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EIGHTEENTH ANNUAL PROGRESS REPORT OF

THE PENNSYLVANIA STATE UNIVERSITY

BREAZEALE NUCLEAR REACTOR

July 1, 1972 to June 30, 1973

Submitted to

United States Atomic Energy Commission

and

The Pennsylvania State University

by

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University Park, Pennsylvania

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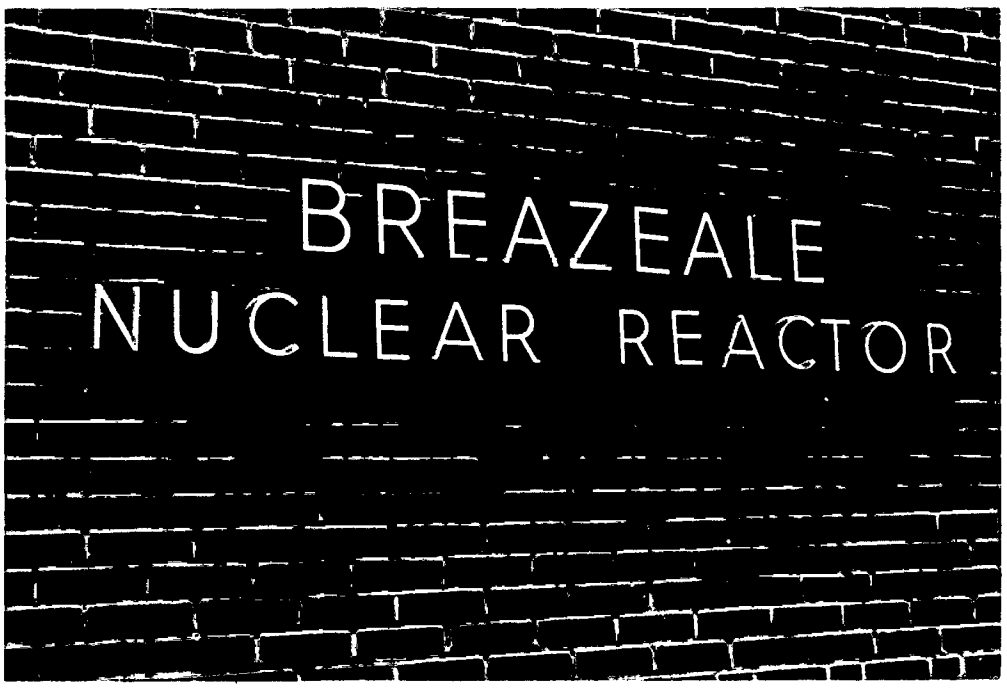


INTRODUCTION AND SUMMARY

I. INTRODUCTION AND SUMMARY

The 18th Annual Progress Report of The Pennsylvania State University Breazeale Nuclear Reactor (PSBR) is prepared and submitted in accordance with the requirements of Contract No. AT(11-1)-3409 with the United States Atomic Energy Commission. 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.

During the past few years, changes in programs and personnel have taken place within the Nuclear Engineering Department and the Penn State Breazeale Reactor (PSBR) which have produced a noticeable shift in the activities of the PSBR staff and the operation of the Facility. The introduction of the Nuclear Engineering Associate degree and Bachelor of Science degree programs established new laboratories at the Facility for which reactor operating time and reactor staff participation were required. A reduction in faculty in the Nuclear Engineering Department and in the PSBR staff has

necessitated an increase in the work load for the reactor staff.

The number of visitors to the Facility increased substantially this past year (from 1,982 to 2,650) and many of these visitors were high school groups conducting critical experiments. *In fact, for the first time during the Spring term, more high school science classes requested time to perform critical experiments than could be scheduled.* Of importance to the success of the high school experiments was the support provided by the A.E.C. trainees in scheduling and conducting these experiments. The A.E.C. traineeship program terminates at the end of this year so that they will no longer be available to help with the high school experiments or reactor operation in general. However, the Eastern Utilities grant has provided monies to partially support the high school tours.

The Nuclear Applications Laboratory has been greatly affected by the recent changes and, as a consequence, this laboratory has had to significantly limit their efforts in assisting University research personnel with their projects. Nevertheless, the capabilities of this laboratory continue to grow. Of importance to this past year's accomplishments are (1) the development of a "Film-lift" technique for the removal of gunshot residues from suspect's hands for subsequent neutron activation analysis, (2) initiation of a new research project to develop a new fence line radiation monitor, (3) identification of several promising tracers to augment the currently used bromine ion tracers for activatable water tracers, and (4) establishing and verifying calculational techniques to be used to design an optimum

subcritical multiplier for the Cf-252 neutron source. This latter project utilized a subcritical TRIGA reactor and a Cf-252 neutron source to provide data to verify the calculational techniques.

Reactor operations data reflect the changes in reactor operational activities as described above. The hours of reactor operation have remained essentially unchanged, but, on the average, the reactor was operated at a lower power. Fewer long term irradiation samples are required and more time has been used for the critical experiments.

Space at the PSBR continues to be limiting to the research capability of the Facility. Plans are being renewed to activate expansion into the nearby Accelerator building.

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

An important result of the fuel management program, sponsored under A.E.C. Contract No. AT(30-1)-4160 and described in the previous annual report, was the discovery of a new refueling scheme which predicted fuel cost savings of approximately $30,000 per year. This scheme uses 12 wt.% U fuel to replace the burned up 8.5 wt.% U fuel. The six 12 wt.% U fuel elements placed in the core last year are meeting expectations. It is estimated that the present core will last another year, reducing fuel costs to less than $6000 per year. A summary of the results of this work was presented by M. J. Cenko and Dr. S. H. Levine at a one-day seminar sponsored by the A.E.C. Division of Nuclear Education and Training. The presentation was made in Denver, Colorado to representatives of other installations that operate TRIGA reactors.

During the past year, the reactor staff has provided reactor operator training to five AEC trainees, three naval students, and one undergraduate. The reactor staff continues to assist in the curriculum planning of several laboratory courses for both undergraduate and graduate credit. Members of the reactor staff continue to be assigned major responsibilities in the Penn State two-year associate degree program for training technicians to work at nuclear power plants and for running the third Summer Institute at Penn State to provide additional education to nuclear science high school teachers. A three-week institute, "Man and Environment" for science instructors from smaller colleges utilized the PSBR. Also, as in past years, operations personnel from Metropolitan Edison received training at the Facility.

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

The next section provides a list of personnel who are associated with the operation of the reactor. Section III describes the PSBR Administrative organization and lists staff changes that have occurred this past year. Section IV provides pertinent information, including statistical data, on the PSBR's operation. Section V 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 VI. However, more detail on these and other research projects are presented in Section VII.

PERSONNEL

II. PERSONNEL

Faculty and Staff

**T. L. Flinchbaugh	- Reactor Supervisor
**G. C. Geisler	- Research Associate
*J. F. Hilbish	- Reactor Operator (Resigned May 73)
**R. C. Houtz	- Reactor Supervisor
W. A. Jester	- Associate Professor
B. K. Lee	- Research Assistant (Resigned Feb. 73)
**S. H. Levine	- Professor
J. R. McKee	- Administrative Aide
**I. B. McMaster	- Research Assistant
P. A. Moran	- Engineering Aide (Resigned March 73)
**J. H. O'Brien	- Reactor Supervisor
**J. L. Penkala	- Research Assistant
K. K. Pillay	- Research Associate
**D. C. Raupach	- Reactor Supervisor
**G. E. Robinson	- Assistant Professor
*K. E. Rudy	- Engineering Aide-Mechanical Services Supervisor
**R. E. Totenbier	- Research Assistant
*D. S. Vonada	- Electronic Designer

Technical Service Staff

W. A. Davy	- Custodian-Driver
J. P. Gauthier	- Custodian-Technician
R. O. Lowrey	- Machinist
*G. L. Adams (Part-time)	- Reactor Operator
*J. S. Tate (Part-time)	- Reactor Operator
*W. C. Weadon (Part-time)	- Reactor Operator

Clerical

M. D. Beward	- Secretary
M. K. Brooks	- Secretary and Receptionist

Graduate Assistants and AEC Trainees

*J. A. Blakeslee	- AEC Trainee
M. A. Bricklemyer	- Graduate Assistant
**M. J. Cenko	- AEC Trainee
S. A. Diab	- Graduate Assistant
*J. A. Easly	- AEC Trainee
W. H. Grush	- Graduate Assistant
R. A. Jabs	- Graduate Assistant
*J. D. Jeffries	- Graduate Assistant

B. W. Lee	- Graduate Assistant
M. A. Mann	- Graduate Assistant
B. D. McKenzie	- Graduate Assistant
S. A. Moss	- Graduate Assistant
*J. N. Neyman	- AEC Trainee
*L. A. Pasquini	- AEC Trainee
*J. W. Rodell	- AEC Trainee
A. C. Romero	- Graduate Assistant
*G. J. Sagliocca	- AEC Trainee
*R. T. Thomas	- AEC Trainee
E. G. Tourigny	- Graduate Assistant
*K. E. Weise	- AEC Trainee
*B. L. Wilks	- AEC Trainee

Health Physics

R. W. Granlund - University Health Physicist
J. K. Schmotzer - Health Physics Assistant

Reactor Safeguards Committee

Dr. A. H. Foderaro, Professor, Nuclear Engineering
Mr. G. C. Geisler, Research Associate and Assistant Director, Breazeale Nuclear Reactor
#Mr. R. W. Granlund, Health Physicist
Dr. A. M. Jacobs, Professor, Nuclear Engineering
Dr. E. S. Kenney, Associate Professor, Nuclear Engineering
Dr. W. P. Kovacik, Advisory Engineer, Westinghouse Research Laboratory
Dr. S. H. Levine, Professor, Nuclear Engineering and Director, Breazeale Nuclear Reactor
Dr. W. W. Pratt, Professor, Physics
Dr. G. E. Robinson, Assistant Professor, Nuclear Engineering and Assistant Director, Breazeale Nuclear Reactor
Dr. W. F. Witzig, Professor, Nuclear Engineering and Department Head, Nuclear Engineering

*Licensed Operator
**Licensed Senior Operator
#Committee Chairman

ADMINISTRATION

III. ADMINISTRATION

During the past year, three resignations occurred: B. K. Lee, a Research Assistant, left in February, 1973 to join GPU Corporation; Mrs. P. A. Moran, an Engineering Aide, resigned in March, 1973 to accompany her husband to New York City, and J. F. Hilbish, a Reactor Operator, left in May, 1973 to accept employment in the nuclear field. Mrs. J. S. Tate, who has been employed (part time) as a reactor operator while completing her Bachelor of Science degree in Nuclear Engineering, resigned due to completion of her program.

In the area of reactor operations, the AEC-Traineeship program continued with Messrs. Blakeslee, Easly, Neyman, Rodell, and Sagliocca becoming licensed reactor operators. In addition, Mr. W. C. Weadon, a Nuclear Engineering undergraduate, also became a licensed reactor operator.

During the past year, members of the Facility Staff were involved in teaching assignments, served as faculty advisors, and were members of thesis committees. Reactor faculty members also supervised a number of research projects. A full description of each project is contained in a later section of this report.

The following chart, Figure 1, shows the Administrative Organization of the Breazeale Nuclear Reactor Facility.

