fluid with no salt rejection. Turtle scutes and thin (60μm) sheets of bovine hoof passed no fluid or salt. SEPA 97 had a mean fluid passage of 180 μl/cm^2-h with 16% salt rejection, both lower than expected. Reconstituted α-keratin has the potential for use in membrane separation of water and solutes. However, further work is needed in developing techniques for fabrication of thicker sheets (between 15 and 50 μm), which are likely to show the desired characteristic under pressure of passage of water but not solutes.

Publication

"Passage of Water and Electrolytes Through Natural and Artificial Keratin Membranes," G. D. Stokes and W. A. Dunson. Submitted.

Biology Department

Permeability and Channel Structure of Reptilian Skin

W. A. Dunson
G. D. Stokes

A study of the permeability of shed epidermis from some terrestrial and fresh-water snakes was conducted. Permeability to Br, Na, and K ions was very low and showed a higher influx than efflux in most cases. Permeability to the smaller water molecule was much greater, and in contrast efflux was higher than influx. Skins from aquatic snakes with larger water permeabilities also showed greater permeabilities to Na and K. The highly aquatic *Regina spetemvittata* has the most permeable skin of any snake. Ethanol fluxes were higher than expected for a tracer of its size, perhaps due to its solubility in lipid. Na fluxes through whole live skins of *Natrix cyclopion floridana* in vitro were not significantly different from those of the shed skin alone. Isolated hinge regions showed complete water impermeability, suggesting that channels through the skin are located only in the scale region. Dermal water efflux into dry air was considerably less than water-to-water efflux. Lipid extraction increased permeability markedly and eliminated the asymmetry of water and ion fluxes. Lipid replacement with linoleic acid restored half of the water impermeability lost during extraction. Protein extraction did not significantly increase membrane permeability but did eliminate the permeability difference between dry and hydrated skins. Two sizes of lipid-lined channels extending through a protein matrix are suggested as a possible model for snake skin. The diameter of the channels apparently varies in relation to the differing water, Na, and Cl concentrations on opposite sides of the skin, but the mechanism of this adjustment is unknown.

Doctoral Thesis

"Permeability Characteristics and Possible Pore Structure of Reptilian and Artificial Keratin Membranes, G. D. Stokes (Zoology Department), 1981, W. A. Dunson, Advisor.

Publication

"Permeability and Channel Structure of Reptilian Skin," G. D. Stokes and W. A. Dunson, Amer. J. Physiol., 1982, in press.

Chemistry Department

The Design of Atomically Defined Catalysts

P. Skell
S. Niznik
J. Schwartz
J. Kennan
J. Ross

New types of heterogeneous catalysts are being made by adsorbing organo-metallic complexes on supports and then removing the organic liquids. These are novel, and possibly important new catalyst systems.

The metals that are currently being used in this study are iridium, palladium, platinum, and rhodium. In order to obtain accurate rate information we must know exactly how much metal is contained in our catalysts. It is for this reason that we have chosen neutron activation analysis for an accurate quantitative determination of metal content in our catalysts.

Dairy and Animal Science Department

Determination of Particulate Digesta Flow in Ruminant Animals with Rare Earth Elements by Neutron Activation

L. P. Muller
G. A. Rogers
T. J. Snyder
G. Okwaro

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.

We have used La, Sm, Ce, Yb, and Co-EDTA as markers of fibrous, grain, and liquid fractions in three different trials. These markers are attached to the feedstuffs and placed into the digestive tract. Subsequent fecal samples are then analyzed at the Breazeale Nuclear Reactor. From these data, the estimated time of feedstuff retention in various segments of the gastrointestinal tract can be calculated. 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 is completed from one of the studies in progress from two other studies. Samples are currently being collected from two other studies.

Paper

"Effects of 0 and 1.2% $NaHCO_3$ with Two Corn Silage:grain Ratios on Milk Production and Digestive Responses of Lactating Cows," T. J. Snyder, L. D. Muller, J. A. Rogers, and S. M. Abrams. Abstract of paper presented at American Dairy Science Assoc. Annual Meeting, 1982.

Entomology Department

Determination of Elemental Composition of Sewage Sludge

R. O. Mumma
D. C. Raupach
D. Lisk
J. Waldman

Sewage sludge samples from many major cities across the United States were neutron activated for the purpose of determining the elemental composition of the samples. These data will be correlated with elemental composition data derived from alternate analytical methods. Also, these sludge samples will be analyzed for various toxic organic chemicals such as PCB's, PBB's and other mutagens.

