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

July 1, 1975 to June 30, 1976

Submitted to

United States

Energy Research and Development Administration

and

The Pennsylvania State University

by

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DISCLAIMER

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INTRODUCTION AND SUMMARY

I. INTRODUCTION AND SUMMARY

The 21st Annual Progress Report of The Pennsylvania State University Breazeale Nuclear Reactor (PSBR) is prepared and submitted in accordance with the requirements of Contract E(30-1)-3409 with the United States Energy Research and Development Administration. This report also provides a summary of the past year's operation for the University Administration.

Administrative responsibility for the Nuclear Reactor Facility rests with the Department of Nuclear Engineering in the College of Engineering. It operates, primarily, as a facility of the University that is available to the several colleges for their education and research programs. In addition, the Facility is made available to Commonwealth industries to provide irradiation services that are essential in solving their engineering research and development problems.

It can be observed in Table 1, page 9, that a sharp reduction occurred in the number of hours the reactor was critical this past year, whereas the energy produced was increased from 710.4 MWH to 820.54 MWH, a sixteen percent increase. There are a few reasons why this occurred. The reactor is being used predominantly for activation samples at full power (1 MW) and many samples could be irradiated for several users. Consequently, both the number of samples and sample hours per shift almost doubled. In addition, last year a significant increase occurred in the number of hours the reactor staff was involved in providing support for the nuclear engineering laboratories.

In particular, an extensive teaching effort was required for 51 Nuclear Engineering Technology students (see IV, Education and Training) during the spring term. This was accomplished by close scheduling and increased efficiency of operation. The point has now been reached where the present size of the reactor staff precludes increased instructional activities during the spring term.

The Cobalt-60 continues to be used at a steady rate except for the total number of sample hours used in the cobalt-60 facility. All other statistics shown in Table 4 have remained approximately constant over the past year.

The radionuclear applications laboratory continues to be the major research user of the reactor. The laboratory is expanding its counting facilities into the adjacent Academics Projects Building to increase its research capability. The Pennsylvania Power and Light Company continues to support the development of a high sensitivity ariborne radiation monitor and the SO_2NO_x removal project. Interesting projects have been initiated in this laboratory regarding environmental monitoring. Although a forensic application continues for the Pennsylvania State Police, other states in the nation are becoming active in using the techniques developed by Dr. Pillay. For example, Dr. Glore of the Michigan State Police spent a week with Dr. Pillay learning techniques. Mr. Dale Raupach is becoming more active in working with University Researchers providing this laboratory with increased capability to perform activation services for the University.

A brief summary of other major happenings and accomplishments during this past year is as follows:

- The new high speed pool-side pneumatic system for transferring irradiated samples from the reactor to the side of the pool was made operative during the past year. It is being used successfully by Dr. W. Rose and Dr. L. Keith to develop their sample and analytical techniques for performing a regional uranium survey. Their research is supported by ERDA.

- The sixth consecutive Nuclear Concepts Institute for Pennsylvania secondary school teachers was held at Penn State and the laboratory portion conducted at the PSBR.

- A total of 22 high school groups (261 students) visited the reactor facilities for a day to perform experiments at the PSBR and tour the facilities.

- Two industrial training programs, one for Pennsylvania Power and Light Company and the other for Metropolitan Edison Company, were completed this past year.

- Dr. S. H. Levine presented the second three week workshop on Fuel Management for the Mexican INEN at their laboratory in Mexico City.

- The fast neutron spectrum in the central thimble of the TRIGA reactor has been determined by J. K. Schmotzer and S. H. Levine using a new unfolding technique. Their measurements show a previous unobserved dip in the neutron spectrum at approximately 12 Mev. This depression in the neutron spectrum becomes more pronounced as one moves further out into the reflector.

The University Reactor Safeguards Committee met four times during the past year to consult with the staff on new or revised radiation experiments, review operation records, and consult on special operating problems.

The next section provides a list of personnel who are associated with the operation of the reactor and lists staff changes that have occurred this past year. Section III provides pertinent information, including statistical data, on the PSBR's operation. Section IV describes in some detail the various educational and training programs conducted at the PSBR and identifies staff participation. The activities and accomplishments of the Radionuclear Applications Laboratory is presented in Section V. However, more detail on these and other research projects are presented in Section VI.

PERSONNEL

II. PERSONNEL

The facility permanent staff underwent little change during the report period. The policy of employing undergraduate students to supplement the permanent staff in reactor operations continued in successful fashion. In this regard, Mr. R. L. Fisher obtained his Senior Reactor Operators license, and Mr. R. L. Gardner left the Facility (and the University) for industrial employment.

Miss Karen Loughrey was promoted to Secretary of the Nuclear Engineering Department and was replaced by Mrs. Rose Fasick from the Department. Mr. Joseph Gauthier retired after 28 years of service with the University and was replaced by Mr. Paul Matthews, who was formerly employed at WPSX.

Significant changes occurred in Health Physics personnel involved in the support of facility operation. Mr. M. Slobedien left the University for employment with the NRC and was replaced by Mrs. Nancy Daugherty from Colorado State. Mr. Jack Schmotzer received his Ph.D. degree and accepted employment with Babcock and Wilcox in Lynchburg, Virginia. Mr. Schmotzer was replaced by Mr. Donald Hollenbach, formerly in charge of the Department's "This Atomic World" program.

The Safeguards Committee continued the periodic rotation of membership described in last year's report. Dr. Gerry Faith, of the Mechanical Engineering Department, replaced Dr. Robinson as Chairman and other changes occurred as detailed in the Personnel table. Also, the name of the committee is in the course of being changed to the "Reactor Safety Committee."

The Organization chart, Figure 1, shows the present areas of responsibility of the permanent staff.

Dr. Levine made plans for a one year sabbatical leave beginning in September, 1976, to be spent with the Technion Institute in Israel.

Table 1

Personnel

Faculty and Staff	
**T. L. Flinchbaugh	-Reactor Supervisor/Nuclear Education Specialist
**G. C. Geisler	-Research Associate
**R. C. Houtz	-Reactor Supervisor/Nuclear Education Specialist
W. A. Jester	-Associate Professor
**S. H. Levine	-Professor
J. R. McKee	-Administrative Aide
**I. B. McMaster	-Research Assistant
**J. H. O'Brien	-Reactor Supervisor
**J. L. Penkala	-Research Assistant
K. K. Pillay	-Assistant Professor
**D. C. Raupach	-Reactor Supervisor/Reactor Utilization Specialist
G. E. Robinson	-Associate Professor
*K. E. Rudy	-Engineering Aide-Mechanical Service Supervisor
**R. E. Totenbier	-Research Assistant
*D. S. Vonada	-Electronics Designer
Technical Service Staff	
W. A. Davy	-Custodian-Driver
**R. L. Fisher (part-time)	-Reactor Operator
J. P. Gauthier	-Custodian-Technician (Retired September 2, 1975)
*R. E. Jones (part-time)	-Reactor Operator
R. O. Lowrey	-Experimental and Maintenance Mechanic
P. Matthews	-Maintenance Worker
*E. L. Resnick (part-time)	-Reactor Operator
Clerical	
M. D. Beward	-Secretary
R. M. Fasick	-Secretary and Receptionist
K. M. Loughrey	-Secretary and Receptionist (Transferred June 7, 1976)

*Licensed Operator
**Licensed Senior Operator

Graduate Assistants and ERDA Trainees

M. J. Cenko	-Graduate Assistant
H. E. Collins	-Graduate Assistant
R. E. Fjeld	-Graduate Assistant
F. J. Hepburn	-Graduate Assistant
H. Y. Huang	-Graduate Assistant
S. D. Kamdar	-Graduate Assistant
R. Menichelli	-ERDA Trainee
S. M. Mirsky	-Graduate Assistant
W. L. Osmin	-Graduate Assistant
P. J. Rose	-Graduate Assistant
W. G. Runte, Jr.	-Graduate Assistant
F. J. Schofer	-Graduate Assistant
F. M. Sider	-Graduate Assistant
E. K. Stover	-Graduate Assistant
M. J. Sulcoski	-Graduate Assistant
D. G. Tilley	-Graduate Assistant
B. C. Towe	-Graduate Assistant
J. D. Urbanski	-Graduate Assistant
D. S. Williams	-ERDA Trainee

Health Physics

N. M. Dougherty	-Associate Health Physicist
R. W. Granlund	-University Health Physicist
J. K. Schmotzer	-Health Physics Assistant (Resigned June 30, 1976)
M. J. Slobodien	-Associate Health Physicist (Resigned October 1, 1975)

Reactor Safeguards Committee

*Dr. P. Barton, Assistant Professor, Chemical Engineering
Dr. G. M. Faeth, Professor, Mechanical Engineering (Present Chairman)
Mr. G. C. Geisler, Research Associate and Assistant Director, Breazeale Nuclear Reactor
Mr. R. W. Granlund, Health Physicist
*Dr. E. H. Klevans, Professor, Nuclear Engineering
Dr. S. H. Levine, Professor, Nuclear Engineering and Director, Breazeale Nuclear Reactor
Mr. E. J. Ney, Manager, Special Projects, Westinghouse Astronuclear Laboratory
Dr. B. R. Parkin, Professor, Aerospace Engineering
*Dr. K. K. Pillay, Assistant Professor, Nuclear Engineering
Dr. W. W. Pratt, Professor, Physics
**Dr. F. J. Remick, Associate Professor, Nuclear Engineering
**Dr. G. E. Robinson, Associate Professor, Nuclear Engineering (Past Chairman)

*Joined committee during the year.
**Left committee during the year.

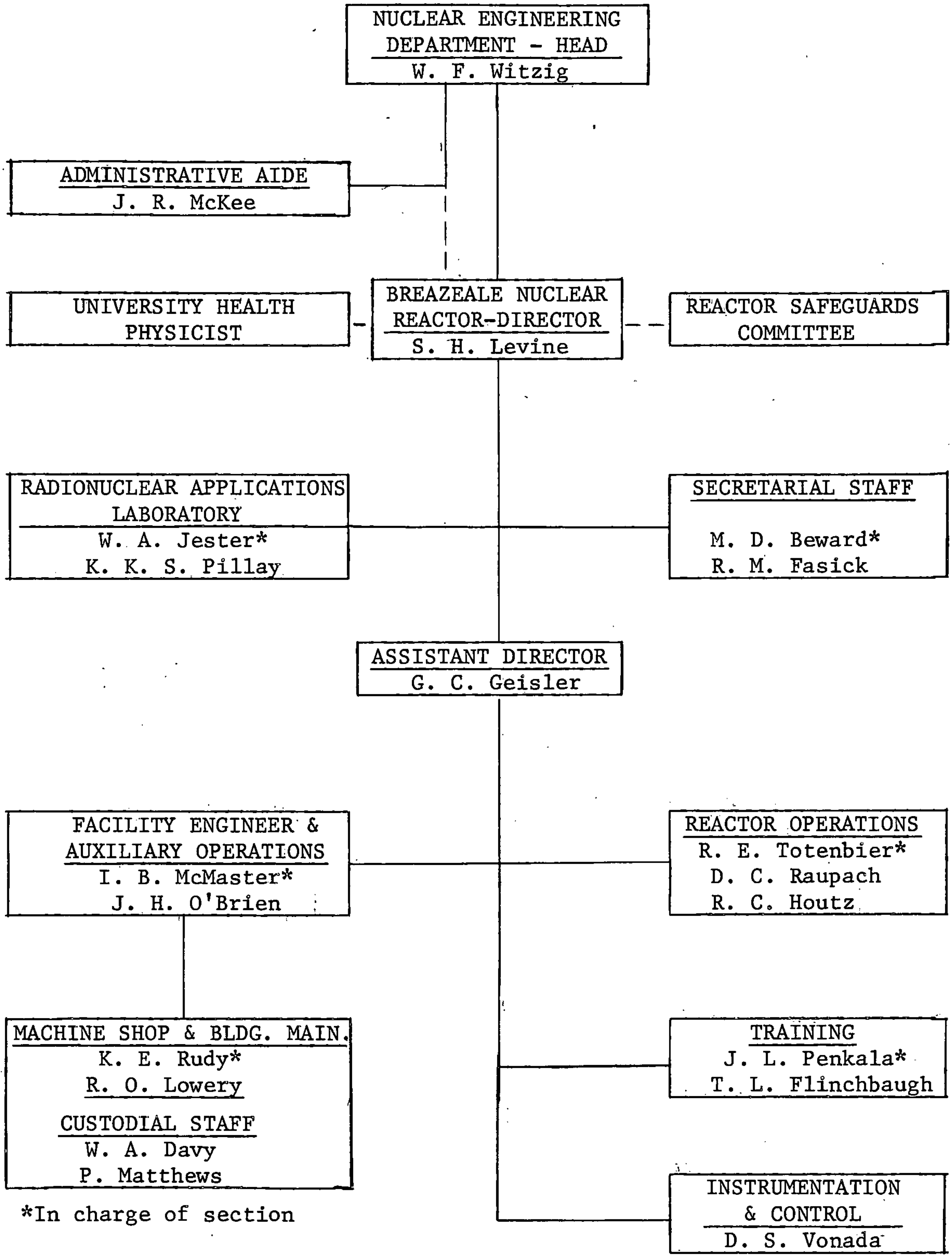

Figure 1

Organization Chart

FACILITY OPERATION

III. FACILITY OPERATION

The operation and utilization statistics for the past two years are listed in Tables 2 and 3 in an effort to reflect the inevitable changes that occur from year to year. One change worthy of note is that it was found possible to schedule an increased number of experiments for simultaneous use of the reactor. Because reactor operating time was used more efficiently, we were able to reduce the number of eight hour shifts and still satisfy the needs for reactor time.