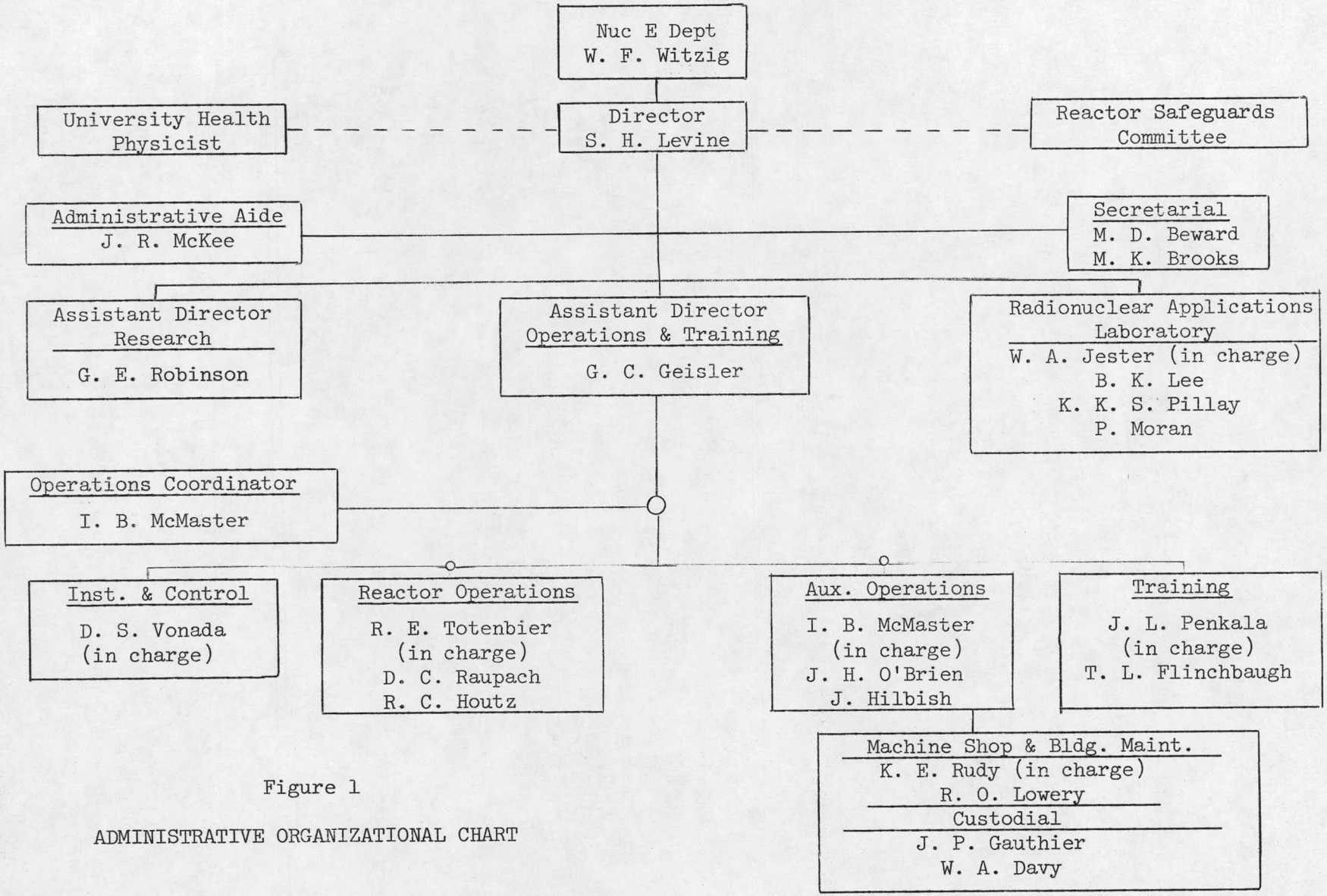


Figure 1

ADMINISTRATIVE ORGANIZATIONAL CHART

FACILITY OPERATION

IV. FACILITY OPERATION

Utilization of the Penn State Breazeale Reactor varies from term to term; however, the statistics in Tables 1 and 2 show a favorable comparison from one year to the next. For example, the total hours of critical time were within six hours when comparing the past two years. The approximately 10% reduction in energy produced reflects greater usage at lower power levels. In Table 2, the utilization in hours per day is comparable when one considers there were 42 more 8-hour shifts in the past year which in effect reduces the hours per day averages.

During July 1972, two weeks were set aside for reactivity checks on various core configurations to gather data for a fuel management program. Also during this time, a new core configuration was established using six 12 wt.% fuel elements in the center of a core of 8.5 wt.% fuel elements. Studies have shown a longer core life can be expected with a mixture of this type. Presently, the PSBR is the only research reactor of its type using a mixed percentage of fuel in its core.

Contrary to the 1971-1972 year, the shift operation was utilized quite extensively during the past year. One week of night shift was cancelled during July to allow for staff vacations. From mid September 1972 through December, a total of 12 four-hour periods were used for a reactor staff retraining program. In order to assure maximum attendance, night shift was canceled one day each week and the reactor was not operated during the retraining sessions.

Table 1

BREAZEALE NUCLEAR REACTOR
OPERATING STATISTICS

June 1, 1971 - May 31, 1973

Operating Data	1971-1972	1972-1973
A. Hours of Critical Time		
1. Hours Critical	1,383.25	1,347.60
2. Approaching Critical	260.20	279.00
3. Adjusting Fuel	50.23	72.92
TOTAL	1,693.68	1,699.52
B. Number of Pulses	292	179
C. Number of Square Waves	48	55
D. Energy Produced in MWH	947.51	851.12
E. Grams U^{235} Burn-up	40.93	36.77
F. Number of Scrams		
1. Planned as part of experiments	78	43
2. Inadvertent		
a. Operator action	12	17
b. System failure	3	5
c. Power failure	3	1
3. Real	8	2
TOTAL	104	68

Table 2

BREAZEALE NUCLEAR REACTOR
UTILIZATION STATISTICS

June 1, 1971 - May 31, 1973
(Per Shift Averages)

		1971-1972	1972-1973
A.	Experimental Facility Usage (Hrs/Day)		
	1. Beam Ports and Vertical Tubes	.32	.76
	2. Thermal Columns	.34	.74
	3. Incore Facilities	.37	.31
	4. Core Face Experiments	2.16	1.73
	5. Number of Users per Day	2.05	1.74
B.	Samples		
	1. Number per Day	6.50	4.53
	2. Sample Hours per Day	4.99	6.73
C.	Reactor Usage (Hrs/Day)		
	1. Operating	3.17	2.81
	2. Shutdown	.94	1.06
	3. Training	.67	.88
	4. Checkouts	.38	.33
	5. Calibrations and Maintenance	.45	.43

Remarks:

1971-1972 averages are based on 437 - 8 hour operating shifts
1972-1973 averages are based on 479 - 8 hour operating shifts

In November 1972, a week of low power experiments and reactivity checks produced additional data for the fuel management study. Towards the end of the year, equipment was completed to allow semi-permanent coupling of the D_2O tank to the center beam tube.

The annual fuel inspection occurred in December 1972. This shutdown period allowed for more fuel management study experiments. The Californium-252 source was used in the reactor for a series of subcritical experiments during this time.

Before returning to routine operation in mid January 1973, a new core configuration was installed which contains a rotating sample irradiation container christened the Merry-Go-Round (MGR). The MGR is designed to hold either 18 or 24 samples sealed in quartz tubing for irradiation periods of up to 30 hours at 1 MW over a three-day period.

The Spring term, normally the busiest time of the year, presented even greater scheduling problems this year. During April and May, at least two high school groups conducted a critical experiment utilizing the reactor for 2-4 hour periods *each* week. In addition, most of these groups also conducted a neutron howitzer experiment for similar time periods. Throughout this period, numerous formal tours were conducted at the Facility. The number of visitors increased considerably this past year from 1,982 to 2,650.

Substantial progress was made on efforts to reduce or eliminate radioactive effluents, by improvements to the waste water handling system and the conversion of the pneumatic transfer system to CO_2 operation.

The Cobalt-60 Facility statistics shown in Table 3 reflect a decrease in the usage of the Facility over the past year in the number of samples run. However, the number of experimenters using the Facility has remained the same. Many of the changes in the Table are a reflection of the increased source strength available from the Natick sources obtained in 1972.

The larger number of sources permit the set-up of four permanent irradiation configurations as opposed to three in the past and in part accounts for the changes in the areas headed; time adjusting Co-60 sources, total number of configuration changes and hours of use/day/configuration.

The higher source strength available with the Natick sources enabled experimenters to obtain higher dose rates in a shorter period of time thus reducing the total hours of sample runs and the total sample hours. The total sample hours figure was also reduced due to fewer long term samples.

Table 3

COBALT-60 STATISTICS

1 June 1971 - 31 May 1973

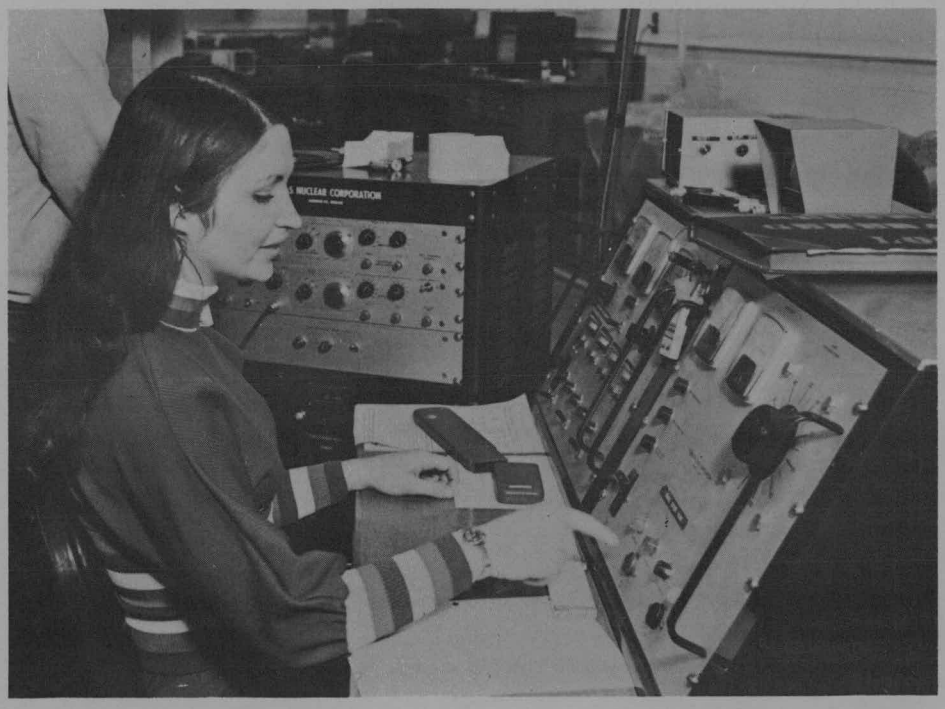
			1971-1972	1972-1973
A.	1.	Time Adjusting Co-60 Sources	46 hrs.	4 hrs.
	2.	Set-up Time	18 hrs.	19 hrs.
	3.	Total Hours of Sample Runs	5,714 hrs.	3,577 hrs.
		TOTAL	5,778 hrs.	3,600 hrs.
B.	1.	Total Number of Samples	509	385
	2.	Total Number of Configuration Changes	24	10
	3.	Total Number of Different Experimenters	34	34
C.	Per Day Averages			
	1.	Number of Experimenters/Day	0.98	.66
	2.	Number of Samples/Day**	5.49	1.7
	3.	Hours of Use/Day/Configurations*	5.69	2.44
D.	1.	Total Sample Hours (No. of individual samples exposed multiplied by hours exposed)	35,485 hrs.	6,168 hrs.

REMARKS: 1971-72 was based on 335 days and three configurations. The Facility was shut down for 30 days (November 8 - December 9, 1971) during installation of 70 sources from Natick Laboratory. 1972-73 is based on 366 days and four configurations.