Geochemistry Department

Models of Formation for Cu-U Occurrences in the Upper Devonian Catskill Formation of PA

A. W. Rose
L. M. Cathles
H. Ohmoto
A. T. Smith

One hypothesis for this phase of the study is that U-rich intervals in stratigraphic sections indicate favorable areas for U or Cu-U mineralization in the red-beds of the Upper Devonian Catskill Formation. It is thought that U-ions adsorbed on clays are a possible source for the uranium found in the many known localities in PA. The clays were formed during the erosion of a U-rich source, possibly a granite. They were transported into the Appalachian basin and were deposited in thick sequences of muds, which became shales upon lithification. In an oxidizing environment, the uranium was leached from the clays during early compaction. The U was concentrated in organic-rich zones in nearby sandstones.

Approximately 100 shale samples (10 gr. each) from one stratigraphic section several kilometers from known U occurrences have been analyzed for U by Delayed Neutron Activation Analsysis (1 megawatt, 60 sec. irradiation, 5 sec. delay, 60 sec. count).

A U-rich interval has been found, and the project is considered a success. Future plans include the analysis of the same samples for Th and possibly more U and Th analyses of shales from other stratigraphic sections.

Materials Science Department

The Effects of Co-60 Gamma Radiation on the Strength Distributions of Simple Borosilicate Glasses and Complex Nuclear Waste Borosilicate Glasses

R. C. Bradt
P. Miriello

The Co-60 facility at the reactor is being used to study the effects of gamma radiation on glasses of simple composition: window, pyrex, and a lead borocilicate; and more complex composition: Savannah River nuclear waste glass (defense type) and Pacific Northwest Labs nuclear waste glass (reprocessing type).

Primarily, the effects of the radiation on the strength and density are being investigated. Three of the five compositions to date have been irradiated. The Savannah River glass is being prepared for irradiation this summer.

Nuclear Engineering Department

Non-Invasive Liquid Level Density Gauge for Nuclear Power Reactors

A. J. Baratta
W. A. Jester
E. S. Kenney
A. H. Foderaro
G. Imel
I. B. McMaster
E. W. Okyere
J. W. Park

The source range detectors of TMI-2 displayed anomolous behavior during the course of the accident. The behavior indicated a possible relation between the detector output and the density and level of coolant in the reactor. Using the data obtained from TMI-2, a concept for a non-invasive liquid level gauge has been developed.

It is the objective of the present experiments to simulate conditions in a partially voided reactor using the PSBR. The effort is intended to

reproduce the outputs observed on the source range detectors during the TMI-2 accident and from that data predict the coolant level.

Experiments to date, using the Penn State Breazeale Reactor, have verified that the neutron level external to the pressure vessel is sensitive to water level variations in the reactor. Current efforts are directed towards verification of the predicted behavior, determination of system spatial resolution, optimization of detector packaging and computer simulation of experiments.

Nuclear Engineering Department

The Development of a Monitoring System Capable of Detecting Low Levels of Radioactive Iodine in the Presence of High Levels of Radioactive Noble Gases

W. A. Jester
A. J. Baratta
T. T. Tseng

The monitoring system is used to detect the exact amount of radioiodine in the presence of high radioactivity of noble gases. Current commercial standard type iodine monitors cannot quantify the amount of iodine under such conditions. The simulated radioactive noble gas is achieved by irradiating a stream of air to produce argone-41. The radioiodine (iodine-128) is made by activating NH_4I in the Rabbit I System of the Breazeale Nuclear Reactor. This radioiodine is introduced into the air stream under controlled conditions.

The proof-of-principal has been completed and work is beginning on a system which will be installed in a nuclear power plant.

Masters Paper

"Concept Evaluation of a Radioiodine Monitor Which Can Operate in High Level of Radioactive Noble Gases," Tseng, Tung-Tse, 120 pages, June 1982.

Masters Thesis

"The Prototype of Iodine Monitoring System," Tseng, Tung-Tse, 1982, W. A. Jester, Advisor.

Nuclear Engineering Department

Nuclear Data-680 Activation Analysis Package Evaluation

W. A. Jester
K. K. Wu

The goal of this project is to evaluate the accuracy of the ND-680 multichannel analyzer combined with a minicomputer. In this system, a LSI-11 microprocessor utilizes the neutron activation analysis software package to analyze the gamma ray spectra of different unknown samples, to find out their elemental concentrations. The apparatus that will be or has been used so far are: The ND-680 systems, the Ge(Li) gamma-ray detector and the Nuclear Reactor for irradiation of unknown samples.

Currently, the student has finished the task of learning to use the ND-680 system and is beginning to test the parameters set up for the neutron activation analysis package. In the future, the student expects to create programs that can be connected to the neutron activation analysis package programs to improve the utilization and efficiency of the ND-680 system for this center.