Table 2 shows utilization in averages per eight hour shifts. Although there was only a slight increase in the number of users per shift, the number of samples irradiated and the number of sample hours per shift were both almost doubled. Greater use of the Merry-Go-Round (MGR), a rotating sample holding device used to irradiate as many as 24 samples simultaneously, is reflected in the increase of both the number of samples and sample hours per shift. Since the MGR was designed primarily for high power and long irradiation times, more of the reactor operating time was spent at full power. In spite of the reduced operating hours, the greater demand for more high power runs resulted in an increase in energy release (MWH). The increase in the number of grams of U-235 consumed is of course a result of the greater energy output.

Table 2

Breazeale Nuclear Reactor Operation Data
June 1, 1974 - May 31, 1976

	1974-1975	1975-1976
A. Hours of Critical Time		
1. Hours Critical	1,382.58	799.87
2. Approaching Critical	384.40	166.95
3. Adjusting Fuel	69.47	16.75
B. Number of Pulses	463	160
C. Number of Square Waves	69	48
D. Energy Release (MWH)	710.40	820.54
E. Grams U^{235} Consumed	36.59	42.26
F. Number of Scrams		
1. Planned as Part of Experiments	71	56
2. Unplanned - resulting from		
a. Operator Action	18	18
b. Abnormal System Operation	16	8

* The majority of these resulted from operation by trainees.

Table 3

Breazeale Nuclear Reactor Utilization Data
(average per shift)

June 1, 1974 - May 31, 1976

	1974-1975	1975-1976
A. Number of Users	1.42	1.58
B. Samples or Experiments		
1. Number	6.24	11.77
2. Sample Hours	23.25	41.22
C. Reactor Usage (hours)		
1. Operating	3.35	3.57
2. Shutdown in Stand-by Condition	1.48	1.12
3. Reactor Operator Training	1.55	1.61
4. Calibration and Maintenance	.36	.44
D. Number of 8-hour shifts	413	224

There were fewer total hours of reactor time spent in reactor operator training due to fewer participants in such programs. Greater detail on these programs is given in Section IV, Education and Training.

The second pneumatic transfer system appears to have been debugged and has been used routinely for several months with satisfactory results.

The fuel inspection was completed during the Winter Term break using a new fuel handling tool designed by I. B. McMaster. The design of the new tool required the lowering of our fuel storage rack and fuel inspection tool an additional four feet. Now all the fuel in the pool is at the approximate same height as the reactor core which eliminates most of the vertical movement of fuel previously required.

Our facility was visited by several regulatory agency inspectors. Two were related to our Physical Protection Program, one in August 1975 and again in May, 1976. No problems were encountered by either of these inspections. Also in May, 1976 an inspection was made of the activities covered by our reactor operating license. In this case, the inspector felt that there was a deficiency in the written instructions provided for various annual and semiannual maintenance items. As a result, we are currently expanding such instructions, although in 11 years of operation of the TRIGA reactor, these items have always been completed in an adequate and timely fashion.

During the past year, the Cobalt Facility has seen little change in the type and number of irradiations being performed. The only outstanding change is the reduction in the number of sample hours as shown in Table 4, item A.4. The approximately halfing of this figure is due to the fact that most of the samples were of a biological nature that produced desired results with fairly short irradiation times.

Table 4

Cobalt-60 Operating Statistics
June 1, 1974 - May 31, 1976

			1974-1975	1975-1976
A.	1.	Time adjusting Co-60 sources (hours)	7	6
	2.	Set-up time (hours)	13	12
	3.	Total hours of facility use	3,962	3,725
	4.	Total sample hours	14,474	7,061
B.	1.	Number of samples	510	596
	2.	Number of configuration changes	9	14
	3.	Configuration available	4	4
	4.	Number of different experimenters	30	33
C.	1.	Number of experimenters/day	0.72	.65
	2.	Number of samples/day	2.9	2.36
	3.	Hours of use/day/configuration	2.7	2.54
	4.	Total days available	365	366

EDUCATION AND TRAINING

IV. EDUCATION AND TRAINING

The most extensive training effort this past year was done for the thirty-five Nuclear Engineering Technology (NET) students enrolled in the Nuc. E. 814 course, Reactor Technology Laboratory. This course was taught by John L. Penkala assisted by Terry L. Flinchbaugh, both of the Penn State Breazeale Reactor (PSBR) operating staff. In addition to the experimentation portion of Nuc. E. 814, the NET students accumulated over 600 man hours of reactor operations experience at the controls of the PSBR console through the cooperative efforts of senior reactor operators Robert E. Totenbier, Ira B. McMaster, Dale C. Raupach, John H. O'Brien, Robert C. Houtz, and Terry L. Flinchbaugh.

During the summer of 1975, the laboratory portion of the sixth consecutive Nuclear Concepts Institute (NCI) for Pennsylvania secondary school teachers was offered at the PSBR. The seventeen participants were guided through their laboratory work by T. L. Flinchbaugh, Donald Hollenbach, Jack Brenizer, and J. L. Penkala. Dr. W. A. Jester assisted with the NCI administratively and with classroom lectures.

As in the past, the Pennsylvania secondary school teachers who participated in the NCI were encouraged to return to the PSBR with their students for a one day field trip. This resulted in 22 high school groups totaling 261 students visiting the reactor facilities for a day of touring and experimentation. Initially the logistical chores involved with the high school group visits were handled by J. L. Penkala and T. L. Flinchbaugh but were subsequently done by graduate student Frederick Schofer. Table 5 summarizes the participation in this program. Incidentally, there were nine utilizers of the Co-60 facility in conjunction with high school science projects, many of them prompted by the high school visits.

Another program which required a maximum effort from the entire operating staff was this year's PSBR license requalification program. The requalification was done in three parts: First, on 14 October 1975, I. B. McMaster started the staff on the facility walkaround examinations. This was followed by R. E. Totenbier's procedure manual familiarity examination. Finally, T. L. Flinchbaugh and J. L. Penkala concluded the requalification exams by composing, administering, and grading the written NRC type examination. By 5 December 1975, all fourteen license holders at the PSBR had successfully requalified.

Two industrial training programs were completed this year. The first was a Reactor Technology and Operations Program (RTOP) which was done for eight Pennsylvania Power & Light (PP&L) Company employees. The RTOP was two weeks long and the participants spent half of their time in class where lectures were conducted by Dr. E. S. Kenney, Dr. G. E. Robinson, Dr. F. J. Remick, and J. L. Penkala.

The remainder of the PP&L Company employee's time was spent in laboratory experiments and in console operating experience where they were tutored by senior staff operators T. L. Flinchbaugh, R. E. Totenbier, R. C. Houtz, D. C. Raupach, J. H. O'Brien, I. B. McMaster and J. L. Penkala.

The second industrial program was done for thirteen Metropolitan Edison Company employees. It was a Reactor Startup and

Table 5

High School Nuclear Science Program 1975-76

High School	Instructor	No. of Students
Chambersburg	Mr. Neol	10
Westinghouse Explorer Scouts	Mr. Maurice	40
Lower Dauphin	Mr. Lyter	21
Wyomissing	Mr. Bell	11
Carlisle	Mr. Kauffman	10
Penn Hills	Ms. Szitas	9
Penns Valley	Mr. Fuller	8
Beatie Tech.	Mr. Leseck	15
Ridgeway	Mr. Koos	9
Union City	Mr. Obert	13
Chestnut Ridge	Mr. Popp	7
Jersey Shore	Mr. Allen	7
Smethport	Mr. Fetter	11
Dunmore	Mr. Gatto	5
North Schuykill	Mr. Welker	6
Exeter	Mr. Murray	8
Waren Area	Mr. Szul	19
Bellefonte	Mr. Young	20
Titusville	Mr. McQueer	5
Marion Center	Mr. Petrosky	11
Troy	Mr. Johnson	4
Parkland	Mr. Eckensberger	12

Groups total - 22

Participants total - 261

Experimentation Program (RSEP) one week long but offered twice. The RSEP was coordinated by J. L. Penkala and T. L. Flinchbaugh and the previous list of senior operators again provided the console operating experience. However, the experimentation portion of the RSEP was aided by PSBR staff members G. C. Geisler, E. L. Resnick, R. A. Jones, and R. L. Fisher along with the senior operating staff.

The participants in the various training programs mentioned above are listed in Table 6.

The net program received additional support from the PSBR facilities and staff in the following ways: The fifteen students enrolled in the Radiological Safety Laboratory course, Nuc. E. 830, were aided in their instruction by J. H. O'Brien. Secondly, each of the fifteen Nuc. E. 830 students was scheduled for 3 hours of reactor familiarization on the console of the PSBR. Additionally, the Nuc. E. 830 students used isotopes produced in the PSBR and thermoluminescent dosimeters irradiated in the Co-60 facility.

Rounding out the involvement in the NET program, D. K.K.S. Pillay offered the Nuclear Technology Laboratory course, Nuc. E. 812, to the 51 NET students in the laboratory facilities available in Room 2 of the PSBR. The faculty advisor for the 50 NET students who were in residence at University Park during the past Spring Term was J. L. Penkala.

A most useful learning experience again resulted for the 20 seniors enrolled in Nuc. E. 430 when they were given the opportunity to manipulate the controls of the PSBR through a complete startup-shutdown operation sequence. This exercise was supervised by staff Senior Operators.

Table 6

Participants in Reactor Training Programs

Name	Sponsor	Program	Started	Completed
*R. L. Fisher	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
T. L. Flinchbaugh	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
G. C. Geisler	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
R. C. Houtz	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
R. A. Jones	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
S. H. Levine	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
I. B. McMaster	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
J. H. O'Brien	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
J. L. Penkala	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
D. C. Raupach	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
E. L. Resnick	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
K. E. Rudy	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
R. E. Totenbier	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
D. S. Vonada	Breazeale Reactor	License Requalification	14 Oct. 1975	5 Dec. 1975
R. H. Bielecki	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
G. Demko	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
M. B. Detamore	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
R. W. Erlinger	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
R. T. Jenson	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
L. D. O'Neil	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
J. B. Rimdky	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
R. D. Wirth	Penn. Power & Light Co.	Reactor Technology & Operations	7 July 1975	14 July 1975
R. R. Booher	Metropolitan Edison Co.	Reactor Startup & Experimentation	10 Nov. 1975	21 Nov. 1975
B. Brann	Metropolitan Edison Co.	Reactor Startup & Experimentation	17 Nov. 1975	21 Nov. 1975
W. T. Conway II	Metropolitan Edison Co.	Reactor Startup & Experimentation	10 Nov. 1975	14 Nov. 1975
E. R. Frederick	Metropolitan Edison Co.	Reactor Startup & Experimentation	10 Nov. 1975	14 Nov. 1975

*Qualified for Senior Reactor Operator License Feb. 1976.