*Three pencils moved to Hot Cell No. 1 for use by microbiology in February 1971 are still in use. A total of 44 runs were made during the past year for 7 different experimenters. This usage is not reflected above.

**Long term samples are counted each day they are irradiated. Thus, the long term irradiation of samples is reflected in C.2 and D.1.

EDUCATION AND TRAINING



V. EDUCATION AND TRAINING

The most significant development in the utilization of the Breazeale Nuclear Reactor in recent years has been its employment in educational and training activities, ranging from the high school to the graduate level. This type of activity has continued to increase, utilizing both Facility hardware and Facility operations personnel.

For the third year, an institute for Pennsylvania high school teachers was conducted to prepare them to teach the "Nuclear Concepts" course. This is a course developed by the Pennsylvania Department of Public Instruction to fill an increasing need for additional (and timely) high school science courses. Members of the reactor staff active in conducting this institute were Drs. Jester and Lee, and Messrs. Penkala and Flinchbaugh, assisted by AEC Trainee Neyman.

As in previous institutes, the participants were encouraged to return with their students for a one day field trip to the Facility. This resulted in 31 groups, totaling 396 students, participating in a day of experiments with the neutron howitzer, the Cobalt-60 Facility, and the reactor itself. While not the major function of the reactor, this program contributed significantly to a high level of reactor use, particularly during the Spring term. The extensive coordination and scheduling effort was Mr. Penkala's, while the conduct of the experiments was primarily by Mr. Penkala, Mr. Flinchbaugh, and AEC Trainees Blakeslee, Easly, Neyman, Rodell and Sagliocca. Table 4 summarizes this program.

Table 4

HIGH SCHOOL SPECIAL PROGRAM GROUP 1972-73

High School	Instructor	Students
West Perry	Mr. Stoops	7
Wyomissing	Mr. Bell	13
Daniel Boone	Mr. Tobias	7
Sullivan County	Mr. DeWire	10
Lower Dauphin	Mr. Lyter	10
Jersey Shore	Mr. Allen	22
Ligonier Valley	Mr. Mannion	15
Ferndale	- - -	20
Berwick	Mr. Foster	10
Ridgway	Mr. Koos	14
Dunmore	Mr. Gatto	7
Titusville	Mr. McQueer	3
Penns Valley	Mr. Fuller	17
Greater Latrobe	Mr. Eckert	4
Riverside	Mr. Modzelesky	10
Pottsville	Mr. Naradko	8
Hanover	Mr. Watts	7
Arch. Bishop Kennedy	Sr. Joseph	8
Hollidaysburg	Mr. Rhodes	25
Kingston Catholic	Sr. Cossman	7
Penn Hills	Mrs. McKissick	6
Altoona	Mr. Beech	17
Carlisle	Mr. Kaufman	15
Thomas Jefferson	Mr. Farrell	25
North Schuykill	Mr. Welker	10
Bellefonte	Mr. Young	7
Penncrest	Mr. Wilhelmson	32
Reading Catholic	Sr. Baus	11
Pittsburgh Explorer Scouts	Mr. Howard	20
Hamburg	Mr. Feeg	17
Alfred Beattie Voc.-Tech.	Mr. Leseck	12
TOTALS	31 GROUPS, 396 PARTICIPANTS	

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The Facility continued to be involved in the undergraduate program with support given to Nuclear Engineering 200, 430, 440, and 441. Mr. Houtz assisted Professor Diethorn in Nuc. E. 200. Mr. Geisler assisted Professor Schultz with Nuc. E. 440. Dr. Robinson's Seniors in Nuc. E. 430 (Design Principles of Reactor Systems) were again given the opportunity to manipulate the reactor controls through a complete startup and shutdown, and as before, this appeared to be a highlight of the course for the students.

The Associate Degree (two year) Program in Nuclear Engineering Technology continued with the final term of the program being given at University Park during the Spring term for nine students. Of the two laboratory courses given at the reactor, Nuc. E. 814 was taught by Mr. Penkala with assistance by Mr. Flinchbaugh, and Nuc. E. 812 was taught by Professor Schultz and Mr. Geisler, with extensive assistance by Mr. Roland Wilkinson. Mr. Wilkinson is a teaching fellow and participated in this course as a part of his student teaching requirements.

The success of the graduates of the two year program in obtaining employment has been particularly gratifying. Of the thirteen students in the 1972 group, twelve students had obtained positions by mid July 1972, and of the 1973 group, all were employed before graduation.

An important event of the past year for both the undergraduate and the associate degree programs was the evaluation by accreditation teams from the Engineering Council for Professional Development. This required extensive effort from most of the instructors in these programs. These efforts were coordinated by Dr. Robinson for the undergraduate program, and Mr. Penkala for the associate degree program.

Graduate students in nuclear engineering used the Reactor Facility in Nuclear Engineering Laboratory 502A, 502B, and 502C during the Fall, Winter, and Spring terms. The student efforts in these courses have been supported by staff members Dale Raupach, Robert Houtz, and Terry Flinchbaugh. The multitude of electronic problems which arise in these courses, plus the various undergraduate courses, are handled by the staff Electronic Designer, Mr. Douglas Vonada.

The AEC Traineeship Program continued successfully during the past year with the graduation of Mr. Pasquini, who is now with the Division of Reactor Development at the AEC; Mr. Wilks, who went to Bettis Atomic Power Laboratory; Mr. Thomas, who was employed by General Electric in San Jose, California; and Mr. Weise, who is going to Gilbert Associates. Mr. Cenko continued work towards his Ph.D. Messrs. Blakeslee, Easly, Neyman, Rodell and Sagliocca are now completing their first year of the program. The latter trainees also completed the In-House Reactor Operating Training Program and passed the AEC Operator's Exam. They are now being used routinely in reactor operations.

Other trainees in the In-House Training Program were three students sent to us by the Navy Civil Engineering Corps to obtain a Master's degree and reactor operating experience. These were Messrs. Current, Urbani, and Filson.

Also completing the Operator Training Program and passing the AEC examination was Mr. William Weadon, a Nuclear Engineering undergraduate student. Mr. Weadon is a transfer from North Carolina State and was licensed on their research reactor. Mrs. Jacqueline Tate,

who has been employed as a reactor operator while completing her undergraduate program, graduated and has accepted a position with Gilbert Associates.

The cooperative training efforts of the BNR and Metropolitan Edison which began in 1969, continued with a one-week program of reactor operation and nuclear experiments for Three Mile Island operating and engineering personnel. Also in the area of utility operator training, plans were made to conduct a one week program of the above type for utility personnel on an "open" basis, if sufficient interest exists. Table 5 lists all participants in the various reactor training programs.

In addition to the summer institute for high school teachers previously described, a three week institute, "Man and the Environment," was given during July for science instructors from the smaller colleges in the eastern and southern section of the United States. The objective was to acquaint the instructors with the factors involved in concerns over environmental radiation, and methods of measuring it. The reactor was used to provide radioactive isotopes for some of the laboratory sessions. Approximately 30 attended from widely scattered institutions. The program was directed by Professor Schultz and the University Health Physicist, Mr. Granlund.

Other activities of less magnitude but perhaps no less significant included:

The provision of radioactive isotopes for 60 students in Chem. 405, Radiochemistry, and four 2-hour sessions demonstrating reactor operation. Professor Dr. Miller, in charge.

Table 5

PARTICIPANTS IN REACTOR TRAINING PROGRAMS

Name	Sponsor	Program	Started	Completed
*W. J. Weadon	Nuclear Reactor	Reactor Operator	October 1972	March 1973
*J. A. Easly	U.S.A.E.C.	Reactor Operator	July 1972	March 1973
*J. W. Rodell	U.S.A.E.C.	Reactor Operator	July 1972	March 1973
*J. A. Blakeslee	U.S.A.E.C.	Reactor Operator	July 1972	March 1973
*G. J. Sagliocca	U.S.A.E.C.	Reactor Operator	July 1972	March 1973
*J. N. Neyman	U.S.A.E.C.	Reactor Operator	July 1972	March 1973
G. A. Kunder	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
L. G. Noll	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
J. C. Banks	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
C. E. Hartman	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
J. E. Keisch	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
R. B. Evans	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
R. A. Washick	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
R. P. Miller	Metro. Edison	Research Reactor Operations	10 June 1973	14 June 1973
D. Lozinski	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
D. R. Weigle	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
J. Zendek	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
G. L. Claar	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
R. Baran	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
R. A. Heffner	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
R. Foor	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
M. P. Lower	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
R. Lloyd	Penn State University	Nuclear Engineering Technology	29 March 1973	7 June 1973
D. C. Current	U.S. Navy	Reactor Operator	August 1972	November 1972
D. Urbani	U.S. Navy	Reactor Operator	August 1972	December 1972
J. V. Filson	U.S. Navy	Reactor Operator	July 1972	December 1972
J. Martin	Penn State University	Special Topics	June 1973	- -

*Qualified for A.E.C. Reactor Operator's License

For 12 medical technology students from Harrisburg Hospital, a Facility tour and laboratory experience in the handling of radioactive isotopes. Dr. Jester, in charge.

For 13 Microbiology 410 students, a Spring term project to determine the effect of radiation on the immune response of mice utilized the "hot cells" and Co-60 sources. Dr. A. Zarkower, in charge.

Four students in Entomology 416 conducted an experiment in Insect Ecology and Control using the Co-60 Facility. Dr. A. A. Hower, Jr., in charge.

For Health Physics graduate students from the University of Pittsburgh, two separate 3-day field training programs were conducted by the Health Physics Office. Each of these involved one day at the reactor with experience in evacuation procedures and the handling of radiation and contamination problems. Mr. Granlund, in charge.

A 16 week work-study program for Mr. Harry Fox III of the State Police Crime Laboratory in activation analysis. Dr. Jester, in charge.

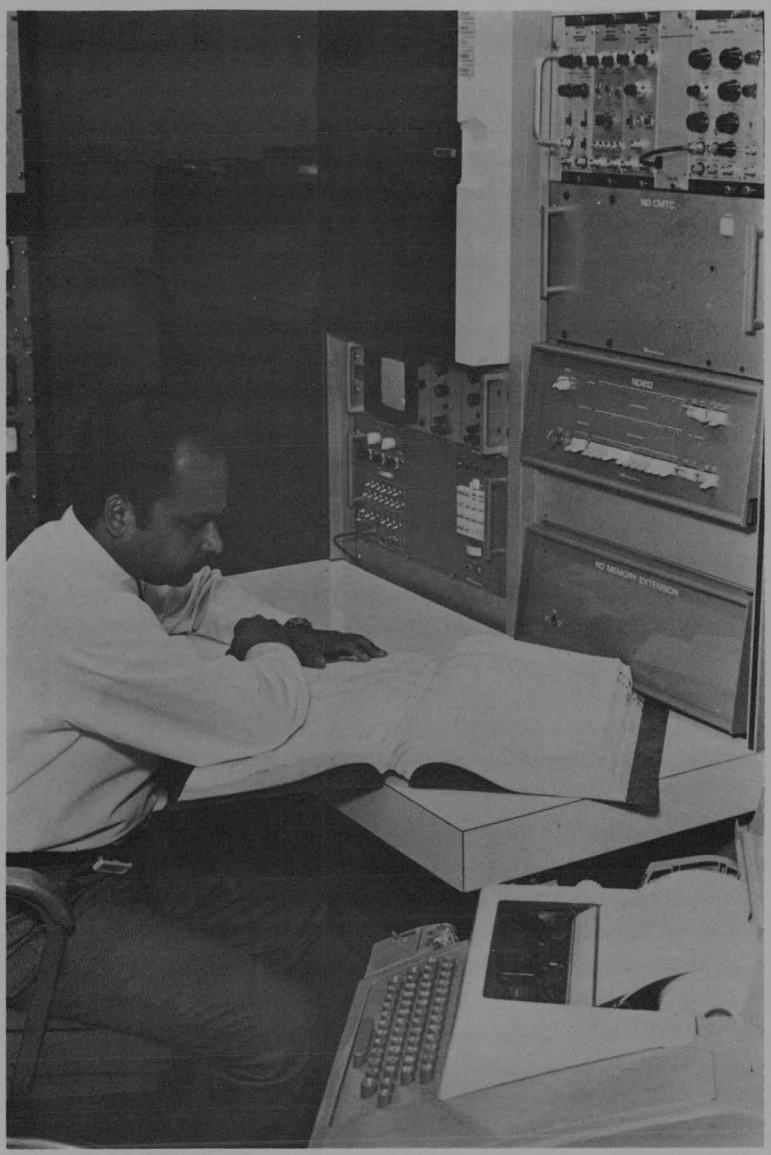
A study to evaluate the cadmium accumulation in lichens collected from the surroundings of a smelting plant in central Pennsylvania was performed by D. A. Matchick as a Term Project for M.E. 472. Dr. K. K. S. Pillay and Dr. K. C. Holmbee supervised.