Masters Thesis

"Nuclear Data-680 Neutron Activation Analysis Package Evaluation," K. K. Wu, 1981, Nuclear Engineering, W. A. Jester, advisor.

Nuclear Engineering Department

Optimum Hydrogeologic Parameters Prediction by the Tracer Breakthrough Curve Method

W. A. Jester
A. R. Jarrett
C. Yu

This research work uses the tracer breakthrough curve to estimate the hydrogeologic parameters such as diffusion coefficients, distribution coefficients, average velocities and effective path lengths, etc. From these parameters, we are also able to tell the nonhomogeneity of the geologic media.

By the method of least square approximation, the tracer breakthrough data are fitted by a uniform flow equation; the optimum effective hydrogeologic parameters are then obtained.

By the method of least square approximation, the tracer breakthrough data are fitted by a uniform flow equation; the optimum effective hydrogeologic parameters are then obtained.

With a saturated column, different soils and traces can be used to estimate the hydrogeologic parameters including distribution coefficients of different nuclides in different soil media.

The reactor is being used to produce bromine-82 which is used as a water tracer to produce breakthrough curves in a soil column.

Nuclear Engineering Department

Beta Dosimetry

S. H. Levine
D. Chang

Two separate tasks are being conducted in parallel for this contract. Beta dosimetry studies are being conducted in performance of one of these tasks and the other involves measurements of the neutron flux and its energy spectrum. A laboratory has been established in the facility for performing accurate beta dosimetry measurements. Initial measurements have been performed with a newly constructed Lucite Beta Irradiation Platform (LBIP) using a 0.011 curie strontium-90-yttrium-90 beta source. These measurements showed that the thermal luminescence detector response can be more than a factor of 4 off if not properly calibrated. Studies are to continue to develop accurate beta dose measurements. Only analytical studies have been performed on the neutron spectrum determination. Future work will involve neutron measurement in the facility.

Nuclear Engineering Department

Dissolution of Crystalline Waste Phases

K. K. S. Pillay
M. Y. Khalil

The effect of amorphism on dissolution of waste phases is being examined. Some crystalline phases are doped with U-235 and irradiated to cause fission fragment damage which renders the phases amorphous. After the radioactivity is reduced to a reasonable level, the dissolution processes will start.

The dissolution of technetium containing phases is also being examined. The phases containing technetium are to be formed in a reducing atmosphere. A glovebox is being used for the reduction process. The liquid β-scintillator will be used to detect the presence of technetium in the dissolving solution.

Nuclear Engineering Department

Radiation Damage in Nuclear Waste Forms

K. K. S. Pillay
M. Y. Khalil

The effect of long term α-decay in crystalline radioactive waste forms is being experimentally investigated. To simulate the α-decay damage, some candidate phases were doped with Li-6 and irradiated in the reactor to produce lithium-6 hydrogen-3 reaction.

Physics Department

Trace Element Analysis of Coal

W. W. Pratt

The neutron activation analysis study of trace element impurities in coal, described in the previous annual report, is being continued. Quantitative measurements have been made for arsenic, cobalt, iron, scandium, selenium, and uranium. Additional quantitative measurements have been started for other trace elements.

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:

The Charles Stark Draper Laboratory, Inc.

R. B. Miller

In the past year the Draper Laboratory has used the Breazeale Nuclear Reactor Facility to investigate the effects of neutron environments on the functional and parametric characteristics of integrated circuits. Results of our experiments have yielded information which is useful in understanding neutron sensitive damage mechanisms in semiconductors. In addition, our research has allowed us to develop damage coefficients necessary for predicting circuit response to neutron environments.

Gulf Research & Development Company

E. G. Miller

Research is continuing at Gulf in the area of shale oil as an alternative to crude oil. The primary element of interest is arsenic, although periodic checks are made for cobalt, tungsten, and bromine.

The responsibility of the Neutron Activation Group is to analyze for multiple elements through rapid computer analysis of Ge(Li) spectrums. At present, we are attempting to transfer the Ge(Li) spectrums into a small Digital Minicomputer ("MINC? LSI-11) for peak search, identification and quantification. Data communication from the minicomputer to an AMDAhl ICF is also being pursued.

Raytheon Company

R. N. Diette

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.

Sylvania - GTE

T. K. Kim

The neutron activation analysis capabilities of the Penn State Breazeale Reactor were utilized to determine the amounts of thorium, uranium, and other radioactive elements present in tungsten ore and tungsten ore sludge samples. These data will be utilized in developing a new tungsten chemical system and other tungsten processes.