Table 6 (continued)

Name	Sponsor	Program	Started	Completed
D. W. Horton	Metropolitan Edison Co.	Reactor Startup & Experimentation	17 Nov. 1975	21 Nov. 1975
R. R. Hoyt	Metropolitan Edison Co.	Reactor Startup & Experimentation	17 Nov. 1975	21 Nov. 1975
R. S. Hutchison	Metropolitan Edison Co.	Reactor Startup & Experimentation	10 Nov. 1975	14 Nov. 1975
T. Illjes	Metropolitan Edison Co.	Reactor Startup & Experimentation	10 Nov. 1975	14 Nov. 1975
A. Miller	Metropolitan Edison Co.	Reactor Startup & Experimentation	10 Nov. 1975	14 Nov. 1975
D. Olson	Metropolitan Edison Co.	Reactor Startup & Experimentation	17 Nov. 1975	21 Nov. 1975
F. J. Scheimann, Jr.	Metropolitan Edison Co.	Reactor Startup & Experimentation	17 Nov. 1975	21 Nov. 1975
G. E. West	Metropolitan Edison Co.	Reactor Startup & Experimentation	10 Nov. 1975	14 Nov. 1975
L. O. Wright	Metropolitan Edison Co.	Reactor Startup & Experimentation	17 Nov. 1975	21 Nov. 1975
L. Aumiller	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
M. B. Bezilla	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
S. Bonasso	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
F. Bosack	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
G. W. Busch	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
D. L. Clabaugh	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
J. L. Dauberman	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
F. R. Dietz	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
J. T. Doman	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
K. E. Enck	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
K. Farabaugh	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
C. L. Gruneberg	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
D. L. Harpster	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
B. L. Jais	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
J. E. Kelly	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
C. D. Kishbaugh	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1975
J. P. Klebon	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
K. B. Krummel	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
M. S. Laidlow	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
C. M. McClain	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
D. K. McCurdy	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
L. W. Miller	Pennsylvania State Univ.	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976

Table 6 (continued)

Name	Sponsor	Program	Started	Completed
M. E. Miller	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
S. A. Mills	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
R. E. Moyer	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
A. J. Polster	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
K. B. Reininger	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
M. W. Rininger	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
D. M. Robine	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
R. G. Rolph	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
W. F. Shura	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
W. G. Smith	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
J. M. Stockmal	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
J. E. Streightiff	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
T. W. Strong	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976
D. A. Vilke	Pennsylvania State University	Nuclear Engr. Technology	11 Mar. 1976	19 May 1976

Because of increased enrollment in the undergraduate program, Nuc. E. 440 was offered at the PSBR facility twice this past year. R. C. Houtz played a most important role in making equipment available for the two offerings of Nuc. E. 440. G. C. Geisler assisted in one of the Nuc. E. 440 sessions. The laboratory course Nuc. E. 441 and three terms of the graduate laboratory course Nuc. E. 502 were conducted at the PSBR again with the assistance of the general staff.

During the summer of 1975, J. L. Penkala offered a Nuc. E. 400 Special Topics course in reactor operations for three nuclear engineering graduate students in which each student manipulated the controls of the PSBR for a total of 30 hours.

It has continued to be standard procedure to seek the assistance of Douglas S. Vonada, staff electronic designer, in solving the multitude of electrical and electronic problems which arise with the reactor and the associated equipment. The success of the courses, institutes, training programs, and demonstrations provided by the staff and faculty is due in large part to D. S. Vonada's electronic prowess.

The PSBR and its staff continued to serve the various colleges and departments of the University in the following instances:

- Forty Chemistry 405 students used 65 service irradiations for preparation of materials for laboratory work and engaged in four sessions of reactor familiarization and study.
- Three Anthropology 14 students used the PSBR facilities as an aid in studying methods in archaeology.
- Twelve Civil Engineering 574 students determined the hydraulic characteristics of a model settling basin through use of radioactive tracers produced at the PSBR.

- A total of 109 students enrolled in Horticulture 407 laboratory session used various materials treated in the Co-60 facility.
- Forty-five University Police Services personnel, who will ultimately be responsible for security checks of the PSBR, were given a two-hour training/retraining session to ensure adequate familiarization with the facilities.
- A total of fifteen students enrolled in a Nuclear Engineering class at Bucknell University spent two days at our facility conducting several reactor related experiments.

Finally, in a continuing effort to provide service and information to any interested person or group, the staff of the PSBR conducted tours for a total of 2,749 visitors during the 1975-76 reporting period.

RADIONUCLEAR APPLICATIONS LABORATORY

V. RADIONUCLEAR APPLICATION LABORATORY

Unlike recent years, the 1975-76 activities of the Radionuclear Applications Laboratory were not dominated by one or two large projects, but instead consisted of many small research and service projects. The laboratory staff continued to consist of Dr. W. A. Jester and Dr. K.K.S. Pillay, with part-time assistance from Mr. D. C. Raupach of the reactor staff. Probably the major event of the year was the completion of a high-speed pool-side pneumatic system. This system was initially set up to do uranium analysis using neutron detectors, but will eventually be set up to do activation analysis involving short-lived radionuclides and gamma ray spectroscopy.

Support has continued from Pennsylvania Power and Light Company for the development of high sensitivity airborne radiation monitors and the SO_2-NO_x removal project. Support has also been received from them to initiate research in the development of high sensitivity water-borne radiation monitors. A new project has been initiated with support from the U.S. Department of Interior through the University's Institute for Research on Land and Water Resources to conduct field tests to evaluate the use of the various non-radioactive but neutron activatable tracers previously identified as having the potential for studying the movement of underground waters.

Another major event was the establishment of a second radiation counting laboratory which is located in Room 103, Academics Projects Building, a building situated next to the Breazeale Nuclear Reactor.

This counting laboratory is equipped with a 2048 channel Northern Scientific Econ II analyzer attached to a 30 cc Ge(Li) gamma ray spectroscopy detector positioned in a newly-constructed low background cave. Also to be located in this lab is the x-ray fluorescence analysis facility which is under development. This will use the same analyzer, but will use a high resolution Si(Li) detector currently on hand.

Forensic applications of nuclear techniques developed at Penn State continued by offering the services of Dr. Pillay to analyze evidence submitted by the Pennsylvania State Police and to present testimony in courts. Another highlight was the request by the Michigan State Police to train one of their senior staff scientists to use film-lift techniques and activation analysis of evidence samples. During the term break between spring and summer, Dr. Glore of the Michigan State Police spent a week with Dr. Pillay at the reactor facility learning the "trade secrets" to adopt the Penn State methods as a routine procedure in the state of Michigan.

Mr. Raupach has been active in working with University researchers and has also been providing services to an increasing number of industrial clients who desire the use of one of the radionuclear techniques which have been developed over the years by laboratory personnel.

On June 16, 1976, Drs. Pillay and Jester presented a tutorial session at the summer meeting of the American Nuclear Society on the topic "Use of Non-radioactive Activatable Tracers," in an area in which they have probably as much expertise as anyone in the country. This session was co-sponsored by both the Isotopes and Radiation Division and the Education Division. Dr. Pillay organized the session and Dr. Jester was session chairman. Dr. Pillay presented the introductory paper entitled "Non-radioactive Activatable Tracers." Dr. Jester followed this with a paper on "Field Use of Neutron Activatable Tracers." Other papers in the session included "Activatable Tracers in Forensics," presented by C. C. Thomas, Jr., SUNY at Buffalo; "Activatable Tracers in Medicine," presented by C. A. Glomski, SUNY at Buffalo; and "Use of Activatable Tracers in Water Treatment Systems," presented by G. G. Eichholz of Georgia Tech.

Summaries of other research projects can be found under Section VII, B. University Research Projects Utilizing the Radionuclear Applications Laboratory.

FACILITY RESEARCH UTILIZATION

VI. 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 divided into three categories: research utilizing the PSBR, research involving the Radionuclear Applications Laboratory (and in most cases the reactor), and research utilizing Auxiliary Radiation Sources such as the Cobalt-60 Facility. In addition, a section is provided on non-University research utilizing the Facility.

The Facility continues to serve as a research tool available to all faculty and graduate students of the various departments and colleges within the University. Fifty-eight faculty members and sixty-three graduate students have used the Facility in the past year for research. This represents a usage by twenty different departments of the University. Names of the individual users and their departmental affiliation are given in Appendices A and B.

The following list of current research projects (arranged in alphabetical order using author's names) indicates the broad utilization enjoyed by the Breazeale Reactor Facility. The 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 Penn State Breazeale Nuclear Reactor (PSBR)

1. Permeability of Snake Skin to Water and Salt

Dr. W. A. Dunson, Biology Department

Fasting yellow-bellied sea snakes (Pelamis) have a very low rate of exchange of Na with sea water. Influx and efflux are balanced at a value near 8 μmoles/100 g·h. This is only a fraction of the rate of exchange found in marine fish. Na influx is due to uptake in the head region; dermal and cloacal influx are minimal. The impermeability of the skin to Na has been confirmed in isolated preparations. The outer keratin layer seems to be the primary barrier, since the shed skin alone is also impermeable. Na efflux can be increased to 140 μm/100 g·h by salt injections, and secretion by the sublingual salt gland can account for all of this loss. Fasting snakes are not in water balance in sea water. There is a net loss of water amounting to about 0.4% body wt/day that probably occurs mainly through the skin. The major osmotic problem of Pelamis in sea water seems to be water balance, not salt balance. Differences in salt gland size among sea snakes might be related to differences in skin permeability to water associated with dermal respiration. The importance of the skin as a permeability barrier suggests that the frequent skin shedding of sea snakes may be related to maintenance of low water permeability as well as to prevention of growth by marine fouling organisms.

2. Water and Sodium Balance in the Diamond Back Terrapin

Dr. W. A. Dunson and G. Robinson, Ph.D. Candidate, Biology Department

Total body water decreased significantly in terrapins exposed to sea water (SW). Although the intracellular fluid decreased somewhat upon SW exposure, the decline in extracellular fluid was almost twice as great. Under conditions of voluntary drinking after salt loading, terrapins substantially increased the volume of the extracellular fluid while maintaining the intracellular fluid near the freshwater (FW) control levels. FW terrapins were consistently heavier than animals of the same plastron length exposed to SW. Thus expression of body fluid volumes as ml/cm plastron length rather than as % body weight is necessary to correct for the loss of total body water with progressive dehydration. Fasted terrapins in SW lost weight at 0.32% weight/day, whereas the rate in FW was 0.21%/day. Water influx and efflux in SW were 0.17 and 0.16 ml/100 g·h respectively. When the efflux was increased by the calculated value for unmeasured respiratory loss, it exceeded the influx by 0.01 ml/100 g·h.

Consequently the net water loss determined with radiotracers (equivalent to 0.24% weight/day) was similar to the difference between the weight losses in SW and FW (0.11%/day). Partitioning studies indicated that the majority of water exchange between the terrapin and SW occurs through the integument. Terrapins in SW underwent a concentration of the body fluids, most of which can be attributed to water loss, not electrolyte gain. The rates of Na influx and efflux were quite low (usually ranging from 6-10 µmoles/100 g·h). In two terrapins the injection of NaCl loads resulted in eight- to 19-fold increases in Na efflux. The uptake of Na from SW occurred orally. The skin was virtually impermeable to Na. The salt gland and possibly the cloaca were the major routes of Na efflux. The injection of NaCl loads resulted in an increase in cephalic Na excretion from a mean of 3.2 µmoles/100 g·h to 32.5 µmoles/100 g·h. Terrapins in SW exhibited a significant increase in bladder urine [K] over the FW controls. There was a direct relationship between plasma [Na], urine [K], and lachrymal salt gland Na-K ATPase content. In comparing SW terrapins with FW painted turtles (Chrysemys) exposed to SW, radiotracer studies demonstrated a similarity in Na influx, but there was at least a four-fold increase in water exchange in the painted turtle. It seems likely that the skins of many aquatic reptiles (marine, estuarine and FW) are impermeable to Na but differ markedly in water permeability.

3. ^{24}Na Fluxes in Tadpoles Exposed to Low pH

Dr. W. A. Dunson and P. Saber, M.S. degree Candidate, Biology Department

The effect of low pH on ion balance in aquatic organisms has in recent years become the object of some attention due to the problems caused by acidic pollutants. Vertebrate classes other than fish have been neglected because, for the most part, they are not found in environments where low pH has a direct effect upon them. In naturally acidic blackwater habitats, such as bogs, the pH often falls low enough to exclude fish.

In contrast to the depauperate fish populations, amphibian populations of certain species are often found in naturally acidic waters. This is particularly significant because most temperate amphibians are entirely aquatic during embryonic and most of larval development. Although populations of amphibians are successful in naturally acidic habitats, it appears that populations are less diverse than in clear water counterparts of blackwater systems.

Previous studies of ionicregulation in amphibian larvae have concentrated on normal water fluxes and ion fluxes and the mechanisms which control them. A comparison of ionicregulation in species which occur in naturally acid habitats and species which are normally absent from such habitats would show whether the mechanisms of ionicregulation in the larvae of acid tolerant anuran species are less sensitive to low pH than those in larvae which do not occur in acidic environments. Furthermore, if populations of species pre-adapted to low pH do occur naturally, it may be possible to use them as indicators of the presence of acidic pollutants.

A comparison of bull frog and green frog embryos and larvae may show whether marked differences in tolerance to low pH exists between species which occur in naturally acid habitats and those which do not.

This study may also help explain why two sympatric anurans, the green frog and bull frog, which often occur in the same habitats do not occur together in naturally acidic habitats.

4. Delayed Neutron Spectrum of ^{87}Br

Drs. E. S. Kenney and P. K. Ray of the Nuclear Engineering Department

An apparatus for separating Bromine isotopes from gross fission gases has been developed together with a neutron spectrometer. The ^{87}Br spectrum has been unfolded using digital computer codes and compared to published results. The spectrum observed is of lower energy than expected and exhibits a definite peak structure.