Three lectures were given to twenty students of the Chemistry 527 class on Activation Analysis. A demonstration of the principles of neutron activation analysis was performed and a tour of the Facility was arranged. Dr. K. K. S. Pillay and Dr. T. H. Risby, in charge.

Approximately 40 Boy Scouts were assisted in obtaining the Atomic Merit Badge by Messrs. Houtz and Vonada.

And finally, to continue the policy of using the Facility to provide information to any interested group, approximately 100 facility tours were given to over 2,650 visitors. A list of these groups is given in Appendix B.

RADIONUCLEAR APPLICATIONS LABORATORY



VI. RADIONUCLEAR APPLICATIONS LABORATORY

This has been a year of transition for the Radionuclear Applications Group. In addition to a number of personnel changes, both staff and student, personnel of the group have been called upon to play a larger role in the Nuclear Engineering Department's instructional load, thereby having less time available for assisting University research personnel. Throughout this period, there has been a continual growth in the capabilities of the group, especially in the area of radiochemical separations, thanks to the efforts of Dr. K. K. S. Pillay. Some of the key events of the year are as follows.

In February of this year, Dr. B. K. Lee, Research Assistant, left the group to take a position in industry. To date, a suitable replacement has not been obtained. In March of this year, Mrs. Patricia Moran (Engineering Aide) left the group upon the graduation of her husband, and there has been difficulty in finding a suitable replacement for her. Several of the senior graduate students completed their degree work and also left the group.

In its second year, the radionuclear forensic program, supported by the Governor's Justice Commission, has been very productive under the leadership of Dr. K. K. S. Pillay.

One of the major accomplishments of this year's efforts has been the development of a "Film-lift" technique for the removal of gunshot residues from suspect's hands for subsequent neutron

activation analysis. This spring, a criminalist of the State Police Crime Laboratory, Mr. Harry Fox, underwent three months of extensive training in order to be able to conduct the activation analysis of gunshot residues from the film tests. A training program is now being developed to allow the State Police to begin to routinely use this technique in the field.

The Pennsylvania Science and Engineering Foundation supported the Nuclear Biomedical Research Program, with the exception of completion of the fluorine-18 production techniques, went unfunded this year, primarily due to cutbacks in the Foundation's funds due to Hurricane Agnes. The program will be supported again during the upcoming year. Concerning the fluorine-18 production - by July of 1972, the production techniques were completely worked out and a sterile product low in tritium and suitable for oral use in human patients was being produced. A noted radiologist, Captain William H. Briner, Professor of Radiology at Duke University, was hired as a consultant to evaluate the techniques and procedures being used. He reported that the methodology being employed was quite satisfactory and the equipment and instrumentation employed in the production and separation of the product were excellent. During the months of July through August, 10 production runs were carried out and the product delivered to Dr. George Jackson. During this period, the product was administered to some 15 patients with various types of bone disorders with good results being obtained in most cases.

In an effort to evaluate the interests of using ^{18}F produced at the Breazeale Nuclear Reactor, some 210 nuclear medical clinicians

throughout Pennsylvania were informed of the laboratory's production capabilities and were invited to attend a meeting on September 19, 1972 at the Breazeale Nuclear Reactor to discuss their needs for this product. Of these responding, 13 clinicians were able to attend the meeting while an additional 14 expressed interest in the program. The results of this meeting and market survey are summarized for the following statements.

1. There is a serious need for a better bone scanning agent.
2. Fluorine-18 appears to be superior to agents currently being used for this application.
3. A new bone scanning agent is just appearing on the market, namely technician-99m labeled polyphosphates, and it appears that this product will be considerably cheaper and more convenient to use than Fluorine-18.

Since there were not sufficient numbers of the clinicians at that time able to commit their organization to the use of this product, and since PSEF support for this program had ended, production of fluorine-18 was stopped. The equipment and facilities have been put in storage in case the demand for this product increases in the future.

The hydrology project for the development of nonradioactive but neutron activatable water tracers has continued with the support of the University's Institute for Research in Land and Water Resources with the identification of several promising tracers to augment the currently used bromine ion tracer.

During this year, a new research project was initiated to develop a fenceline monitor for the on-line qualitative detection of radioactive gases being emitted from nuclear reactors. A very promising technique is being developed under this program which is being supported by an Eastern Utilities grant.

The laboratory continues to provide research services to a wide variety of University personnel and organizations as listed in the following sections. Other in-house services conducted in support of reactor and health physics personnel are not listed. Also not listed are the numerous meetings with researchers within and without the University in which counsel is given concerning the application of the various radionuclear techniques to solve their problems. Only these projects which result in a significant use of the facilities of the Breazeale Nuclear Reactor are listed in the subsequent section.

The laboratory personnel again gave their free, annual, five-day activation analysis workshop on March 21, 22, 23, 26, and 27.

Concerning equipment additions to the laboratory - it was reported last year that a Nuclear Data 4400 programmable pulse height analyzer had been obtained for the laboratory. Despite its great potential, this equipment has been a major disappointment during this last year, because of both hardware and software problems. Prior to his leaving, Dr. Lee was spending a major portion of his time trying to get and keep the machine running. The problems are just now becoming resolved.

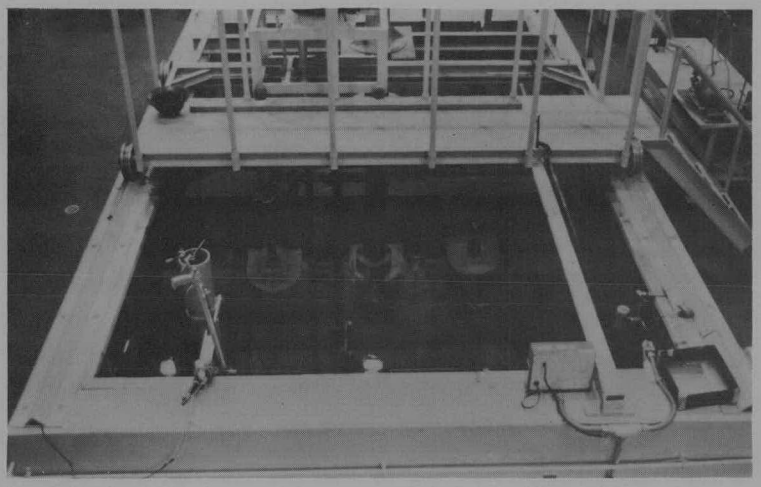
Because of a vacuum leak resulting in the destruction of the older of two high resolution Ge(Li) detectors, a replacement detector

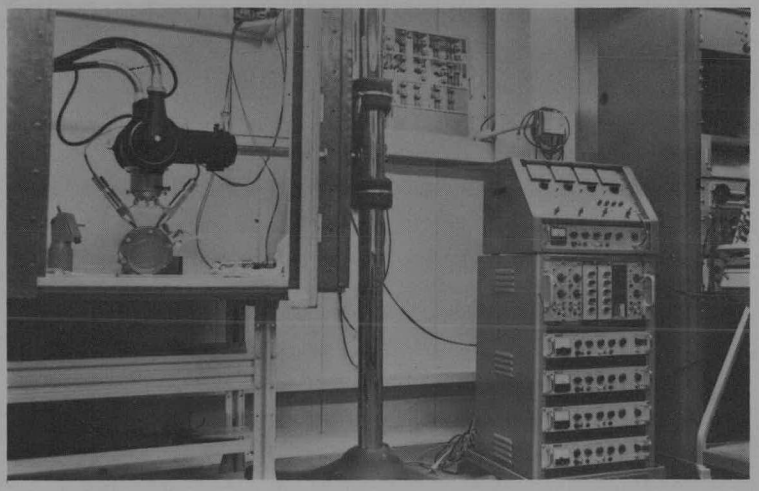
was obtained from Edax International giving higher resolution and greater detection efficiency.

For the fenceline monitor program, a large 4" diameter by 4" thick Na(Tl) radiation detector was obtained from Harshaw Chemical Company. This detector was especially designed for use in the outdoor environment and contained an ^{241}Am alpha source for producing a calibration peak for use with a spectrum stabilizer to help correct for gain changes due to environmental temperature changes.

Some of the more significant equipment for the radiochemistry laboratory included a Virtis shell freezer and freeze dryer and a large 3/4 horsepower International centrifuge.

In addition, work has continued on the development of an optimum design of a subcritical reactor for multiplying a Cf-252 neutron source. An irradiation facility of this type can be operated by personnel not having an AEC reactor operators license. Calculational techniques to be used in designing the optimum core have been established and TRIGA experiments, utilizing the Cf-252 neutron source, performed that verified the calculational techniques.





FACILITY RESEARCH UTILIZATION

VII. FACILITY RESEARCH UTILIZATION

Research continues to utilize the major portion of the available operation time of the reactor and the Cobalt-60 Facility. A wide variety of research projects are currently in progress as indicated on the following pages. For convenience, the University oriented research projects are divided into three categories: research projects utilizing the PSBR, research projects involving the Nuclear Applications Laboratory (and in most cases the reactor), and research utilizing the Cobalt-60 Facility. In addition, a section is provided on non-University research projects 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. Forty-seven faculty members and fifty-four graduate students have used the Facility in the past year for research. This represents a usage by fifteen different departments of the University. Names of the individual users and their departmental affiliation are given in Appendix A.

The following list of current research projects (arranged in alphabetical order using author's names) indicates the broad utilizatition enjoyed by the Nuclear 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. Dynamic Radiography (Neutron)

Dr. A. M. Jacobs, Dr. E. S. Kenney and NDEA Fellow P. Rose of the Nuclear Engineering Department

Using neutrons for dynamic radiography makes possible the imaging of the motion of hydrogenous intervals within metallic containers. In addition to the study of imaging point dynamics in the collimator systems, neutron "holography" is being developed using coded masks as a more efficient scattered field sensing mechanism.

2. Neutron Diffraction from Vibrating Crystal Systems

Dr. E. S. Kenney and Graduate Assistant J. D. E. Jeffries of the Nuclear Engineering Department

The Facility was used to measure the diffracted intensity of thermal neutrons incident on systems of one and two vibrating crystals. It was noted that up to 95% of the neutrons are twice diffracted and that a decided cooling is observed in the vibrating crystal situation as compared to neutrons from a stationary crystal. Quartz piezoelectric crystals were used in all studies with ceramic piezoelectric benders providing adequate deformation for the rather stiff flexure made crystals.