APPENDIX A

APPENDIX A

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

COLLEGE OF AGRICULTURE

Dairy & Animal Science

Abrams, Stephen M.
USDA Pasture Research Laboratory

Muller, Lawrence D., PhD
Professor of Dairy Science

Okwaro, Gilbert, MS
Graduate Student

Rogers, John A., PhD
Research Associate

Snyder, Timothy J., MS
Research Assistant

Entomology

Mumma, Ralph O., PhD
Professor of Chemical Pesticides

Lisk, Donald, PhD
Professor of Vegetable Crops
Cornell University

COLLEGE OF EARTH AND MINERAL SCIENCES

Geosciences

Cathles, L. M., PhD
Professor of Geochemistry

Lustwerk, Rigel L., BS
Graduate Student

Ohmoto, H., PhD
Professor of Geochemistry

Rose, Arthur W., PhD
Professor of Geochemistry

Smith, Arthur T., MS
Graduate Student

Materials Science

Bradt, Richard C., PhD
Professor of Material Science

Miriello, Patricia S., BS
Graduate Student

COLLEGE OF ENGINEERING

Agricultural Engineering

Jarrett, Albert R., PhD
Associate Professor of Agricultural Engineering

Lehman, Dale A., BS
Graduate Assistant

Civil Engineering

Nesbitt, John B., ScD
Professor of Civil Engineering

Nuclear Engineering

Baratta, Anthony J., PhD
Assistant Professor of Nuclear Engineering

Bonner, Joseph J., MS
Auxiliary Operations Specialist

Catchen, Gary L., PhD
Assistant Professor

Chang, Daren, BS
Graduate Student

Diethorn, Ward A., PhD
Professor of Nuclear Engineering

Flinchbaugh, Terry L.
Nuclear Education Specialist

Foderaro, Anthony B., PhD
Professor of Nuclear Engineering

Ford, Bonnie C.
Project Assistant

Imel, George, PhD
Assistant Professor of Nuclear Engineering

Jester, William A., PhD
Associate Professor of Nuclear Engineering

Kenney, Edward S., PhD
Professor of Nuclear Engineering

Khalil, M. Y., BS
Graduate Assistant

Levine, Samuel H., PhD
Professor of Nuclear Engineering

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

McMaster, Ira B., BS
Research Assistant

Okyere, E. W., MS
Graduate Assistant

Park, Jaewoo W., BS
Graduate Student

Penkala, John L., S
Research Assistant

Pillay, K. K. Sivasankara, PhD
Adjunct Professor of Nuclear Engineering

Raupach, Dale C., BS
Reactor Utilization Specialist

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

Rudy, Kenneth E.
Senior Engineering Aide

Shillenn, James K.
Energy Education Specialist

Totenbier, Robert E., BS
Research Assistant

Tseng, Tung-Tse, BS
Graduate Student

Waldman, Joseph
Undergraduate Student

Witzig, Warren F., PhD
Professor of Nuclear Engineering

Wu, Kwok Kwan, BS
Graduate Student

Yu, Charlie, MS
Graduate Student

COLLEGE OF THE LIBERAL ARTS

Anthropology

Hatch, James W., PhD
Assistant Professor of Anthropology

Miller, Patricia E., BA
Graduate Student

COLLEGE OF SCIENCE

Biology

Connell, Joseph P.
Undergraduate Student

Dunson, William A., PhD
Professor of Biology

Freda, Joseph, BS
Graduate Student

Stokes, Glenn, MS
Graduate Student

Chemistry

Kennan, John, BS
Graduate Student

Niznik, Shelly, BS
Graduate Student

Ross, Jeffery, BS
Graduate Student

Schwarts, Jo-Ann, BS
Graduate Student

Skell, P. S., PhD
Professor of Chemistry

Physics

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

Pratt, William W., PhD
Professor of Physics

INTERCOLLEGE RESEARCH PROGRAMS AND FACILITIES

Health Physics Office

Granlund, Rodger W., BS
University Health Physicist

Hollenbach, Donald H.
Health Physics Assistant

APPENDIX B

APPENDIX B

FORMAL GROUP TOURS

1981			Participants
July	6	Alumni Vacation College	23
	7	Alumni Vacation College	32
	15	Energy for the '80s (s)	31
	17	Youth Conservation Corps.	20
	20	Harrisburg Hospital Technicians	20
	22	Alumni Vacation College	27
	23	Forest Chapel Senior High	30
	29	Nuclear Concepts' Families	4
	30	Upward Bound	7
Aug.	3	Waterworks Operators Association of PA (4)	54
	5	Intensive English Communications	13
	11	Youth Conservation Corps	10
	11	Student Group	5
Sept.	1	Student Orientation	3
	2	Student Orientation	21
	3	Student Orientation	18
	4	Student Orientation	19
	5	Upclose	13
	17	Pennsylvania Office Managers Association of United Electric Corporations	18
	25	Science Technology & Society	14
Oct.	12	Food Science 521	8
	16	Nuclear Engineering 401	14
	20	Life Science Interest House	11
	21	Girl Scouts	12
	22	Geological Sciences 303	15
	27	Physics 100 (2)	49