5. Unfolding Fast Neutron Spectra and Cross Sections in a TRIGA Reactor

Dr. S. H. Levine and J. K. Schmotzer, Ph.D. Candidate, Nuclear Engineering Department

An iterative algorithm has been developed which unfolds integral reaction rate data to yield either differential neutron spectra, $\phi(E)$, or differential cross sections, $\sigma(E)$. The algorithm provides rapid convergence and relative independence from the starting guess. It is computerized in the FATDUD unfolding code. The FATDUD code has been used to unfold neutron spectra in a TRIGA reactor; these spectra were subsequently used to unfold two threshold reaction cross sections.

Eight threshold reactions were used to measure the TRIGA fast neutron spectra: $^{24}Mg(n,p)^{24}Na$, $^{27}Al(n,\alpha)^{24}Na$, $^{27}Al(n,p)^{27}Mg$, $^{46}Ti(n,p)^{46}Sc$, $^{55}Mn(n,2n)^{54}Mn$, $^{58}Ni(n,p)^{58}Co$, $^{90}Zr(n,2n)^{89}Zn$, and $^{115}In(n,n')^{115m}In$. The activation rates for each of these reactions were measured at eight positions in the central thimble of the Penn State Breazeale Nuclear Reactor at distances ranging from 2.65 to 23.65 in. above the core center line. The unfolded neutron spectra show two interesting features. The first of these is a depression in the fast flux at 3 Mev corresponding to a peak in the $^{16}O(n,\alpha)^{13}C$ cross section; it has been reported previously. A second depression in the unfolded neutron spectra appears at 12 Mev and corresponds to a peak in the $^{16}O(n,p)^{16}N$ cross section; this depression has not been previously reported.

The eight unfolded neutron spectra were subsequently used to demonstrate cross section unfolding. The reaction rates for $^{48}Ti(n,p)^{48}Sc$ and $^{51}V(n,\alpha)^{48}Sc$ were measured at each of eight irradiation positions. These two cross sections were then unfolded using the best literature values as starting guesses. The unfolded cross sections are in good agreement with other differential measurements reported in the literature. Their fission-averaged values are 0.25 mb for $^{48}Ti(n,p)^{48}Sc$ and 0.020 mb for $^{51}V(n,\alpha)^{48}Sc$.

6. Radiation-induced Paramagnetic Defects in GeO_2

Drs. D. P. Madacsi and J. F. Houlihan of the Department of Physics (Shenango Valley Campus)

Paramagnetic transition-metal ions in single crystals of the rutile-type hosts TiO_2 and SnO_2 have been extensively studied by electron spin resonance (ESR) techniques. However, because of the unavailability of single crystals of sufficient size, ESR studies of transition-metal ions in the rutile or tetragonal form of GeO_2 had not been reported until very recently. Harvill and Roy of the PSU Materials Research Laboratory were probably the first to successfully grow high-purity single crystals of tetragonal GeO_2 of size appropriate for ESR studies (mm-size dimensions). The hydrothermal crystal-growth technique employed by them was later successfully applied by this researcher (under the direction of the late Dr. Harvill at the University of Connecticut), to the growth of GeO_2 single crystals doped with various transition-metal elements. Subsequent ESR studies of V^{4+}, Cr^{3+}, and a radiation-induced hole-like defect in tetragonal GeO_2 have recently been reported. This work has been extremely productive because of the many correlations which could be made with studies of the same paramagnetic impurities in the isomorphic compounds SnO_2 and TiO_2.

The many additional paramagnetic defects which have been studied in SnO_2 and TiO_2 provide a wealth of research problems for which an isomorphic series study may now be completed. It is proposed that these studies be carried out in GeO_2 with the expectation that the correlations observed will be as fruitful as those already obtained for the V^{4+} and Cr^{3+} impurities. The radiation-induced hole-like defect in GeO_2 mentioned above has not been observed in SnO_2 or TiO_2, although several other radiation-induced defects have been observed in those hosts. Therefore, additional study of radiation-induced paramagnetic defects in GeO_2 is also proposed.

7. A Low Intensity Transition in the Decay of ^{175}Hf

Dr. W. W. Pratt of the Physics Department

A study of the decay of ^{175}Hf, using a Ge(Li) gamma ray spectrometer has confirmed the presence of a weak transition in ^{175}Lu. A gamma ray was found with an energy of 253.3 $\pm$ 0.2 Kev and an intensity (relative to 100 for the 343 Kev gamma ray) of 0.21 $\pm$ 0.02.

8. Decay of ^{115m}Cd

Dr. W. W. Pratt of the Physics Department

A recent study of the decay of the 43 day isomer of ^{115}Cd has indicated the presence of 8 weak gamma ray transitions in ^{115}In which have not previously been reported. A measurement of the ^{115m}Cd gamma ray spectrum is in progress, using a 40 cm^3 Ge(Li) gamma ray spectrometer to search for these new gamma rays.

9. Decay of Nuclear Isomers

Dr. W. W. Pratt and J. Herritt, Graduate Assistant, Physics Department

Experiments have been performed to study the use of a pulsed neutron beam to produce isomers in the millisecond regions. The aim of the work is to investigate the decay schemes of isomers such as ^{136m}Ba and ^{24m}Na. It has been found that fast neutrons from the tail of the TRIGA pulse result in a large background with the shielding arrangements tried to date and that decay scheme measurements will not be practicable until a means of reducing this background by a considerable factor has been found.

10. Hindered Beta Decay of ^{95m}Nb

Dr. W. W. Pratt and A. Al-Zubaidi, Graduate Assistant, Physics Department

A recent study of the decay of ^{95m}Nb has shown hindered beta decay transition to known levels in ^{95}Mo at 204.12, 786.19, 820.61 and 1039.25 Kev. These beta decay transitions were found to be 2 to 3 orders of magnitude slower than those observed in the decay of ^{95m}Tc. The gamma ray transitions following beta decay of ^{95}Zr are being studied with a 40 cm^3 Ge(Li) gamma ray spectrometer to search for weak gamma rays from the decay product ^{95}Nb and to determine whether these hindered beta transitions can be confirmed.

B. University Research Utilizing the Radionuclear Applications Laboratory

1. The Partitioning of Several Rare Earth Elements Between Silicate Melts and Aqueous Vapor

Dr. C. W. Burnham and T. Flynn, Ph.D. Candidate,
Department of Geosciences

The fractionation of the rare earth elements in geochemical systems has been known for over 20 years. A considerable effort has been expended in measuring these rare earth patterns both in terrestrial rocks and minerals and in lunar samples. However, despite this ever increasing data base, a real analysis of the controlling variables (e.g. pressure, temperature, rock chemistry, etc.) must ultimately depend on laboratory experiment. Towards this end the behavior of several rare earths (Ce, Er, Gd, Yb) are being experimentally examined in geochemically pertinent systems.

Briefly, the technique involves irradiating rare earth solutions in the Breazeale Nuclear Reactor facility and employing the radioactive products as tracers in the system of interest. Solutions of selected rare earth tracers and silicate melt are equilibrated at appropriate pressure and temperature conditions. After the experiments are completed, both the aqueous and melt phases are analyzed by γ-ray spectrometry. In this manner, a distribution coefficient is derived for the particular rare earth element(s).

Preliminary results, employing ^{153}Gd, have shown that the composition of the aqueous phase can be critical in controlling the distribution coefficient. For example, the partitioning of Gd between a granitic melt and distilled water is approximately 300/1 in favor of the melt phase. Addition of 1.2 MCl^- to the system changes this value to approximately 20/1 in favor of the melt.

Currently, the other rare earths are being examined as well as the role of melt chemistry and water pressure. Completion of the experimental work will hopefully take place by the Fall of 1976.

2. Development of a Fence-line Monitor for the Detection of Low Level Airborne Radioactive Gases

Dr. W. A. Jester and S. Pandy and F. Hepburn, Graduate
Assistants, Nuclear Engineering Department

A second generation system of the airborne radioactive gas monitor was completed using air compression and gamma-ray spectroscopy and a Ge(Li) detector. This new system has demonstrated a sensitivity in the range of 10^{-10} μCi/ml for the various radioactive gases emitted from nuclear reactors. It has been calibrated using irradiated Krypton and Argon clathrates and field tested at the Breazeale Nuclear Reactor and at the Three Mile Island Nuclear Generating Station. More tests are planned for the future.

3. Use of Neutron Activatable Tracers for Evaluating the Simulation of Water and Chemicals Movement Through Porous Media in the Field

Dr. W. A. Jester of the Nuclear Engineering Department,
Dr. H. B. Pionke, Dr. W. R. Heald, and A. S. Rogowski of the Northeast Water Shed Research Center, USDA and
W. Osmin, Graduate Assistant, Nuclear Engineering Department

The purpose of this research is as follows: 1) compare the observed chemical transport in underground waters with that predicted according to hydrologic modeling and measurements, and 2) improve methodology of applying neutron activation analysis to ground water movement in large water sheds. The hydrologic research watersheds for this project are being provided by the Northeast Watershed Research Center of the U.S. Department of Agriculture. This project is a continuation of previous work to develop the methodology for using non-radioactive but neutron activatable tracers.

4. Development of an X-ray Fluorescence Capability

Dr. W. A. Jester and R. Schofer, Graduate Assistant,
Nuclear Engineering Department

Because of continued interest in X-ray Fluorescence Analysis by University researchers, work is continuing to set-up the equipment to provide this type of service. A higher output X-ray machine is on loan from the University's Health Physics Office. A high resolution Si(Li) detector is available for obtaining the X-ray spectra. Work is now underway to design the sample holder head which will be positioned over the radiation detector.

5. Investigation of the Fold Surface of Polyethylene Single Crystals

Dr. I. R. Harrison, Material Sciences Department, and
J. Runte, M.S. degree Candidate, Solid State Science Department

It is well known that polyethylene (PE) single crystals grown at specific temperatures from dilute solution are monolayer, chain folded lamallite structures. These lamallae are composed of a thin top and bottom surface of amorphous (fold) material surrounding a crystalline core. In the present work, the nature of the amorphous region (i.e., the fold surface) is being altered by the addition of bromine and the subsequent replacement of the bromine by aromatic residues. The properties of the crystals which depend on the nature of the fold surface are then being examined by fourier transform infrared spectroscopy and differential scanning calorimetry. Neutron activation analysis is being used to readily determine the concentration of bromine on the crystal surfaces.

6. Neutron Activation Analysis of Axum Obsidian

Dr. J. W. Michels, Anthropology Department, Dr. W. A. Jester, Nuclear Engineering Department, and L. de Mendoza, Ph.D. Candidate, Anthropology Department

A total of 226 obsidian artifact specimens from a number of archaeological sites in Axum-Yeha, Ethiopia, were processed in an effort to determine their contents of Sodium and Manganese relative to 1 mg. of their mass. These values, and their ratio, have been proved to be an effective means to identify obsidians, and link them to their respective geological sources, thus rendering possible their use as evidence for the reconstruction of trade routes, patterns of distribution, and eventually to elucidate problems on the socio-political organization of extinct societies.

The Axum project was exploratory in its essence, as to look for primary patterns in the distribution of obsidians at diverse sites over a large region in the Tigre Province.

Results suggest the occurrence of at least seven, and perhaps up to 10, different "types" of obsidian in the sample. Five of these are discrete enough as to permit clear discrimination among themselves, while the remaining show differential extents of overlapping when arranged along a continuous scale.

This information was obtained primarily as to constitute a base upon which test hypotheses could be forwarded and tested by further research, as part of a major project which is to be carried out in following years.

7. Neutron Activation Analysis of Obsidian Artifacts from Kaminaljuyu, Guatemala

Dr. J. W. Michels, Anthropology Department, Dr. W. A. Jester, Nuclear Engineering Department, and L. de Mendoza, Ph.D. Candidate, Anthropology Department

A sample of 131 artifact specimens collected during excavations at Kaminaljuyu were tested for their contents of Sodium and Manganese, in order to determine the degree of homogeneity or heterogeneity in the composition of the material used for making tools at the site. Problems investigated and discussed are: 1) the affects of chemical composition on the hydration rate of obsidian; 2) the effects of alien political control on the local exploitation and distribution of obsidian; and 3) the relation of trace element composition of obsidian to its visual appearance, and which types of obsidian are selected for certain artifact types.

Results show that about 95% of obsidian analyzed came from the four or five extrusions of the major geologic source known as El Chayal, and that only 4% were from Ixtepeque.

8. Obsidian in Kaminaljuyu and the Valley of Guatemala

Dr. J. W. Michels, Anthropology Department, Dr. W. A. Jester, Nuclear Engineering Department, and L. de Mendoza, Ph.D. Candidate, Anthropology Department

Previous research (Hurtado, 1973) has shown that the major archaeological site in the valley of Guatemala, namely the civic and ceremonial centre of Kaminaljuyu had utilized a single major source of obsidian, El Chayal, for the elaboration of tools, for over 1300 years. A further step in this research, was aimed to the determination of a means for the recognition of obsidians from each of a number of quarries that were thought to correspond to the El Chayal source, since the contents of Sodium and Manganese and their ratio were not adequate basis for such discrimination. The content of Rubidium was tested, but its discriminatory power proved to be no more efficient than the one already proved for Na:Mn. Instead, a multivariate statistical technique that uses data on the activity of several radionuclides produced by Neutron Activation, has achieved a sufficiently discriminatory basis for the characterization of 6 of these quarries, three of them only recognizable from the artifact specimens found at Kaminaljuyu. Fieldwork, planned to be carried out in the Summer of 1976 will attempt to locate these and other quarries. The distribution of "kinds" of obsidian between and within sites is expected to provide insights regarding the changing patterns of socio-political and economic organization in pre-Columbian Guatemalan society.