3. Delayed Neutron Spectrum Studies from Selected Precursors

Dr. E. S. Kenney and Graduate Assistant P. K. Ray of the Nuclear Engineering Department

The Reactor Facility has been used to produce thermal neutron and gamma ray fields to study the delayed neutron energy spectra problem. The year has been spent calibrating the equipment for energy resolution and gamma ray discrimination. A chemical separation system has been constructed to provide selected delayed neutron precursors at the counting station. The system has been designed to minimize interference from other neutron sources and gamma rays.

4. Resonance Escape Probability Studies

Dr. S. H. Levine and Graduate Student P. Furtato of the Nuclear Engineering Department

Resonance escape probability studies have been initiated using a staked foil method to determine the self-shielding characteristics of resonance absorption. The calculational techniques for predicting the self-shielding characteristics of such foils in fast and thermal reactor spectra are to be evaluated and compared with the experimental data.

5. Californium-252 Neutron Source Experiment

Dr. S. H. Levine, Dr. W. A. Jester, Graduate Assistant B. D. McKenzie and Graduate Student B. W. Lee of the Nuclear Engineering Department

Neutron multiplication of Cf-252 neutron sources with a subcritical assembly is being studied both analytically and with the TRIGA reactor. Analytical methods have been developed to accurately predict multiplication measurements made with a subcritical TRIGA core. Work is now proceeding to establish the optimum geometry core for multiplying Cf-252 neutron sources.

6. Threshold Activation Experiments

Dr. S. H. Levine, Mr. D. C. Raupach and Graduate Student J. K. Schmotzer of the Nuclear Engineering Department

A technique for unfolding activation cross-sections by exposing threshold detectors to several different calibrated neutron spectra is being developed. This technique will permit measuring new activation cross sections.

7. TRIGA Fuel Management

Dr. S. H. Levine, Dr. W. F. Witzig, Graduate Assistant A. J. Easly and Graduate Assistant M. J. Cenko of the Nuclear Engineering Department

Fuel management studies of the TRIGA reactor are being continued. As a result of this study, TRIGA fuel costs have been greatly reduced by reloading the TRIGA with 12 wt.% in lieu of 8.5 wt.% U fuel (savings of approximately $25,000 to $30,000 per year have been attained). Reloading 6 of the 12 wt.% U fuel in the center of the core will last for two years of operation, whereas it would take over 40 new 8.5 wt.% U fuel elements to maintain reactor operation over the same period of time. The TRIGA Core Management Model (TRIGA C-M Model) developed to perform fuel management studies, is being checked experimentally to improve the accuracy of the model.

8. Spot Sampling and Measurement for Ambient Atmospheric Argon-41

Dr. W. W. Miller, Undergraduate W. G. Stroud, Jr. and Undergraduate F. W. Vosbury of the Chemistry Department

It appears that there are potentially four methods for the acquisition of a large enough sample of the atmosphere or components of the atmosphere adequate for measurement of ^{41}Ar concentration levels in the region of non-occupational tolerance or lower. They are compression, condensation, adsorption, or fractionation. Two of these have been investigated in this work.

A. Adsorption - After preliminary investigation of adsorption isotherms of the components of the atmosphere over various grades of molecular sieve, it was found that selective adsorption looking towards isolation of the argon component does not appear promising, but that simply "brute force" total adsorption of an atmospheric sample freed of moisture and CO_2 does lead to a simple inexpensive direct observation and measurement of ^{41}Ar at non-occupational tolerance levels. A one liter (approximate) glass, cylindrical vessel filled with about one kilogram of the appropriate molecular sieve immersed in a liquid nitrogen was used. About 100 to 120 liters of the atmosphere was passed through a moisture and CO_2 removal column and then through the apparatus in approximately one hour. The vessel and liquid nitrogen were placed alongside a 3" crystal multichannel analyzer assembly and counted.

B. Condensation - The Nuclear Engineering Department has supplied funds for the construction of a small heat exchanger condenser which, immersed in a liquid nitrogen bath, will liquify samples of the atmosphere. Trouble has been experienced obtaining liquid-light joints, but liquefaction rates of approximately ten liters (gas) per minute were obtained showing a potential for the collection of one-half to one cubic meter samples for measurement by procedures similar to the above. Aspects of moisture and CO_2 removal measurement efficiencies, collection and measurement times are comparable to the above procedure.

Equations have been developed relating the observed count for optimum time of the 1.27 MEV gamma ray peak of ^{41}Ar to the concentration level in the atmosphere from which the sample was drawn with the predetermined absolute detection efficiency and the functional form of the time-dependent atmospheric sampling rate. Observations were made of the atmosphere in the reactor bay, the reactor control room, corridors in the laboratory wing and outdoors downwind of the Facility under several conditions of reactor operation.

The results are internally consistent and appear to be reliable. The reactor bay and reactor control room concentration levels after extended operation at 1 MW are a major fraction of, but appear not to exceed, occupational tolerance.

9. Low Intensity Gamma Rays in the Decay of ^{51}Ti

Dr. W. W. Pratt and Graduate Student J. A. Rakowski of the Physics Department

A study of the gamma ray spectrum of ^{51}Ti has been carried out using high resolution Ge(Li) spectroscopy in a search for weak transitions from excited states in ^{51}V. The purpose of this experiment is to obtain information on the comparative half lives associated with the beta decay transitions populating the states. Information of this type is of interest in clarifying the applicability of different models to nuclei in this mass region.

10. Decay of ^{95}Zr

Dr. W. W. Pratt of the Physics Department

A study of the gamma ray spectrum of ^{95}Zr is in progress in an effort to resolve discrepancies in the properties of some of the excited states in ^{95}Nb as observed in different experiments. In particular, two levels at 724 and 757 keV appear on the basis of radioactive decay studies to have spin and parity of $7/2^+$, while nuclear reaction studies indicate states of $3/2^-$, $3/2^+$ and $5/2^+$, all in the same energy region. An attempt is in progress to clarify the energy level structure of ^{95}Nb by looking for low intensity transitions in the decay of ^{95}Zr which can be associated with spin 3/2 and 5/2 states in ^{95}Nb.

11. Radioactive Decay of ^{110m}Ag

Dr. W. W. Pratt of the Physics Department

The gamma ray spectrum of ^{110m}Ag was measured with a Ge(Li) spectrometer. Several weak transitions were found. These include gamma rays of 365, 626, 997, 1085, 1334, 1784 and 1904 keV which have previously been reported but have not been confirmed; and a previously unreported gamma ray of 1421 keV. These results are in good agreement with a recently proposed energy level diagram for ^{110}Cd.

12. Isomeric States in Barium Isotopes

Dr. W. W. Pratt and Graduate Student J. A. Herritt of the Physics Department

A 320 ms isomeric state is known to be associated with one of the barium isotopes. It has, however, alternately been attributed to ^{135}Ba produced by inelastic neutron scattering in ^{135}Ba and to ^{136}Ba which could be produced by neutron capture in ^{135}Ba. In order to resolve this discrepancy, an experiment is in progress using a pulsed neutron beam extracted from one of the beam hole

apertures. It is planned to bombard separated isotopes of ^{135}Ba and ^{136}Ba with both thermal and fast neutrons and to study the activity produced as a function of the isotopic abundance of the target and of the neutron energy.

13. Ternary Fission in ^{235}U

Dr. W. W. Pratt and Graduate Student L. J. Pilione of the Physics Department

A dielectric track detection technique is being used to study the process in which a third particle is emitted along with the two major fission fragments. In addition to the well known cases of neutron and alpha emission, there are relatively rare cases in which other charged particles are emitted. The present study is designed to measure the mass, energy and direction of emission of charged particles in the range between lithium and oxygen.

14. Neutron Activation Analysis of Alkali Metals in Pegmatitic Quartz and Its Fluid Inclusions

Dr. F. E. Wickman and Research Assistant R. A. Horn of the Geosciences Department

Seventeen samples of quartz and its fluid inclusions from pegmatites in southern Black Hills, South Dakota, and six samples from two graphic granites from unknown localities have been analyzed for Na, K, Rb and Cs by neutron activation analysis. After irradiation, surface contamination was eliminated by ion exchange and the alkali metals were extracted by comminution and leaching for gamma-ray spectrometry. The procedure was tested in various ways. No relation could be established between the Na/K ratios of the whole quartz and its fluid inclusions.

The spatial locations for six specimens from the Helen Beryl pegmatite were known. The Na/K atomic ratios of the samples are mainly a function of their vertical positions in the pegmatite. The ratios of the central -core quartz apparently indicate a much higher temperature (perhaps 550-650°C) than those closer to the upper wall (perhaps 200-300°C). This is consistent with the theory of permatite qenesis by Jahns and Burnham (1969). The other pegmatites could not be discussed from this viewpoint, but the observed range of Na/K, 0.1-16.1, is consistent with published experimental results. The fluid inclusions of quartz from two graphic granites give very different Na/K atomic ratios: 1.5-2.1 and 16.1-26.5 respectively, apparently related to differences in their formation history, high values indicating low-temperature reactions.

15. Neutron Activation Analysis of Gold-Bearing Quartz and Its Fluid Inclusions

Dr. F. E. Wickman and Research Assistant K. M. Krupka of the Geosciences Department

Neutron activation analysis is used to determine the alkali metal concentrations in quartz samples and the contained fluid inclusions. The quartz samples are from gold-bearing quartz veins in the O'Brien Mine in Northwestern Quebec. The project will determine if any trends in the alkali metal concentrations exist vertically and horizontally along the quartz veins.

The activation analysis of the quartz samples will consist of having the samples irradiated at the nuclear reactor followed by gamma ray spectrometry using the Ge(Li) detector system in the Department of Geosciences. Analysis of the fluid inclusions contained in these quartz samples will follow the methods used by Horn and Wickman with several improvements.

16. Fast Reactor Spectrum Assembly (FRSA)

Dr. W. F. Witzig, Dr. S. H. Levine, Graduate Assistant S. S. Diab, Graduate Student V. Perez-Pita, AEC Trainee L. A. Pasquini and Graduate Student D. J. Florek of the Nuclear Engineering Department

This project involves the construction of an assembly to produce fast neutron spectra similar to that in the LMFBR using Pathfinder fuel, steel, and graphite. The assembly will be supported on a special cart so that the assembly can be moved to and from the PSBR beam port. The special cart has been constructed and tested to hold 6 tons (assembly weight is 4.5 tons). Of importance to this project is the construction of a fission plate. Pure U-235 foils are to be loaned to PSU by the AEC to construct the fission plate which will also be useful in providing an intense source of fission neutrons.

17. Analyses and Measurement of the Argon-41 Effluent from the PSBR

Dr. W. F. Witzig and Graduate Assistant D. A. Matchick of the Nuclear Engineering Department and University Health Physicist R. W. Granlund

Radioactive Argon-41 is produced in the air filled cavities and pool water at the PSBR. Concentrations of ^{41}A near background are to be measured in and around the Facility. A device for increasing the effective measurement potential by means of a high-pressure concentration technique has been constructed. This device will be positioned at various points to examine radioargon levels as a function of position and time (reactor power transients, operating schedule). An analysis in conjunction with the measurement has been performed and will be used to correlate the measurement data.

B. University Research Projects Utilizing the Radionuclear Applications Laboratory

1. Isolation and Quantification of Selected Thyroid Metabolites Using Chromatography and Neutron Activation Analysis

Dr. A. Anthony and Graduate Assistant J. D. Blannett of the Biology Department, Dr. W. A. Jester and Dr. B. K. Lee of the Nuclear Engineering Department

The object of this project was to develop a procedure by which the four major thyroid metabolites could be quantified. These include thyroxine (T_4), Tri-lodothyronine (T_3) diiodotyrosine (Dit) and monoiodotyrosine (Mit). The procedure developed consisted of four distinct stages. 1) Isolation of the thyroid metabolites from serum samples using ion exchange columns, 2) concentration of the isolated compounds using a modified freeze-dry technique, separation of the four compounds using paper chromatography, and 4) direct quantitative measurements of the compounds using neutron activation analysis of their iodine contents.