Formal Group Tours (continued)

1981			Participants
Nov.	3	American Society of Mechanical Engineers	9
	5	Engineering Graphics 50	32
	6	Students from Altoona Campus	4
	7	Union H S	11
	10	State College Area Junior H S	6
	11	Altoona NET Students	6
	19	Pennsylvania Power & Light Company	16
Dec.	2	Nittany Dorm Students	8
	3	Slippery Rock State College	9
	4	Dickenson College	11
	8	Bucknell University	12
	15	Chestnut Ridge H S	10
	15	Police Services Orientation	7
	15	State College Area Junior H S	21
	17	Police Services Orientation (2)	18
	18	Police Services Orientation	6
1982			
Jan.	6	Engineering Graphics 50	21
	7	Police Services Orientation	5
	8	Police Services Orientation	4
	12	Higher Education 101	10
	14	Police Services Orientation	4
	14	Arts and Architecture Interest House	3
	19	Entomology 416	25
	21	Nuclear Engineering Students	3
	27	Jersey Shore H S	15
	28	Human Development	4

Formal Group Tours (continued)

1982			Participants
Feb.	4	Geological Sciences 303	27
	9	Higher Education 101	12
	10	Future Farmers of America (2)	21
	11	Engineering and Applied Science Interest House	9
	16	Plant Breeding 407 (2)	50
	17	Plant Breeding 407	6
	18	Plant Breeding 407	14
	19	Chemical Engineering 430	33
Mar.	10	Student Group	4
	12	Penn Cambria H S	21
	17	Bedford H S	18
	18	Wyomissing H S	10
	19	Coop Undergrad Education Program	16
	19	Boy Scouts	25
	20	Lion Ambassadors	20
	20	Society of Women Engineers (2)	19
	22	Bellefonte Scout Troup	20
	24	Bellefonte H S	27
	26	Upper Saint Clair H S	24
	26	Ridgeway H S	13
	29	Villa Maria Academy	9
	30	Society of Physics Students - Dickenson College	12
	31	Delone Catholic H S	11
Apr.	1	Penns Valley H S	13
	2	Berwick H S	11
	2	Journalists	7
	6	Red Land H S	10
	7	Pennsylvania Rural Electric Association	8
	15	Selinsgrove H S (2)	50
	16	Pittsburgh Explorer Post	27

Formal Group Tours (continued)

1982			Participants
Apr.	20	Engineering Graphics 50	73
	20	State College H S (2)	43
	21	West Perry H S	10
	22	Society of Physics Students	3
	22	PP&L Energy Educators	7
	23	Horseheads H S	30
	26	Physics 101	12
	27	Physics 101 (2)	35
	27	Selinsgrove H S (2)	45
	28	Warren Area H S	34
	29	Professor Fitz & Guests	7
	29	North Schuylkill H S	16
	29	Phi Tau Sigma - Mechanical Engineers	11
	30	Punxsutawney Area H S	22
	30	Chestnut Ridge H S	9
May	5	Daniel Boone H S	27
	6	Harbor Creek H S	13
	6	PEA Relay Committee	10
	6	Park Forest J H S	6
	7	Marion Center H S	10
	7	Maple Avenue Middle School	25
	11	Harrisburg Hospital	16
	11	Geological Sciences 303	20
	13	Metallurgy 412	4
	14	Altoona 8th Graders (2)	60
	14	South Park H S	14
	17	Mifflinburg Area H S	29
	18	Geological Sciences 303	22
	19	Dickenson College	4
	19	Altoona Campus (2)	50

Formal Group Tours (continued)

1982			Participants
June	1	Inter American Executive Management Group	25
	3	Visiting Mechanical Engineering Students from Iceland	12
	3	State College High School - Chem. II	13
	10	Elderhostel '82	10
	15	Student Orientation	9
	17	Student Orientation	22
	22	Pennsylvania Vocational Conference	6
	22	4-H Congress	26
	23	4-H Congress	15
	24	Students	2

137 Groups

2,125 Visitors