9. Migration of Trace Metals in Tree Trunks

Dr. W. W. Miller, Chemistry Department, Dr. K.K.S. Pillay, Nuclear Engineering Department and R. Hesson, B.S. degree Candidate, Chemistry Department

An effort, through neutron activation analysis, to determine the extent of longitudinal and transverse migration of the trace metals in trees is a part of a continuing project in the chronometry of environmental trace elements.

10. Trace Elements in Small Volume Air Sampling Procedures

Dr. W. W. Miller, Chemistry Department, Dr. K.K.S. Pillay, Nuclear Engineering Department and T. Risby and G. Rosenberger, M.S. degree Candidates, Chemistry Department

A comparison of neutron activation with atomic absorption methods and their ultimate sensitivity limits for application to elemental analysis of particulate matter in small volume air sampling in environmental studies is being investigated.

11. Oxidation of Organic Halogen Compounds

Dr. W. W. Miller and A. Stein, B.S. degree Candidate, Chemistry Department

This research involves the use of tracer bromine to follow the fate of the halogen in organic compounds when they are subjected to wet oxidation for destruction of the organic portion.

12. Mechanisms of Bone Resorption and Accretion _in Vivo_ (N.I.H. grant AM 04362)

Dr. W. J. Mueller and D. Benner and B. Lobaugh, M.S. degree Candidates, Poultry Science Department

The goal of the project is to determine the role of blood flow in the mechanism of action of parathyroid hormone and in bone metabolism. Blood flow is measured at three different times by injecting successively 15 micron spheres labeled with ^{85}Sr, ^{169}Yb or ^{51}Cr into the heart. Since the microspheres are slightly larger than the capillaries, they become trapped in different organs during their first passage. Thus, the fraction of the injected dose recovered in an organ is equal to the fraction of the cardiac output which this organ received. The 400 Channel Gamma Spectrometer together with computer program 10661 was used to resolve the gamma spectra.

13. Nature's Pollution Almanac

Dr. K.K.S. Pillay of the Nuclear Engineering Department

Investigations conducted over the past three years have provided adequate evidence to prove that certain species of trees are capable of accumulating and preserving trace elemental pollutants from their immediate environment. The pollution records in trees can be chronologically sorted out via judicial applications of dendrochronological and neutron activation analysis measurements. This continuing investigation, so far, examined 30 different trace elements in six different species of trees. These trees - Flowering Cherry, Honey Locust, Hemlock, Lilac, Arborvitae and Northern Red Oak - ranged in age from 25 to 110 years. Some of the well-known environmental changes that happened in central Pennsylvania can be readily correlated with characteristic pollution profiles generated from these tree ring analyses.

The pollution almanac kept by trees can permit an unbiased evaluation of the impact of industrial activities both past as well as present. Applications of this method can be extended to monitoring both radioactive and nonradioactive elements. Since trees are grown in most regions of the world, one of the unique applications of this method would be for regional and global comparisons of certain types of environmental pollutants.

14. Precious Metal Constituents of Shale Rocks

Dr. K.K.S. Pillay of the Nuclear Engineering Department
and Dr. E. W. Biederman, Jr., Assistant Director of
PENNTAP, The Pennsylvania State University

An exploratory investigation to identify and quantitate the precious metal constituents of some of the Colorado shale rocks was initiated during this period. Samples received through the courtesy of private companies now operating shale oil recovery plants were examined using neutron activation analysis. The investigations conducted so far have examined both raw shale rocks as well as spent shale rocks from the retorts. Some of the samples showed significant levels of valuable metals such as gold, silver, titanium, copper, manganese, and uranium. It is planned to undertake an extensive study to evaluate the economic potentials of recovering these metals, thereby help reduce the cost of oil recovered from shale deposits.

15. Performance Evaluation of Ion Exchangers Used in Nuclear Installations

Dr. K.K.S. Pillay of the Nuclear Engineering Department
and Dr. S. Daniels, Radiation Management Corporation,
Philadelphia, Pennsylvania

Ion exchangers are used extensively in nuclear industry for coolant and waste clean-up systems. In particular, there are stringent standards to be met by the ion exchangers used in the primary coolant systems. These include very high decontamination factors, resistance to radiation and temperature effects, and careful control of trace element constituents. Several of these quality control analyses were undertaken for a major manufacturer of ion exchangers. The work done in association with the Radiation Management Corporation of Philadelphia evaluated the performance of a dozen new ion exchangers being developed for the primary use of nuclear power plants. During these performance evaluation studies, tracer techniques and neutron activation analyses studies were conducted at the Breazeale Nuclear Reactor facility.

16. Corrosion of Reactor Materials in Light Water Reactors

Dr. K.K.S. Pillay and R. Menichelli, M.S. degree Candidate, Nuclear Engineering Department

This program is part of an ambitious effort to develop research capabilities in new areas that directly relate to nuclear power generation. In particular, an attempt is being made to develop systems capable of measuring extremely small quantities of activation products and still lesser amounts of fission products in reactor coolants. The objective of this program is to design and install a test facility in the core of the Penn State TRIGA Reactor so that the kinetics of corrosion of a variety of materials used in the construction of reactor cores can be studied. The design of the experimental facility must be preceded by developing components and units that are reliable for long term operation.

The initial design of a system involving a large flow rate of water through the test chamber, containing radioactive core construction material, is now being tested using a bench-top model. Deionized water is being pumped at varying flow rates through the chamber containing activated zircalloy-2 and zircalloy-4 fuel claddings. The data accumulated from the test runs will be used to design a facility that can be installed in the reactor (PSTR) core.

This program is partially supported by one of the ERDA student fellowships at the Nuclear Engineering Department of The Pennsylvania State University.

17. Forensic Activation Analysis

Dr. K.K.S. Pillay, Dr. W. A. Jester and S. Moss, R. Kuis, and D. Driscoll, Graduate Assistants, Nuclear Engineering Department

The forensic activation analysis efforts at the Breazeale Nuclear Reactor continued at a lower level during this report period. Primary activities were in: 1) Analyses of evidence collected by the Film-Lift method developed at Penn State and presenting this evidence on behalf of some of the law enforcement agencies in the Commonwealth of Pennsylvania; 2) graduate theses preparations on the extensive investigations conducted on the trace element composition of human hair and its practical applications in forensic investigations; 3) offering assistance to other law enforcement agencies to adopt the new criminal investigation techniques developed at Penn State. The latter included assistance to forensic laboratories as well as educational institutions offering training programs. One of the senior scientific staff of the Michigan State Police laboratories underwent a week's extensive training at Penn State under the guidance of Dr. Pillay.

18. On-Line Monitoring of Very Low Levels of Water-borne Radioactivity

Dr. K.K.S. Pillay, Dr. W. A. Jester and M. Sulcowski, M.S. degree Candidate, Nuclear Engineering Department

The objective of the program now underway is to develop a reliable, but fast, monitoring method for the secondary water systems of a nuclear power plant. The activity levels in these effluents are generally at background levels, although there are occasions when they may rise above these levels. However, such releases must be reported, identifying the nuclear species and their quantities. This, in general, is extremely difficult to accomplish unless elaborate chemical procedures are used to isolate, identify, and measure the radionuclides contained.

The investigations now underway at the Breazeale Nuclear Reactor involve the following conceptual design: 1) a probe strategically located in the effluent line which can detect the change in gross levels of radioactivity in water; 2) a valve downstream from the probe which can quickly divert a partial flow of water to a system where a Penn State developed process will concentrate the radioactive nuclides into a high specific activity, and 3) an efficient energy resolving detector system to measure the γ-emissions and convert this data to the specific activities of nuclides which are activation and fission products of reactor and fuel materials.

The key to accomplishing this is the development of a system that will efficiently concentrate low level radioactive nuclides in water to a higher specific activity. Two independent approaches to accomplishing this objective are being investigated. One of the methods is the use of a liquid extraction method, including a liquid ion exchanger. The second method under investigation involves a rapid electrolysis process using a flowing mercury electrode to electrolyze and deposit the ionic species in water onto the mercury in one cell. In another cell, this mercury, containing the radioactive material, becomes the anode and here it is concentrated in a fixed volume of water contained in this cell. The continuous circulation of mercury between the two cells allows the concentration of radioactivity in the second electrolytic cell.

These investigations are supported by the Pennsylvania Power and Light Company.

19. Kinetics of the Survival of White Blood Cells in Artificial Heart Pumps

Dr. K.K.S. Pillay of the Nuclear Engineering Department
Dr. W. H. Pierce, Associate Professor at the Hershey Medical Center and J. Hart, M.S. degree Candidate, Thoracic Surgery (College of Medicine) at the Hershey Medical Center

A method of employing nonradioactive activable tracers to monitor the kinetics of the depletion of blood cells was used during this study. The problem examined involved the study of large laboratory animals fitted with artificial heart pumps being developed at the Hershey Medical Center of The Pennsylvania State University. One of the serious problems encountered during the installation of artificial heart pumps in animals is the deposition of proteins on the inside surfaces of the pump resulting in depletion of white cells from the circulating blood. The rate of depletion of these white cells, as well as the influence of corrective methods adopted to minimize or eliminate this white cell depletion, are studied using blood tagged with a stable tracer (^{50}Cr). A quantity of about 10^{-10} gms of chromium per milliliter of blood is adequate for studying the kinetics of this process. After introducing the tracer (^{50}Cr) in the blood system of the animal fitted with the artificial heart pump, blood samples are removed periodically and the rate of depletion of chromium (and indirectly the depletion of white cells) is measured by neutron activation analysis.

Using these procedures, nine animals fitted with artificial heart pumps have been examined during this period.

20. Tests of Sampling and Analytical Techniques for Regional Uranium Surveys (ERDA Project)

Dr. A. W. Rose, Dr. M. L. Keith and D. Langmuir, Geosciences Department; Dr. W. A. Jester and D. C. Raupach, Nuclear Engineering Department and R. Schmiermund, S. Pirc, and D. Mahar, Ph.D. degree Candidates and L. Korner, J. Crock, S. Tobias, D. Hsi, and C. Chomicky, M.S. degree Candidates, Geosciences Department

A regional uranium survey of the United States, using geochemistry of stream water and sediments, is being initiated by the Energy Research and Development Administration. The Penn State Project, supported by ERDA includes a pilot study of uranium distribution around known sandstone - type uranium deposits in eastern Pennsylvania and tests of various sampling and analytical techniques.

Principal objectives are to determine the controlling variables and to devise simple geochemical methods that will give maximum sensitivity for traces of uranium and maximum contrast between anomalies and background. Uranium analysis of rocks, soils and sediments and of acid extracts of stream sediments were carried out by the delayed neutron method, using a neutron detector and high speed pneumatic transfer system that were designed, installed, and operated by the reactor staff.

21. The Characteristics of American Coals in Relation to their Conversion to Clean Energy Fuels

Dr. W. Spackman, Geosciences Department,
Dr. P. L. Walker, Material Sciences Department,
N. H. Suhr, Director, Mineral Constitution Laboratory,
Dr. A. Davis, Coal Research Section, Dr. H. L. Lovell,
Mineral Engineering Department and Dr. R. H. Essenhigh,
Dr. F. J. Vastola and Dr. P. H. Given of the Fuel Science section and H. Gong, all of the College of Earth and Mineral Sciences

The project utilizes the reactor as an analytical aid in determining the amount of uranium in various American coal samples. Uranium data obtained here are to be used in conjunction with other analytical data to characterize coals and potential by-products and to determine whether the behavior of coals in various industrial processes can be predicted from a knowledge of their compositions.

22. Neutron Activation Analysis of Cerebro-Spinal Fluid

Dr. W. A. Weidner, M.D., K. L. Miller, Health Physicist,
Department of Radiology, Hershey Medical Center and
Dr. K.K.S. Pillay and D. C. Raupach, Nuclear Engineering Department

This project is designed to determine if there are neutron-activatable metallic ions (such as lead or mercury) in cerebro-spinal fluid which may indicate manifest central nervous system disease. The cerebral spinal fluid is obtained (with written consent of the patient) during myelography and pneumoencephalography for comparison purposes. A pilot study may be performed on thirty samples to determine if significant differences exist which may warrant further investigation.