This technique has not been perfected to the stage of clinical application but the results to date appear very promising. Support for this project was obtained from The Pennsylvania Science and Engineering Foundation.

2. A Survey of the Concentration of Strontium-90 in a Contaminated Forest Ecosystem

Dr. E. D. Bellis, Dr. E. L. Cooper and NSF Trainee L. S. Hinkle of the Biology Department, Dr. G. W. Wood of the School of Forest Resources and Dr. W. A. Jester of the Nuclear Engineering Department

During the early to middle 1960's, a portion of the Quehanna wilderness area was contaminated by an unknown amount of ^{90}Sr. This study is aimed at surveying the concentrations of this isotope existing in the various ecosystem components: Mammals, vegetation and humus. The survey might provide valuable information on indicator species, species which might be followed before, during and after the construction of a nuclear reactor facility and indicate possible environmental contamination. In addition, this survey might give some indication of the cycling of the ^{90}Sr through the food chain.

About 2/3 of the samples have been analyzed for their ^{90}Sr content. This is done by extracting the ^{90}Y from the samples and counting the precipitate in the wide beta counter for one hour and calculating back to the ^{90}Sr content.

3. Determination of Concentrations and Variations of Trace Minerals in Human Milk

Dr. H. A. Gutherie and NDEA Fellow M. F. Picciano of the Division of Biological Health and Dr. W. A. Jester of the Nuclear Engineering Department

Research was undertaken to determine the amounts and variability of chromium, copper, iron and zinc in breast milk. It is known that these trace elements vary considerably among individuals, but the extent of variation within individuals is not known.

Since human milk is specific for humans, just as the milk of other mammals is specific for their young, infant feeding regimens are based on the use of human milk or substitute modified to resemble human milk. It is known, however, that the composition of human milk is influenced by a great number of factors. Any one sample of human milk may not necessarily represent the nutritional quality of the milk produced by the mother. Thus, the amount of variability of these trace elements will supply useful information for an understanding of infant requirements for these elements.

Copper, iron and zinc concentrations are being determined by atomic absorption spectrophotometry. Currently, a method of chromium determination is being developed using neutron activation analysis.

4. Biology of the Alaskan Eskimo

Dr. E. E. Hunt and Graduate Assistant I. G. Pauson of the Anthropology Department

As part of the International Biological Program (I.B.P.), multidisciplinary studies of the biology of the Alaskan Eskimo have been undertaken at several different locations in Alaska and Canada for a number of years. For some time, it has been known that elderly Alaskan Eskimos suffer a considerable degree of osteoporosis - it has recently been discovered that younger adults are also prone to excessive bone loss. As part of a broad based study of the nutritional intake of Eskimos, it was decided to investigate the background radioactivity (in view of the fallout from Soviet nuclear testing). Since the Eskimo rely on caribou meat as a food staple, it was not unreasonable to assume that some of this radioactivity might be detectable in the hair of elderly individuals. Although nutritional and mineral imbalances (such as the presence of radioactive substances) might be related to excessive bone loss, the association is by no means clear. However, tests failed to indicate the presence of significant deviations from background radiation, even in the hair of a 75 year old Eskimo male.

of 2000 psig. The NaI(Tl) detector has been purchased and preliminary measurements of reactor produced Argon-41 have been made. An all weather shelter for the system is now being constructed, the backbone of which will be an elaborate electronic temperature control system required to maintain the stability and safety of the radiation detector. An instrument panel will be designed to provide visual and graphical readout of the various system monitors. The ultimate goal is to tie the system into an on line minicomputer for system control and data processing.

7. Activation Analysis of AEC Standard Samples Using a ^{252}Cf Source

Dr. W. A. Jester and Graduate Student B. W. Lee of the Nuclear Engineering Department

As part of a larger program involving users of AEC supplied Californium-252 neutron sources, personnel of the Radionuclear Applications Laboratory, were requested to conduct activation analysis of two sets of standard samples containing unspecified amounts of 13 trace elements. The Facility's Californium-252 source was employed in using a specially designed source and sample holder. Irradiation fluxes in the various sample positions were monitored and found to vary from 2.5×10^6 to 4.0×10^6 neutrons/second/cm^2. Various combinations of irradiation, decay and counting times were employed to optimize the detection sensitivity for the various elements.

The results of this work are as follows:

		Concentration (ppm) ± 20*	
Trace Element	Isotope Identified	Liquid Standard	Solid Standard
Na	^{24}Na	496 ± 9	320 ± 14
Al	--	N.D.	N.D.
V	--	N.D.	N.D.
Mn	--	N.D.	N.D.
Co	^{60}Co	127 ± 53	235 ± 95
Cu	--	N.D.	N.D.
Zn	^{69m}Zn	342 ± 68	9823 ± 2470
As	^{76}As	115 ± 240	1145 ± 418
Mo	^{99}Mo	N.D.	N.D.
Cd	^{115}Cd	2642 ± 230	1467 ± 205
Eu	^{152m}Eu	1.81 ± 0.33	0.93 ± 0.21
Hg	^{197}Hg	659 ± 209	N.D.

*Two Standard Deviations N.D. - Not Detected

8. Development of the Capability for the Production of Medical Grade Fluorine-18

Dr. W. A. Jester, Dr. B. K. Lee, Dr. K. K. S. Pillay, Mrs. P. M. Moran and Graduate Assistant M. A. Bricklemeyer of the Nuclear Engineering Department, Dr. G. L. Jackson of the Harrisburg Hospital and Graduate Assistant J. D. Blannett of the Biology Department

An improved technique for the production and purification of Fluorine-18 has been accomplished by members of the radionuclear applications laboratory.

Fluorine-18 is a radioisotope useful as a bone scanning agent to detect bone disorders. Because of its short half life (110 minutes), the dose is minimal and its chemical affinity for calcium makes it selective to bone tissue.

Production of this isotope involves a double reaction in which thermal neutrons from the reactor react with lithium-6 producing tritons which in turn bombard oxygen-16, thereby producing the fluorine-18, i.e.,

$$^{6}_{Li}(n,^{3}H);\quad ^{16}O\ (^{3}H,n)^{18}F$$

Lithium carbonate enriched in lithium-6 is the material being irradiated providing both this isotope and oxygen-16.

The fluorine-18 is separated from the lithium carbonate by distillation and purified by multiple evaporation to reduce the tritium content of the final product.

A product sterile, low in tritium and acceptable for oral administration has been produced by this process. One major advancement over previously reported techniques is a reduction of the tritium released to the environment during production by almost two orders of magnitude.

During the period of three months, ten shipments of this product were sent to Harrisburg Hospital and administered to approximately 15 patients upon which subsequent bone scans were performed.

9. Using the Bromide Ion as a Neutral Activatable Tracer in an Effort to Locate the Source of Acid Mine Drainage Polluting a Municipal Well

Dr. W. A. Jester of the Nuclear Engineering Department and Graduate Student K. A. Uhler of the Civil Engineering Department

The bromide ion has been established as an excellent neutron activatable tracer for studying the movement of surface and underground water. In this project, it was used as a tracer in a deep coal mine located in Clarion County in an effort to determine whether the waters in this mine were the source of acid mine drainage reaching a deep well used as a municipal water supply. The results of this pollution study were inconclusive since the bromide ion spike did not show up at the well. It is believed that either the mine waters were not the source of pollution or that sampling was ended prior to the time when the tracer spike reached the well.

10. Lubrication System for Stainless Steel Die Casting

Dr. E. E. Klaus and Graduate Assistant C. W. Lai of the Chemical Engineering Department

Part of the project involves the analysis of a phosphate ester film on a graphite surface. Upon irradiation with neutrons, the phosphate ester gives rise to 14.3 day half-life ^{32}p activity whereas the graphite is essentially inactive except for some background activities due to inherent impurities. The net ^{32}p activity can be obtained by subtracting the background activity of a blank graphite sample from the gross activity of the sample with ester film. Film thickness is then obtained by solving the combined production and decay equation. Film uniformity is detected by measuring the activity at various parts of the surface, which is partially covered by a movable lead shield. Similarly, the impurity distribution in the graphite can be determined by scanning the activity of a blank graphite sample.

11. An Investigation of the Polarity of Naturally Occurring Sulfur Impurities in Lubrication Oil

Dr. E. E. Klaus, Mr. E. J. Tewksbury and Graduate Student R. L. Fuhrman

Crude oil contains from essentially zero to 14% (by weight) sulfur impurities depending upon its origin. Lub oil base stock can still contain as much as 1% sulfur impurities, depending on the degree of refining. These sulfur impurities are separated by paper chromatographic techniques. The sulfur zones on the paper are located by irradiating the chromatograms ($S^{32}(n,p)p^{32}$) and scanning them for p^{32}. A sensitivity of 40 ppm has been achieved

using this technique. The polarity of the sulfur impurities are compared to known additives which are effective in boundary lubrication. The effects of oxidation on the polarity of the sulfur impurities is also being studied. From these data, a better understanding of the role of sulfur impurities in boundary lubrication will be obtained.

12. Sodium-24 Removal from Irradiated Biological Samples Using Wet-Ashing and Hydrated Antimony Pentoxide Extraction

Dr. B. K. Lee, Dr. K. K. S. Pillay and Dr. W. A. Jester of the Nuclear Engineering Department

As reported in the last annual report, procedures have been established for the removal of radioactive sodium from irradiated biological samples. It has been found that the previous technique of sample processing which included freeze drying prior to irradiation resulted in the loss of certain heavy metals, especially mercury from the sample. During this last year, a controlled post-irradiation wet ashing technique was set up. In this procedure, the biological samples are irradiated as collected. The samples were then wet ashed in a special apparatus designed by Dr. Pillay which eliminated the loss of volatile metals during the ashing step. The resulting sample was then perculated through a HAP column for sodium-24 removal. This technique produces very little loss of heavy metals.

13. Land Disposal of Contaminated Lime Wastes from SO_2 Scrubbers

Dr. G. W. McKee and Undergraduate T. A. Rightnour of the Agronomy Department and Dr. W. A. Jester of the Nuclear Engineering Department

Sulfur dioxide scrubber wastes, consisting primarily of hydrated lime, can be disposed of by incorporating them into agricultural soil or acid mine refuse and spoils. Agricultural lands might serve primarily as a sink for the wastes. When applied to strip mine and refuse banks the calcium in the wastes would be effective in neutralizing acidity and help create a favorable environment for plant growth.

It is known that the waste contains some contaminants such as sulfur molybdenum, heavy metals, etc., which could be potential water and soil pollutants if present in excessive amounts. To date, plant-response to the wastes in soils has been examined and chemical analysis of major plant nutrients has been completed. The Reactor Facility is being utilized for qualitative and quantitative activation analysis of the waste for elements which cannot be identified by other means. With this additional knowledge, a more accurate prediction can be made as to the feasibility of land disposal.

14. Obsidian Artifacts from Kaminaljuyu Characterized by Na and Mn Neutron Activation Analysis

Dr. J. W. Michels and Graduate Assistant L. H. deMendoza of the Anthropology Department and Dr. W. A. Jester of the Nuclear Engineering Department

Neutron activation analysis of obsidian artifacts on the basis of trace elements content has proved useful in the characterization and identification of raw material sources for archaeological tools. Yet, the number of radionuclides being utilized for this purpose tends to increase, reducing the possibilities of producing comparable information between research projects performed by specialists in many parts of the world.

Faster and easier techniques, reducing the number of elements in the analysis of obsidians have been tested showing that the content of sodium and manganese together with the ratio of their weights related to the total mass, is a highly reliable value that fingerprints accurately different obsidian flows within relatively small geographic areas.

To determine whether pre-columbian inhabitants of the Valley of Guatemala, especially those at the Kaminaljuyu site, produced their tools utilizing obsidian from a major single flow or from a number of them located at different regions, artifact samples were selected with calculated dates through an obsidian hydration dating technique.

The result of the neutron activation analysis showed that an overwhelming percentage of the artifacts were made of raw material from a single major source (98%), while the remaining 2% came from other sources. Previous evidence obtained by a similar work provided the necessary information to conclude that the major source is one at the Chayal area, while the secondary source is Chimaltenango. A visual inspection of the samples supported this outcome due to the noticeable different appearance in these two "kinds" of obsidian.

The regularity in the nature and composition of the obsidian, utilized in Kaminaljuyu, provided yet more important results for the purposes of dating techniques since the rate of hydration of this material is unquestionably constant through time, a factor that has been proven crucial in the accuracy of calculations in the measurement of the hydration rim in artifacts.

15. Neutron Activation Analysis of Obsidian Artifacts from the Valley of Mexico

Dr. J. W. Michels, Undergraduate M. J. Manfredo and Undergraduate L. S. Newman of the Department of Anthropology

Obsidian material suitable for the fabrication of useful implements as well as items of aesthetic and symbolic value has long served as an important economic commodity during the prehistory of central Mexico. The object of this research is to identify the geological sources of the raw material and the distributional patterns of economic exchange that operated during various periods. This information will contribute to a fuller understanding of the role of economic variables in the evolution of complex cultural systems in central Mexico. The reactor is used to provide sodium and manganese ratios with which to identify the geological source of each artifact.

16. Na and Mn Neutron Activation Analysis of Obsidian Artifacts from Maquixco, Mexico

Dr. J. W. Michels and Undergraduate N. S. Westlake of the Anthropology Department and Dr. W. A. Jester of the Nuclear Engineering Department

The purpose of this research was to determine the source of grey and green obsidian artifacts utilized at the site of Maquixco, Mexico during the Classic Period (300-900 A.D.) and Aztec Period (1200-1519 A.D.). It was hypothesized that the green obsidian would be predominantly from the source of Cerro de las Navajas and the grey obsidian from Barranca de los Estetes. This study indicated that Cerro de las Navajas was definitely the primary source of green obsidian and that the grey probably came from Barranca de los Estetes during both periods. However, further studies utilizing more grey samples are needed for positive identification of the grey source or sources.

17. Neutron Activation Analysis of Mercury in the Tissues of Aquatic Animals

Dr. K. K. S. Pillay and Mr. G. C. Geisler of the Nuclear Engineering Department and University Health Physicist R. W. Granlund

Mercury pollution is recognized as a serious hazard because of its cumulative poisoning effects. Examination of several products of sea whales showed that at least one of them (whale steak) had mercury contents in excess of 40 ppm. This investigation included the analysis of several whale oil samples, caviar, and sea food items. The one sample found to contain the excessive amounts of mercury was used to demonstrate neutron activation analysis (non-destructive) for the Nuc. E. 400 workshop - "Radiation in the Environment - during the summer of 1972.

18. Cadmium in the Environment and Its Possible Accumulation in Animal Tissues

Dr. K. K. S. Pillay of the Nuclear Engineering Department and Mrs. V. R. Hunt of the Biological Health Division

The increasing concern over the role of Cd in the environment and its possible association with hypertension and cardiovascular diseases have prompted a preliminary investigation to measure the levels of Cd in lichens from polluted and nonpolluted areas, as well as human teeth from persons from these areas. The neutron activation analysis for cadmium showed that the cadmium content of lichens from Magnolia, Massachusetts was 4.2 ppm, while lichens from an area near Lewistown, Pa. had a cadmium level of nearly 100 ppm. However, comparison of the cadmium content of teeth (children's) showed no significant differences in cadmium levels (0.24 and 0.27 ppm, respectively). While lichens may be useful environmental monitors for Cd, teeth may not be the proper tissue to monitor the levels of Cd in humans. Other tissues such as eye and brain are being presently considered as tissues for future examination of Cd levels.

19. Investigation of the Trace Element Constituents of Human Hair Using Multiple Nondestructive Neutron Activation Analysis

Dr. K. K. S. Pillay, Dr. W. A. Jester, Graduate Assistant M. A. Bricklemyer and Graduate Assistant S. H. Moss of the Nuclear Engineering Department

Evidence from crime scenes, when properly analyzed, can aid in reconstructing crime scenes, developing suspects and demonstrating positive or negative relationships between the suspect and the crime under investigation. The analysis of trace elements in compositional testing has emerged as a key to individualization of physical evidence such as hair, paint, paper, etc. The high sensitivity and specificity of neutron activation analysis has been increasingly used in the determination of compositional (elemental) characteristics of evidence materials. However, the development of a comprehensive data base - a firm statistical foundation - is presently lacking for the effective use of all trace element analysis techniques. An ambitious investigation now underway at the Breazeale Nuclear Reactor is to develop a sufficient data base to evaluate the potential use of neutron activation analysis of the trace elements in human hair as forensic evidence.

The hair analysis program is currently collecting hair samples from nearly 600 donors from different parts of Pennsylvania. This group consists of people of different age groups, occupation, and environmental exposures. The hair samples are initially separated as the hair matrix and the surface contaminants and both these are separately analyzed to determine over 22 elements using

multiple neutron activation. While the hair samples being analyzed include different members of the same family, they also include periodically collected samples from the same individuals to determine the variations in trace element composition of hair with tissue.

20. New Methods in the Collection and Analyses of Gunshot Residues as a Forensic Evidence

Dr. K. K. S. Pillay and Dr. W. A. Jester of the Nuclear Engineering Department and Mr. H. A. Fox of the Pennsylvania State Police

Analysis of gunshot residues left on human skin have been used since 1933 as a method of determining whether an individual had fired a gun recently. However, the test procedures used in the thirties and thereafter (called the "paraffin test") became obsolete and lost its validity because of the increasing amounts of other materials in our environment that can result in positive reactions to chemical tests. The use of trace element analysis to detect gunshot residues was introduced in 1959 and in 1964 the first application of neutron activation analysis for this purpose was introduced. Today, neutron activation analysis to determine the presence of gunshot residues is a method accepted by courts and is routinely being used by some law enforcement agencies.

The research program at the Breazeale Nuclear Reactor supported by the Pennsylvania State Police and the Governor's Justice Commission is designed to develop capabilities for the Pennsylvania State Police Crime Laboratory to use the new technology for routine applications. The investigations conducted so far have resulted in (1) the development of a unique formulation of pure reconstituted cellulose material called "FILM-LIFT," which when applied on human body surfaces forms a readily removable film. This film carries with it almost all the particulate residues on the skin which can be used to collect and analyze gunshot residues. Since the major composition of the material is of molecules with C, H, and O only, this makes a highly desirable medium to collect gunshot residues for neutron activation analysis.

The research efforts have also developed procedures to detect and quantitate trace levels of Ba, Sb, Cu, and Au in film lifts to identify the presence of gunshot residues. The analytical techniques are capable of distinguishing the difference between gunshot residues deposited through handling of firearms or ammunitions from those resulting from the discharge of a firearm.

21. Investigation of the Distribution Pattern of Firearm Discharge Residues between the Point of Firing and the Target

Dr. K. K. S. Pillay, Dr. W. A. Jester, Graduate Student B. W. Lee and Graduate Assistant D. C. Driscoll of the Nuclear Engineering Department

When a firearm is discharged, the emissions from the gun carry pyrolyzed residues of materials from the bullet, primer, casing, and the barrel of the gun. One of the court-accepted methods of identifying gunshot residues is through the analysis of some of the unique trace elements (such as Ba, Sb, Cu, and Au) in these residues. However, a series of investigations conducted at Penn State have demonstrated that there are distinguishable differences in the distribution patterns of gunshot residues between the point of firing and the target when different types of guns are used. Careful experimentation conducted so far has also revealed that (1) the distribution pattern is different for center-fire and rim-fire ammunitions; (2) the distribution pattern and density is dependent on the distance between the point of firing and the target; (3) these patterns are reproducible in controllable environment. These findings are being carefully reexamined and evaluated through newly designed experiments and non-destructive neutron activation analysis.

The above mentioned findings seem to have the potential to be a valuable tool in criminal investigations to determine (a) the direction from which a gun was discharged with respect to a victim; (b) the approximate distance between the point of firearm discharge and the victim; (c) the possible difference between a suicide and a homicide and (d) some of the characteristics that could determine the kind of firearm that was used.

22. Trace Elements in Early Precambrian Ultramafic Volcanic Rocks

Dr. N. H. Suhr, Dr. A. W. Rose and Graduate Assistant J. F. Villaume of the Geosciences Department

In recent years, unusually iron- and magnesium-rich volcanic rocks have been discovered in several of the very old geological provinces of the world. In many cases, gold deposits are associated with these rocks. Other workers have hypothesized that these unusual rocks contain much higher amounts of gold which has subsequently been concentrated into ore deposits. In this study, 23 samples of such rocks from South Africa and Ontario have been analyzed for gold, to test whether the content is unusually high. The analytical method involved dissolution of the rocks in hot aqua regia, collection of the gold on a special resin-loaded disc, followed by activation of the disc and counting the daughter products of the activated gold.

The gold content of the rocks was found to be 1 ppb or less, in the normal range for other igneous rocks. There is no indication of an unusually high gold content in these samples.

C. University Research Projects Utilizing the Cobalt-60 Facility

1. Mechanism of Leukemia Virus-Induced Immune Suppression

Dr. W. S. Ceglowski, Teaching Assistant M. J. Siegel, NDEA Fellow R. F. Mortensen, Research Assistant B. P. Campbell and Research Assistant G. V. LaBodie of the Microbiology Department

Suppression of immune competence appears to be an attribute shared by a number of oncogenic agents. The murine leukemia virsuses have been studied in our laboratory in order to evaluate the mechanism by which they mediate this profound immunosuppression. All these studies rely very heavily on the utilization of inbred mice which have been rendered immuno-incompetent by radiation with a ^{60}Co source at the Breazeale Nuclear Reactor. These irradiated recipient mice are then transfused with lymphoid cells from either normal or virus-infected donors. In this manner an assessment of the effect of the leukemia viruses on host immune competence is determined.

2. Molecular Beam Scattering

Dr. D. R. Frankl and Graduate Assistant D. E. Houston of the Physics Department

Alkali halide crystals are irradiated in the Cobalt-60 Facility so that the crystals will cleave more readily. The structure of cleavage surfaces is then studied.

3. A comparative Morphological/Anatomical Study of the Seedlings of Gossypium Following Seed Irradiation

Dr. C. J. Hillson and Graduate Student J. P. Reed of the Biology Department

The recent past has seen an increased use of ionizing radiation sources for basic plant research. Documented reports of morphological, physiological, anatomical, and cytological changes in plants due to radiation exposure are numerous. Among the more common morphological effects are growth inhibition in roots, seedlings and stems, and growth stimulation of the shoot.

It is the intent of this investigation to determine to what extent the morphology and anatomy of cotton seedlings are altered by various acute doses of gamma radiation. Seedlings for this study were grown from irradiated and non-irradiated seeds. The Cobalt-60 Facility was used to accumulate an acute total dose of 5,000, 10,000, 20,000 and 30,000 roentgens. These seeds, irradiated while imbibing distilled

water, were transferred immediately to a growth medium as were the non-irradiated seeds and after a prescribed growing period were killed and fixed. To date, histological preparations are being made for subsequent study.