C. University Research Utilizing Auxiliary Radiation Sources Such as the Cobalt-60 Facility

1. The Influence of Endogenous Mycorrhizae on Acid Phosphatage Activity of Plant Roots

Dr. H. Cole, Plant Pathology Department; Dr. D. Baker, Agronomy Department, and L. Burpee, Ph.D. degree Candidate, Plant Pathology Department

Endogenous (vesicular-arbuscular) mycorrhizae are structures formed as a result of symbiotic associations between plant roots and particular species of soil-borne fungi. These fungi increase the capacity of roots to absorb nutrients, particularly phosphorus. A few plant species do not appear to be infected by these fungi in nature and yet, they have the capability of successfully competing with mycorrhizal species. It is possible that nonmycorrhizal species have a high extracellular root acid phosphatage activity, thus enabling them to utilize more nonlabilas soil phosphorus than mycorrhizal species.

In order to investigate the "phosphatage hypothesis" it is essential to work under quotobiotic conditions. Soil sterilization by γ-irradiation is recommended because it has little effect on the physical and chemical properties of soil.

2. Demonstration for Teaching Principals of Mutation Breeding

Dr. D. L. Garwood, Horticulture Department

Corn seed (Zea mays L.) was exposed to varying levels of gamma irradiation (0, 2.5, 5, 10, 20, and 30 kr) from the Co-60 Facility. Seed was planted in the greenhouse and used as a demonstration in a laboratory of Horticulture 407 (Plant Breeding) to show the effect of various irradiation levels on plant growth. Seed exposed to 2.5 and 5 kr produced stunted plants while no plants were obtained from the higher exposures. Treated plants were self-pollinated and will be examined for induced mutants in the M2 generation.

3. Cellular and Subcellular Effects of Ionizing Radiation on Two Marine Algae

Dr. C. J. Hillson and K. Lynch, M.S. degree Candidate, Biology Department

The exposure of higher plants to ionizing radiation has been shown to result in various cytological, morphological, and physiological changes. Among the more common changes are the inhibition of mitosis, chlorophyll synthesis, and growth, as well as the vacuolation and swelling of cells. Yet, to date, little is known of the effects of ionizing radiation on marine algae.

It is the intent of this investigation to determine the extent of cellular and subcellular structural changes occurring in two marine algae after various acute doses of gamma radiation. The criteria of the control population is to be compared to that of the experimental at specific time intervals. The Cobalt-60 Facility was used to accumulate total doses of 7,000, 10,500, 13,750 and 16,500 R.

4. Backscatter X-Ray Radiography

Dr. A. M. Jacobs and Dr. E. S. Kenney, Nuclear Engineering Department and B. Towe, M.S. degree Candidate, Bio Engineering

In the progress of our current research on coded apertures for three-dimensional X-ray static and dynamic imaging, an intriguing, albeit less ambitious, concept of static radiography has developed. Specifically, a narrow beam of collimated X-rays is raster scanned over an object and the resulting X-ray field scattered back toward the X-ray source is detected. The serial data obtained can be employed to develop a backscatter X-ray image of the internal structure details of an optically opaque object. The image produced from this perspective can reduce contrast confusion introduced by adjacent obscurant structures (esp. backing material of relatively high opacity). We have accomplished initial demonstrations of backscatter X-ray projection.

There are several cases of medical diagnostic problems, and many situations of industrial inspection and quality control where conventional X-ray radiography is difficult or impossible to apply due to adjacent internal obscurant structures, or a restriction to one side access. The modified radiation path employed in the proposed backscatter X-ray projection technique could offer a solution to such imaging problems. Examples of such problems include: In medical diagnostic imaging - the inner ear, fractures in facets of the cervical spine, the laryngeal airway, optic formania, and the mandibular joint. And, in industrial inspection and quality control - heavy machinery, components with one-sided access, large pipes in service, subsurface imperfections in materials of castings and composites, and contained mechanisms with relatively large support structures.

5. Dynamic Radiography

Dr. A. M. Jacobs, Dr. E. S. Kenney, Nuclear Engineering Department, Dr. W. A. Weidner, Head, Department of Radiology, Hershey Medical Center and D. G. Tilley, Ph.D. degree Candidate, Department of Radiology, Hershey Medical Center

Dynamic Radiography is a new non-invasive imaging technique that utilizes the radiation scattered from the heart during fluoroscopy to monitor cardiac motion. A detailed description of eqicardial motion is imprinted on the scattered radiation field reflected from the interface where the epicardium is adjacent to the lung. A collimated detector system is focused on this region and records the intensity of scattered radiation which is a function of the epicardial motion. The wave forms emanating from the detectors are time recordings of cardiac motion that can be visually inspected or subjected to computer analysis to identify important parameters of the motion. Initial studies with dogs have been conducted to establish the normal parameters of cardiac motion and to determine whether infarcted regions of the myocardium can be identified with this technique. The results of these studies indicate that the proper analysis of ventricular motion wave forms will discern dyskinetic segments of myocardium.

6. SO_2 and NO_x Removal from Flue Gas Using Gamma Radiation

Dr. W. A. Jester, Dr. K.K.S. Pillay, Professor M. A. Schultz, and W. Runte and S. Kamdar, Graduate Assistants, Nuclear Engineering Department

The major focus of this project continues to be the investigation of the radiochemistry of gaseous systems containing SO_2 and NO_x to obtain a better understanding of the radiochemistry of flue gas irradiated by gamma radiation. This year, a comprehensive theory has been developed in an effort to explain the various mechanisms taking place. Of increasing interest is the role played by water vapor and condensed water droplets to promote the oxidation of SO_2 and NO_x to high oxidation states and their subsequent reaction with one another.

7. Heavy Metals Movement in Soils

Dr. L. T. Kardos and R. C. Sidle, Ph.D. degree Candidate, Agronomy Department

Time dependent batch equilibrium study to determine the kinetics of adsorption of Cu, Zn, and Cd by forest soils. Co-60 Facility was used to sterilize soils so that there was no microbial factor affecting the adsorption kinetics. Results will be used to predict the movement of Cu, Zn, and Cd in soils both in time and space.

8. Large Aperture Scatter X-ray Camera

Dr. E. S. Kenney, Dr. A. M. Jacobs, and S. Pandey, Ph.D. degree Candidate, Nuclear Engineering Department

A high logic speed scintillation camera is being developed to produce motion pictures of the motion of the surface of the human heart. At the present state of research, various scintillators are being evaluated by Monte Carlo computer studies to select the optimum choice of speed and resolution, and low noise preamps are being tested to produce minimum resolution loss due to noise deterioration of detection pulses. The final camera will view a select region of the heart's surface defined by an articulated collimator operating with a constant potential X-ray generator.

9. X-Ray Pseudo-holography

Dr. E. S. Kenney, Dr. A. M. Jacobs and R. Sider, Ph.D. degree Candidate, Nuclear Engineering Department

Scatter X-ray images have been created using Fresnel coded apertures. The present work is directed towards improving image quality through elimination of background and artifacts. Simple objects of a mechanical nature have been used showing a resolution of the order of 1/16". As expected, the images are tomographic. The early decoding was done using a laser and optical bench. The more recent work is concentrated in the area of computer processing and decoding.

10. An Investigation of Aerosol Charging in a Nonequilibrium Bipolar Ionic Region

Dr. S. H. Levine, Nuclear Engineering Department,
Dr. R. J. Heinsohn, Mechanical Engineering Department
and R. Fjeld, Ph.D degree Candidate, Nuclear Engineering Department

A theoretical and experimental study of particle charge acquisition in a region containing unequal current densities of ions of opposite polarity (a nonequilibrium bipolar region) has been conducted. A continuum model of ion transport is combined with charging expressions to describe the nonequilibrium bipolar charging of aerosal particles. Experiments utilizing an eleven millicurie ^{90}Sr-^{90}Y beta source and electric and magnetic fields are performed to verify the calculational method. Trajectories of 50-100 micron diameter glass beads falling through the experimental apparatus are recorded on film by a photographic technique utilizing an open aperture camera and stroboscopic light source. Predicted increases in the particle charging rate upon application of a magnetic field of approximately 1000 gauss was clearly demonstrated by experiments. Measured charging rates are in fair agreement with theory, especially in the presence of the magnetic field. The research provides a quantitative basis upon which particle charging and motion in bipolar ionic regions may be calculated.

11. Behavior of the Adult Gypsy Moth: Sexual Commercialization

Dr. J. V. Richerson, V. Mastro, and Dr. E. A. Cameron, Entomology Department

Research investigated the hypothesis that irradiated lab-reared sterile female gypsy moths are as attractive to feral male moths as non-irradiated feral females. Currently, tethered fertile females are being used to monitor mating disruption tests using the sex pheromone disparlure. One problem is the possibility of escape of these monitor females and subsequent deposition of fertile egg masses in the test area. Sterile females would be considerably safer to use. Tests conducted by USDA personnel in 1964, 1967, and 1970 indicated that irradiated sterile male and female gypsy moths were as active and attractive as non-irradiated fertile moths. However, these tests were conducted using a chemical which has since been discovered not to be the sex pheromone of the gypsy moth. No recent published work has compared the sexual activity of irradiated gypsy moth to the non-irradiated moths in areas not treated with a "sex attractant."

The cobalt-60 facility was used to irradiate 100 female gypsy moth pupae which were 9-10 days old with 20,000 R at a dose rate of ca 5400 R/min. Females emerging from these pupae and non-irradiated feral and lab-reared females were placed out in an uninfested forest. Feral males were released into these test sites and their sexual responses to the females were monitored.

Irradiated and non-irradiated females were also placed out in a natural population of gypsy moth in Centre County to measure the response of native males to the test females.

In both tests, irradiated lab-reared females were less attractive to feral males than both the non-irradiated females. In the uninfested test, both sterile and fertile lab-reared females were equally attractive but both were less attractive than feral females. The non-irradiated feral females were more attractive than either of the lab-reared test females.

12. Application of Dynamic Radiography to Two-Phase Flow

Dr. G. E. Robinson, Dr. A. M. Jacobs, Dr. E. S. Kenney, and D. Williams, M.S. degree Candidate, Nuclear Engineering Department

The purpose of this project is to use dynamic radiography to examine two-phase flow. Using two-phase flow in the bubble regime, the bubbles act as scattering centers for the incident radiation. Two intersecting photon detectors are used to observe the scattered x-rays. The outputs of these detectors are cross correlated and a frequency analysis is performed. The correlated signal will give a high response when a change in density is observed, which is due to the liquid-vapor interface. The frequency analysis gives two fundamental frequencies which will be related to two important parameters in the nuclear engineering field: 1) fluid flow rate, and 2) bubble diameter.

In this investigation, the liquid flow rate will be varied and the bubble size will be varied to find the minimum bubble size which can be detected using this technique. The bubbles will be produced from a heated wire immersed in the water vessel, because of this the bubble size can be varied by changing the saturation conditions of the system.

The water vessel was constructed from pyrex glass tubing, 30 centimeters in length and 51 millimeters diameter. It is the goal of this investigation to shield the water vessel with various thicknesses of metal and attempt to reproduce the data with this set-up to confirm that bubble detection using this technique is possible for flow in metal pipes.

13. Californium-252 Neutron Spectrum Measurement

Dr. W. F. Witzig, Dr. S. H. Levine and H. Collins and D. Hoyniak, M.S. degree Candidates, Nuclear Engineering Department

The current research is aimed at measuring the spontaneous fission neutron spectrum from a Cf-252 source. The neutron spectrum is obtained by utilizing the (n,p) reaction in a gas proportional counter. The counters use as a filling gas either hydrogen or methane depending on the energy range of interest. By use of these two filling gases, we will be able to measure the energy dependent spectrum over the range 10 Kev to 3 Mev.

The Cf spectrum will be measured by suspending a source in a large room in the Academic Projects Building. A selected counter tube will then be used to measure the recoiled proton spectrum, which will be separated from gamma ray pulses by means of pulse shape discrimination. The proton recoil spectrum will then be corrected for electric field distortion in the tube and wall and end effects which occur because the counter is finite. This corrected proton recoil spectrum will then be differentiated to convert it to a neutron spectrum.

At the present time, calibration of four counters is underway. This calibration is used to get the tube gain as a function of operating voltage for each of the counters. The gamma ray discrimination circuits are under construction.

Ultimate use of the proton recoil counter will be in conjunction with the fast subcritical assembly which is located in the reactor beam hole laboratory.

D. Non-University Research Utilizing the Facilities of the Penn State Breazeale Nuclear Reactor

The facilities of the Penn State Breazeale Nuclear Reactor (PSBR) are made available to state, federal, and industrial organizations. Organizations using these facilities in their research and development programs include:

Raytheon Company

In general, Raytheon's work at the nuclear reactor consists primarily of irradiating electronic devices and, in some instances, electronic circuits in order to assess the damage effects on these parts due to neutron bombardment. Data from these tests are used to predict survivability/vulnerability levels of electronics equipment that might be subjected to various nuclear environments. Data is also used to aid in the design of radiation tolerant electronic equipment.

Charles Stark Draper Laboratory, Inc.

Investigation of Neutron Environment Effects on Transistors and Integrated Circuits

P. R. Kelley, Staff Engineer and R. B. Miller and J. F. Lescher

The nuclear reactor facility has been used to investigate how neutron environments effect the functional and parametric characteristics of transistors and integrated circuits. The results of this research will provide greater insight in understanding neutron sensitive damage mechanisms in integrated circuits. In addition, the studies undertaken will provide data for determining damage coefficients which will be useful for predicting circuit responses to neutron environments.

THESES PUBLICATIONS & REPORTS

VII. THESES, PUBLICATIONS AND REPORTS

Theses, publications and reports pertinent to the use or operation of the Facility are listed below.

Theses

1. "The Effect of Radiation on the Inception of Nucleate Boiling," R. H. Arnold, M.S. Thesis, 1975, Nuclear Engineering Department, G. E. Robinson, Advisor.

2. "The Valley of Guatemala as a Port of Trade," K. L. Brown, Ph.D. Thesis, 1975, Anthropology Department, Dr. W. T. Sanders, Advisor.

3. "Measurement of the Neutron Spectrum of ^{252}Cf," H. Collins, M.S. Paper, 1976, Nuclear Engineering Department, W. F. Witzig, Advisor.

4. "Particle Charge Acquisition in a Bipolar Ionic Atmosphere," R. A. Fjeld, Ph.D. Thesis, 1976, Nuclear Engineering Department, S. H. Levine and R. J. Heinsohn, Co-advisors.

5. "The Partitioning of Several Rare Earth Elements Between Silicate Melt and Aqueous Vapor," R. T. Flynn, Ph.D. Thesis, 1976, Geochemistry Department, Dr. C. W. Burnham, Advisor.

6. Instrument calibration and field measurements of ^{41}Ar, P. Gesalman, Senior research project, Environmental Engineering Department, W. S. Diethorn, Advisor.

7. "Decay of Nuclear Isomers," J. A. Herritt, M.S. Thesis, 1976, Physics Department, W. W. Pratt, Advisor.

8. "Phosphate and Molybdate Adsorption on Soil Oxides," S. B. Hornick, Ph.D. Thesis, 1975, Agronomy Department, Dr. D. E. Baker, Advisor.

9. "A Comprehensive Evaluation of Short-Lived Radioisotopes Having Potential Diagnostic Scanning Applications, D. B. Jarrell, M.S. Thesis, 1975, Nuclear Engineering Department, W. A. Jester, Advisor.

10. "Source Multiplication Studies Using a ^{252}Cf Neutron Source," B. W. Lee, Ph.D. Thesis, 1975, Nuclear Engineering Department, Dr. S. H. Levine, Advisor.

11. "Cellular and Subcellular Effects of Ionizing Radiation on Two Marine Algae," K. G. Lynch, M.S. Thesis, 1974, Biology Department, C. J. Hillson, Advisor.

12. "Molecular Beam Scattering from Clean LiF Surfaces," J. A. Meyers, Ph.D. Thesis, 1975, Physics Department, Dr. D. R. Frankl, Advisor.

13. "Utilization of Neutron Activation Analysis for Characterization of Hair by Trace Element Composition." S. H. Moss, M.S. Thesis, 1976, Nuclear Engineering Department, K.K.S. Pillay, Advisor.

14. "An Evaluation of Existing Medical Radiation Imaging Devices." S. Pandey, M.S. Paper, 1976, Nuclear Engineering Department, E. S. Kenney, Advisor.

15. "Measurement of Delayed Neutron Spectrum from ^{87}Br Created in the Thermal Fission of ^{235}U." P. K. Ray, Ph.D. Thesis, 1975, Nuclear Engineering Department, E. S. Kenney, Advisor.

16. "Ceramic Continuity and Change in the Valley of Guatemala," P. M. Rice, Ph.D. Thesis, 1975, Anthropology Department, Dr. F. R. Matson, Advisor.

17. "Sodium and Water Balance in the Estuarine Diamondback Terrapin, Malachemys," G. D. Robinson, Ph.D. Thesis, 1975, Biology Department, Dr. W. A. Dunson, Advisor.

18. "Neutron Pseudo-Holography," P. J. Rose, Ph.D. Thesis, 1975, Nuclear Engineering Department, Dr. A. M. Jacobs, Advisor.

19. "Irradiation of Flue Gas Constituents in High Gamma Fields to Remove SO_2 and NO_x Constituents," W. G. Runte, M.S. Thesis, 1976, Nuclear Engineering Department, W. A. Jester, Advisor.

20. "^{24}Na Fluxes in Tadpoles Exposed to Low pH," P. Saber, M.S. Thesis 1976, Biology Department, W. A. Dunson, Advisor.

21. "Tests of Sampling and Analytical Techniques for Regional Uranium Surveys," R. Schmiermund, D. Mahar and S. Pirc, Ph.D. Theses 1976, Geosciences Department, A. Rose, Advisor.

22. "Unfolding Fast Neutron Spectra and Cross Sections in a TRIGA Reactor," J. K. Schmotzer, Ph.D. Thesis, 1976, Nuclear Engineering, S. H. Levine, Advisor.

23. "The Deisgn and Shielding of a Fission Plate to be Used as a Fast Neutron Source for a Fast Reactor Spectrum Assembly," J. D. Seebald, M.S. Paper, 1975, Nuclear Engineering Department, Dr. S. H. Levine, Advisor.

24. "Heavy Metals Movement in Soils," R. C. Sidle, Ph.D. Thesis, 1976, Agronomy Department, L. T. Kardos, Advisor.

25. "Effects of Acute Gamma Radiation of <u>Pediastrum boryanum</u> (Turpin) Meneghine," A. J. Slavinski, M.S. Thesis, 1975, Biology Department, Dr. C. J. Hillson, Advisor.

26. "Neutron Spectrum Derivation from Proton Recoil Proportional Counter Spectra," W. R. Spears, M.S. Thesis, March 1976, Nuclear Engineering Department, W. F. Witzig, Advisor.

27. "A New Method for Imaging Epicardial Motion Using Scattered Radiation." D. G. Tilley, Ph.D. Thesis, 1976, Nuclear Engineering Department, A. M. Jacobs, Advisor.

28. "Identification and Evaluation of Water Tracers Amenable to Post-Sampling Neutron Activation Analysis," K. A. Uhler, Ph.D. Thesis, 1974, Civil Engineering Department, Dr. W. A. Jester, Advisor.

29. "Proton-Recoil Counting Techniques Using Gas Proportional Counters," F. A. Wolfe, Master of Engineering, June 1975, Nuclear Engineering Department, W. F. Witzig, Advisor.

PUBLICATIONS, REPORTS, AND ORAL PRESENTATIONS

1. "Changes in Blood Flow to Bones During the Hypocalcemic and Hypercalcemic Phases of the Response to Parathyroid Hormone." Endocrinology 98 (2): 403-412. February, 1976, J. N. Boelkins, M. Mazurkiewicz, P. E. Mazur and W. J. Mueller of the Poultry Science Department.

2. "Use of Procedures in the Management of the Penn State Breazeale Reactor," Paper presented at a Conference on Reactor Operating Experience, August, 1975, Albuquerque, New Mexico, G. C. Geisler, S. H. Levine and R. E. Totenbier of the Nuclear Engineering Department.

3. "Particle Charge Acquisition and Motion in a Bipolar Low Atmosphere," Transactions of the American Nuclear Society, in print, R. A. Fjeld and S. H. Levine of the Nuclear Engineering Department.

4. "Kr-85m Ventilatory Scan Agent," Proceedings of 22nd Annual Meeting, Society of Nuclear Medicine, p. 539, June 1975, G. L. Jackson, W. A. Jester and K. N. Prasad of the Nuclear Engineering Department.

5. "Field Use of Neutron Activatable Tracers," Transactions of the American Nuclear Society, 1976, W. A. Jester, Nuclear Engineering Department.

6. "Public Technology Transfer Programs of Penn State's Nuclear Engineering Department," Transactions of the American Nuclear Society, 1976, W. A. Jester, J. R. McKee and W. F. Witzig of the Nuclear Engineering Department

7. "Dynamic Radiography for Non-Destructive Testing," a chapter in Research Techniques in Nondestructive Testing, Vol. 3, (in press) E. S. Kenney and A. M. Jacobs of the Nuclear Engineering Department.

8. "Radiation Imaging - An Interesting Utilization of Nuclear Engineering Methodology," Nuclear Technology 27: 1975, E. S. Kenney and A. M. Jacobs of the Nuclear Engineering Department.

9. "Experience with 12 wt.% U TRIGA Fuel at the Penn State Breazeale Reactor," Paper presented at TRIGA Owners Conference, March 1976 in Salt Lake City, Utah, S. H. Levine, R. E. Totenbier, and G. C. Geisler of the Nuclear Engineering Department.

10. "A Positive Action Handling Tool for TRIGA Fuel," Presented at TRIGA Owners Conference, March 1, 1976 in Salt Lake City, Utah, I. B. McMaster of the Nuclear Engineering Department.

11. "Neutron Activation Analysis of Axum Obsidian," The Pennsylvania State University, 1975 (ms.) Report by L. H. de Mendoza of the Department of Anthropology.

12. "Neutron Activation Analysis of Guatemala Obsidian," The Pennsylvania State University, 1975 (ms.) Report by L. H. de Mendoza of the Department of Anthropology.

13. "Nuclear Engineering Technology - A Two Year Associate Degree Program - Phase I." Paper presented at the joint meeting of the American Nuclear Society and the Canadian Nuclear Association, Toronto, Canada, June 1976, J. L. Penkala of the Nuclear Engineering Department.

14. "Activation Analysis and Dendrochronology for Estimating Pollution Histories," Transactions of the American Nuclear Society 21(3): 22(1975), K.K.S. Pillay of the Nuclear Engineering Department.

15. "Activation Analysis and Dendrochronology for Estimating Pollution Histories," Journal of Radioanalytical Chemistry 32: 151-171 (1976), K.K.S. Pillay of the Nuclear Engineering Department.

16. "Nature's Pollution Almanac," Forrest Notes 125, 7 (Spring 1976), K.K.S. Pillay of the Nuclear Engineering Department.

17. "Distribution of Firearm Discharge Residues as Revealed by Neutron Activation Analysis." Journal of Radioanalytical Chemistry 27, 421-438 (1975), K.K.S. Pillay, D. C. Driscoll, and W. A. Jester of the Nuclear Engineering Department.

18. "A Low-Intensity Transition in the Decay of ^{175}Hf," Physical Review Chapter (in press), W. W. Pratt of the Physics Department.

19. "Delayed Neutron Spectrum from ^{87}Br," Nuclear Instruments and Methods, (in press), P. K. Ray and E. S. Kenney of the Nuclear Engineering Department.

20. "The Relative Attractiveness of Irradiated Lab Reared Female Gypsy Moths and Non-Irradiated Lab Reared and Feral Females," Journal of Economic Entomology (submitted for publication April 21, 1976) J. V. Richerson of the Entomology Department.

21. "Water and Sodium Balance in the Estuarine Diamondback Terrapin (Malaclemys)," Journal of Comparative Physiology 105:129-152, 1976, G. D. Robinson and W. A. Dunson of the Biology Department.

22. "Reconnaissance Geochemical Techniques for Detecting Uranium Deposits," presented at April 1976 meeting in Fredericton, N. B., and accepted for publication in Journal of Geochemical Exploration, A. W. Rose and M. L. Keith of the Geosciences Department.

23. "Paramagnetic Centers in Reactor-Irradiated Single Crystals of Tetragonal GeO_2," Bulletin of the American Physical Society 21:347 1976, M. Stapelbrock, O. R. Gilliam, and D. P. Madacsi of the Physics Department.

24. "Dynamic Radiography - A Technique Employing Scattered Radiation to Monitor Surface Motion," Medical and Biological Engineering, 1976, D. G. Tilley, A. M. Jacobs, E. S. Kenney, W. A. Weidner, and K. L. Miller of the Nuclear Engineering Department and Hershey Medical Center.

25. "Dynamic Radiography - An Evaluation of Cardiac Motion by the Analysis of Scattered Radiation During Fluoroscopy," Investigative Radiology 10:2, 1975, W. A. Weidner, A. M. Jacobs, E. S. Kenney, K. L. Miller, and D. G. Tilley of the Nuclear Engineering Department and Hershey Medical Center.

APPENDIX A

APPENDIX A

Faculty and Staff Members Utilizing the Facilities of the Penn State Breazeale Nuclear Reactor (Including the Cobalt-60 Facility and the Radionuclear Applications Laboratory).

Baker, Dale E., B.S., M.S., Ph.D.
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Frankl, Daniel R., B.Ch.E., Ph.D.
Professor
Department of Physics
College of Science

Garwood, Douglas L., B.S., M.S., Ph.D.
Assistant Professor
Department of Horticulture
College of Agriculture

Geisler, George C., B.S., M.S.
Research Associate and Assistant Director, Breazeale Reactor
Department of Nuclear Engineering
College of Engineering

Given, Peter H., B.A., M.A., Ph.D.
Professor
Fuel Science Section
College of Earth and Mineral Sciences

Granlund, Roger, B.S.
Health Physicist
Institute of Science and Engineering

Harrison, Ian R., B.Sc., M.S., Ph.D.
Associate Professor
Department of Material Sciences
College of Earth and Mineral Sciences

Heinsohn, Robert J., B.S., M.S., Ph.D.
Associate Professor
Department of Mechanical Engineering
College of Engineering

Hillson, Charles J., B.S., M.S., Ph.D.
Professor
Department of Biology
College of Science

Houlihan, John F., B.A., M.A., Ph.D.
Assistant Professor
Department of Physics
College of Science

Houtz, Robert C.
Reactor Supervisor
Department of Nuclear Engineering
College of Engineering

Jackson, George L., B.S., M.D.
Clinical Associate Professor
Section of Nuclear Medicine
Harrisburg Hospital and
Hershey Medical Center

Jacobs, Alan M., B. Engr., M.S., Ph.D.
Professor
Department of Nuclear Engineering
College of Engineering

Jester, William A., B.S., M.S., Ph.D.
Associate Professor
Department of Nuclear Engineering
College of Engineering

Kardos, L. T., B.S. M.S., Ph.D.
Professor
Department of Agronomy
College of Agriculture

Keith, MacKenzie L., B.Sc., M.Sc., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Kenney, E. S., B.S., M.S., Ph.D.
Professor
Department of Nuclear Engineering
College of Engineering

Langmuir, Donald, A.B., M.A., Ph.D.
Associate Professor
Department of Geosciences
College of Earth and Mineral Sciences

Levine, Samuel H., B.S., M.S., Ph.D.
Professor and Director of Breazeale Nuclear Reactor
Department of Nuclear Engineering
College of Engineering

Lovell, Harold L., B.S., M.S., Ph.D.
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Department of Mineral Engineering
College of Earth and Mineral Sciences

Madacsi, David P., B.S., M.S., Ph.D.
Assistant Professor
Department of Physics
College of Science

Mastro, Victor C.
Research Assistant
Department of Entomology
College of Agriculture

Matson, Frederick R., B.S., M.A., Ph.D.
Research Professor
Department of Anthropology
College of Liberal Arts

McKee, Hohn R., B.S.
Administrative Aide
Department of Nuclear Engineering
College of Engineering

McMaster, Ira B., B.S.
Research Assistant
Department of Nuclear Engineering
College of Engineering

Michels, Joseph W., B.A., M.A., Ph.D.
Professor
Department of Anthropology
College of the Liberal Arts

Miller, Kenneth L, B.S., M.S.
Health Physicist
Department of Radiology
Hershey Medical Center

Miller, Warren W., B.S., Ph.D.
Professor
Department of Chemistry
College of Science

Mueller, Werner J., Ing. Agr., Dr. Sci. Tech.
Professor
Department of Poultry Science
College of Agriculture

Nesbitt, John B., B.S., S.M., Sc.D.
Professor
Civil Engineering Department
College of Engineering

O'Brien, John H.
Reactor Supervisor
Department of Nuclear Engineering
College of Engineering

Penkala, John L, B.S.
Research Assistant
Department of Nuclear Engineering
College of Engineering

Pierce, William S., B.S., M.D.
Associate Professor
Department of Surgery
Hershey Medical Center

Pillay, Sivasankara, K.K., B.Sc. (Hons.), M.Sc., Ph.D.
Assistant Professor
Department of Nuclear Engineering
College of Engineering

Pratt, William W., B.S., Ph.D.
Professor
Department of Physics
College of Science

Raupach, Dale C., B.S.
Reactor Supervisor
Department of Nuclear Engineering
College of Engineering

Richerson, Jim V., B.A., M.Sc. Ph.D.
Research Associate
Department of Entomology
College of Agriculture

Robinson, Gordon E., B.S., M.S., Ph.D.
Associate Professor
Department of Nuclear Engineering
College of Engineering

Rose, Arthur W., B.S., M.S., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Sanders, William T., B.S., M.A., Ph.D.
Professor
Department of Anthropology
College of Liberal Arts

Schmotzer, Jack K., B.S., M.S., Ph.D.
Health Physics Assistant
Institute for Science and Engineering

Schultz, Mortimer A., B.S.
Professor
Department of Nuclear Engineering
College of Engineering

Spackman, William, Jr., B.S., M.S., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Shur, Norman H., A.B., M.S.
Associate Professor
Mineral Constitution Laboratories
College of Earth and Mineral Sciences

Totenbier, Robert E., B.S.
Research Assistant
Department of Nuclear Engineering
College of Engineering

Vastola, Francis J., B.A., Ph.D.
Professor
Fuel Science Section
College of Earth and Mineral Sciences

Walker, Philip L., Jr., B.S., M.S., Ph.D.
Professor
Department of Material Sciences
College of Earth and Mineral Sciences

Weidner, William A., M.D.
Department of Radiology
Hershey Medical Center

Witzig, Warren F., B.S., M.S., Ph.D., PE.
Professor
Department of Nuclear Engineering
College of Engineering

APPENDIX B

APPENDIX B

Graduate Students Utilizing the Facilities of the Penn State Breazeale Nuclear Reactor (Including the Cobalt-60 Facility and Radionuclear Applications Laboratory).

College of Earth and Mineral Sciences

Chomicky, C., Geosicences Department

Crock, J., Geosciences Department

Hsi, D., Geosciences Department

Korner, L., Geosciences Department

Mahar, D., Geosciences Department

Pirc, S., Geosciences Department

Schmiermund, R., Geosciences Department

Tobias, S., Geosciences Department

College of Agriculture

Benner, D., Poultry Science Department

Boelkins, J. N., Poultry Science Department

Burpee, L. L., Plant Pathology Department

Hornick, S. B., Agronomy Department

Lobaugh, B., Poultry Science Department

Mazur, P. E., Poultry Science Department

Mazurkiewicz, M., Poultry Science

Sidle, R. C., Agronomy Department

College of Engineering

Arnold, R. H., Nuclear Engineering Department

Collins, H., Nuclear Engineering Department

Driscoll, D. A., Nuclear Engineering Department

Fjeld, R. A., Nuclear Engineering Department

Gesalman, P., Environmental Engineering Department (Undergraduate)

Hepburn, F., Nuclear Engineering Department

Hoyniak, D., Nuclear Engineering Department

Jarrell, D. B., Nuclear Engineering Department

Kamdar, S. D., Nuclear Engineering Department

Kuis, R. L., Nuclear Engineering Department

Lee, B. W., Nuclear Engineering Department

Menichelli, R., Nuclear Engineering Department

Moss, S. H., Nuclear Engineering Department

Osmin, W. L., Nuclear Engineering Department

Panday, S., Nuclear Engineering Department

Ray, P. K., Nuclear Engineering Department

Rose, P. J., Nuclear Engineering Department

Runte, W. G., Nuclear Engineering Department

Schmotzer, J. K., Nuclear Engineering Department

Schofer, R. F., Nuclear Engineering Department

Seebald, J. D., Nuclear Engineering Department

Sider, R. G., Nuclear Engineering Department

Spears, W. R., Nuclear Engineering Department

Sulcoski, M., Nuclear Engineering Department

Tilley, D. G., Nuclear Engineering Department

Towe, B. C., Bio-Engineering Department

Uhler, K. A., Civil Engineering Department

Williams, D., Nuclear Engineering Department

Wolfe, F. A., Nuclear Engineering Department

College of Science

Al-Zubaide, A., Physics Department

Flynn, R. T., Geochemistry Department

Gilliam, O. R., Physics Department

Herritt, J. A., Physics Department

Hesson, R., Chemistry Department

Lynch, K. G., Biology Department

Meyers, J. A., Physics Department

Risby, T., Chemistry Department

Robinson, G. D., Biology Department

Rosenberger, G., Chemistry Department

Runt, J. P., Solid State Science

Saber, P., Biology Department

Slavinski, A. J., Biology Department

Stapelbrock, M., Physics Department

Stein, A., Chemistry Department

College of Liberal Arts

Brown, K. L., Anthropology Department

deMendoza, L. H., Anthropology Department

Rice, P. M., Anthropology Department

APPENDIX C

APPENDIX C

Formal Group Tours

	1975		Participants
July	2	Upward Bound High School Seniors	46
	3	Geological Science 303	37
	15	Alumni Vacation College	39
	17	Alumni Vacation College	37
	27	Pittsburgh House Steward Hall Students	18
	22	Youth Conservation Corps - Greenwood Furnace	9
	25	Soil Conservation	10
	29	Geological Science 498	21
	31	Chambersburg Area Senior High School	10
Aug.	12	4-H Group	5
	18	American Nuclear Society	26
Sept.	10	Nuclear Engineering 502A	16
	10	Wives of Commonwealth Campus Officials	19
	18	Higher Education 101	41
	30	Physics 100	23
	30	Physics 100	19
Oct.	1	Dairy Science 521 - Radiophysiology	41
	2	Physics 100	56
	2	Nuclear Engineering 401	11
	3	Chemistry 526	9
	6	Science Technology and Society 471	10
	8	Nuclear Engineering 410	6

1975			Participants
Oct.	13	Police Services	13
	14	Police Services	7
	15	Biological Science 3	66
	15	Police Services	10
	16	Police Services	10
	16	Nuclear Engineering 805 - Hazleton Campus	10
	21	American Nuclear Society	12
	23	Valley Rural Electric Association - Huntingdon	10
	23	Exployer Scouts - Post #385	25
	24	Fairmount Elementary School	74
	28	Nuclear Engineering 401	11
	30	Geological Science 303	32
	30	Nuclear Engineering 440	29
	30	Fairmount Elementary School	82
	31	Pittsburgh Campus - Advanced Score Power System	33
Nov.	4	Westinghouse Explorer Scouts	40
	6	Freshman Engineers	58
	7	Huntingdon Area Middle School	59
	16	Huntingdon Eighth Graders	63
	18	Ligoneer High School	18
	24	Lower Dauphin High School	21
	25	Wyomissing High School	11
	26	Altoona High School	10
Dec.	2	Bucknell University	10
	8	Punxsutawney High School	38
	10	Natural Resources Management	36

			Participants
	1975		
Dec.	10	Free University Course	3
	17	Society of Engineering Science	17
	18	West Side Area Vocational Technology	51
	1976		
Jan.	9	Altoona Campus	8
	13	Police Services	3
	13	Boy Scouts - Chesterhill Troop	4
	13	Carlisle High School	10
	13	Bucknell University	5
	19	Physics 101	19
	19	Engineering 5	49
	20	Physics 101	23
	22	Physics 101	18
	29	Geological Science 303	28
Feb.	3	Nuclear Engineering 200	16
	5	Geological Science 303	21
	6	Material Science Class	14
	10	Nuclear Engineering 200	17
	11	Journalism Class	7
	12	Greer School (Tyrone)	6
	12	Penn Hills High School	9
	12	Penns Valley High School	8
	24	Liberal Arts - Science & Technology Class	11

1976			Participants
March	4	Alternative School State College	10
	8	Alternative School State College	8
	12	Beatie Technical High School	15
	16	Ridgeway High School	9
	19	Nuclear Engineering 401	27
	23	Union City High School	13
	30	Jersey Shore High School	7
	30	Chestnut Ridge High School	7
April	2	Slippery Rock College	13
	2	Physics 237	14
	6	Smethport High School	11
	6	Dunmore High School	5
	7	Kishacoquillas High School	15
	12	Physics 100	15
	13	North Schuylkill High School	6
	13	Exeter High School	8
	13	Physics 100	13
	14	Physics 100	9
	15	Physics 100	18
	20	Warren Area High School	19
	21	Southern Columbia Area High School	47
	22	Geological Science 303	35
	27	Bellefonte High School	20
	28	Penn Cambria High School	28
	30	Physics 237	4

1976			Participants
May	1	Open House	192
	3	Cambria Heights High School	109
	4	Titusville High School	5
	4	Marion Center High School	11
	6	Biological Science 3	37
	7	Chemistry 427 - Neutron Activation Analysis	22
	7	Assoc. of College Chemistry Teachers	14
	7	Nuclear Engineering 420	7
	10	Bald Eagle Area High School	34
	11	Higher Education 101	4
	11	Troy High School	5
	11	Parkland High School	12
	13	Harrisburg Hospital Nuclear Medical School	11
	14	Chemistry 427 - Neutron Activation Analysis	23
	20	Penn Tab Advisors	12
	21	State College High School	119
	29	Nuclear Engineering Graduates and families	81
June	2	Hamburg Area High School	7
		Total	2,749