4. Dynamic Radiography (X-Ray)

Dr. A. M. Jacobs, Dr. E. S. Kenney and Graduate Assistant D. G. Tilley of the Nuclear Engineering Department

"Dynamic Radiography" is the terminology used to describe the general area of imaging the motion of the intervals of optically opaque objects. The X-ray radiation phase of the work has, this year, been devoted to the development of a "Scattered-Ray Analyzer to Detect Cardiac Wall Dynamics." The analyzer has already been tested on a human patient at the Hershey Medical Center with remarkably successful results.

5. Industrial Applications of Dynamic Radiography

Dr. E. S. Kenney and AEC Trainee G. Sagliocca of the Nuclear Engineering Department

The Reactor Facility is being used to provide sources of radiation in research on fluid flow profiles. By combining the point imaging characteristics of the Dynamic Radiograph concept developed here at the University and ideas from correlation flow research, a new type of flow profile device is being perfected. Using penetrating radiation as the probe, correlations are being studied for various related radial and axial positions in a water flow loop.

6. Radiation Imaging Using Fresnel Zone Plates

Dr. E. S. Kenney and Graduate Assistant R. G. Sider of the Nuclear Engineering Department

The Reactor Facility was used in conjunction with work on "Fresnel Plate" imaging and Dynamic Radiography. This interesting method combines advances in optical holograph and coded apertures in radar research to penetrating radiation imaging. Basically, the technique provides dramatic increases in aperture sizes and corresponding efficiency increases for devices akin to spin hole cameras and collimated detectors.

7. Exploratory Irradiation of Polymers

Dr. D. E. Kline of the Material Sciences Department

Certain polymers which may be useful in biomedical applications have been irradiated at the Cobalt-60 Facility. Irradiation effects are being investigated since there may be interest in sterilizing some parts by irradiation at a later date.

8. Charging Airborne Particulate Matter Using Radiation and Magnetic Fields

Dr. S. H. Levine and EPA Graduate Air Pollution Control Trainee R. A. Fjeld of the Nuclear Engineering Department, Dr. R. J. Heinsohn of the Mechanical Engineering Department and EPA Graduate Air Pollution Control Trainee G. W. Malamud of the Chemical Engineering Department

The generation of compton scattered electrons and the trapping of these electrons or β-source electrons in a magnetic field to intensify ion production in gas pollutants is being studied. An analytical model has been developed to calculate the above processes and an experimental arrangement is being constructed in a hot cell to obtain experimental data on these processes.

9. Prevention of Radiation Damage in Glass via Hydrogen Impregnation

Dr. L. N. Mulay and R. DiSalvo of the Material Sciences Department and Dr. D. M. Roy of the Materials Research Laboratory

It has been found that upon high pressure-high temperature impregnation of hydrogen gas into glass, the glass becomes more resistant to discoloration by gamma irradiation. The object of this research was to examine the color centers produced by irradiation in a complex borosilicate glass and determine the mechanism through which hydrogen interacts to destroy these centers. The Co-60 Facility was utilized to provide gamma irradiation to doses of 2×10^8 R. The principal characterization techniques employed in the study were electron paramagnetic resonance spectroscopy (EPR) and optical and infrared absorption spectroscopy. The necessary data have been collected and analyzed and publications on the subject are being prepared.

10. The Influence of Gamma Radiation on the Inception of Nucleate Boiling

Dr. G. E. Robinson and AEC Trainee J. N. Neyman of the Nuclear Engineering Department

The purpose of this research is to investigate the influence of gamma radiation on the inception of nucleate boiling from a flat heated surface. A pool boiling system is being constructed in one of the "hot cells." Isolated bubble growth from a heated ribbon immersed in Freon 12 will be investigated. A comparison of the ribbon temperature to initiate boiling with and without Co-60 radiation present will be made. The influence of saturated versus subcooled liquid will also be investigated.

11. Thermoluminescent Dosimetry

Dr. G. E. Robinson, Mr. J. H. O'Brien and Mr. J. F. Hilbish of the Nuclear Engineering Department and University Health Physicist R. W. Granlund

The Cobalt-60 Facility is being used to study the response of thermoluminescent dosimeters (CaF and LiF) to various gamma ray doses. The effects of orientation and high doses, as well as the effects on calibration after reusing the dosimeters are being studied. The effect of the gamma and neutron environment of the reactor on the dosimeters is also under study.

12. Collection of Particulate Matter Using Gamma Ray Ionization

Professor M. A. Schultz, Dr. E. H. Klevans, Graduate Assistant T. G. Bartholet and AEC Trainee J. W. Rodell

Limited experimental work was performed during the past year. Analytical work was undertaken to better interpret the observed phenomenon.

13. Low Temperature Chemistry

Dr. W. A. Steel, Dr. J. Riehl and Graduate Assistant R. J. Emrich of the Chemistry Department

It has previously been observed[1,2] that there exists a magnetic field dependence of proton spin-lattice relaxation rate of

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[1]Clough S. and Mulady, B. J., Phys. Rev. Letters, Vol. 30 #5 (1973) p. 161.

[2]Glöttli, H. Sentz, A. and Eisenkremer, M., Phys. Rev. Letters, Vol. 28 #14 (1972) p. 871.

molecules in the solid phase at liquid helium temperatures containing methyl groups that are undergoing tunneling rotation. At these low temperatures, proton spin-lattice relaxation is enhanced by magnetic fields due to rapidly relaxing paramagnetic impurities. An observed dependence on the applied field is attributed to a resonance between the tunneling frequency of the rotating methyl groups and the Larmor frequency of the paramagnetic centers.

Since dimethyl acetylene (2-butyne) contains rotating methyl groups, an investigation is underway to determine the possibility of such an effect in this material at low temperatures. The paramagnetic centers are the free-radical species produced in solid 2-butyne by gamma irradiation in the Cobalt-60 Facility at liquid nitrogen temperatures for periods of 15 to 30 minutes. Observations have been made concerning the effect at liquid helium temperatures, and attempts are underway to extend the measurements into the temperature range of liquid hydrogen.

14. Coloration of Minerals in Rocks by ^{60}Co Gamma Rays

Dr. F. E. Wickman of the Geosciences Department

Exploratory experiments were performed to see whether cobalt-60 gamma ray irradiations could be used to distinguish minerals in rocks. The results were negative because the difference developed was too small.

15. Effects of Inhaled Pollutants on the Immune Response of Mice

Dr. A. Zarkower, Graduate Student K. E. Eby and Graduate Assistant S. D. Miller of the Veterinary Science Department

The effects of inhaled pollutants on the immune responses of mice is being investigated. Normal irradiated (using cobalt-60 gamma rays) mice were tested for the ability of lymphoid cells from experimental and control mice to reconstitute a normal immune response. This was an effort to ascertain if the particulates caused alteration of the immune response at the level of the antibody forming cells (lymphocytes). Carbon dust was shown not to affect the lymphocytes, but cilica dust was shown to cause alterations in the immunocompetence of splenic cells.

D. Non-University Research Projects 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 at times which do not conflict with the University's educational and research programs. Organizations using these facilities in their research and development programs include:

Raytheon Company

The radiation effects groups of the Raytheon Company is responsible for assessing the effects of nuclear radiation on components used in electronic systems. The PSBR has been used to irradiate semiconductor devices from the SAM-D and TRIDENT programs.

THESES PUBLICATIONS & REPORTS

VIII. THESES, PUBLICATIONS AND REPORTS

Theses, publications and reports (both written and ordal) pertinent to the use or operation of the Facility are listed below

Theses

1. "Neutron Activation Analysis of Obsidian Artifacts from Kaminaljuyu, Guatemala," L. H. de Mendoza, M.S. paper, 1973, Dr. J. W. Michels, Advisor.

2. "Gamma Ray Measurements Utilizing Thermoluminescent Dosimetry," J. F. Hilbish, M.S. Thesis, 1973, Nuclear Engineering Department, Dr. G. E. Robinson, Advisor.

3. "Neutron Activation Analysis of Alkali Metals in Regnatitic Quartz and Its Fluid Inclusions," R. A. Horn, M.S. Thesis, 1972, Geosciences Department, Dr. F. E. Wickman, Thesis Advisor.

4. "Investigation of Thermal Neutron Beam Manipulation by Vibrating Crystalline Media," J. D. E. Jeffries, Ph.D. Thesis, 1972, Nuclear Engineering Department, Dr. E. S. Kenney, Thesis Advisor.

5. "Subcritical Multiplication Studies with Cf-252 Neutron Source," B. D. McKenzie, M.S. Thesis, 1973, Nuclear Engineering Department, Dr. S. H. Levine, Thesis Advisor.

6. "Effect of Carbon Silica Dust on the Cellular and Humoral Immune Responses of Mice," S. D. Miller, M.S. Thesis, 1973, Microbiology Department, Dr. A. Zarkower, Thesis Advisor.

7. "The Measurement of the Concentration of Ambient Ar^{41} in the Atmosphere over a Nuclear Reactor," W. G. Stroud II, B.S. Thesis, 1973, Chemistry Department, Dr. W. W. Miller, Thesis Advisor.

8. "Dynamic Radiography Imaging the Motion of a Surface," D. G. Tilley, M.S. Thesis, 1973, Nuclear Engineering Department, Dr. A. M. Jacobs, Thesis Advisor.

9. "Geochemistry of Some Precambrian Ultramafic Rocks," J. F. Villaume, M.S. Thesis, 1973, Nuclear Engineering Department, Dr. A. M. Jacobs, Thesis Advisor.

10. "The Use of a Quantitative Cyrocondenser for the Determination of Ar^{41} in the Atmosphere," F. W. Vosbury, B. S. Thesis, 1973, Chemistry Department, Dr. W. W. Miller, Thesis Advisor.

Publications and Reports

1. "Leukemia Virus-Induced Immunosuppression in the C57BL/6 Mouse," Abst. Ann. Mtg., A.S.M. 230, 1972, B. Campbell, W. S. Ceglowski and H. Friedman, Microbiology Department.

2. "Results of Penn State's TRIGA Fuel Management Studies," AEC sponsored seminar, Denver, Col., Oct. 1972, M. J. Cenko and S. H. Levine, Nuclear Engineering Department.

3. "Immunocyles and Leukemia Virus Infection: Effect on Bone Marrow and Thymus Cell Interaction," Microenvironmental Aspects of Immunity, pp. 499-505, Ed. B. D. Jankovic and K. Isakovic, Plenum Press, New York, 1973, W. S. Ceglowski, G. V. LaBodie and H. Friedman, Microbiology Department.

4. "Suppression of the Humoral Immune Response by Friend Leukemia Virus," Virus Tumorigenesis and Immunogenesis, pp. 167-180, Academic Press, New York, Ed. W. S. Ceglowski and H. Friedman, Microbiology Department.

5. "EPR Studies of Radiation Damage in Hydrogen-Impregnated Glass," presented before the Glass Division of the American Ceramic Society, Oct. 1972, Bedford, Pa., R. SiSalvo, Material Sciences Department.

6. EPR Studies of Radiation Damage in Hydrogen-Impregnated Glass, J. Amer. Soc., 55, 536 (1972), R. DiSalvo, D. M. Roay and L. N. Mulay, Material Sciences Department.

7. "Thermal Analysis of The Pennsylvania State University Breazeale Nuclear Reactor," Nuclear Technology, 19, 1, pp. 6-15, 1973, J. A. Haag and S. H. Levine, Nuclear Engineering Department.

8. "Dynamic Radiography as a Technique of Imaging Biological Flaws," Proceedings of the International Symposium on Holography in Biomedical Sciences, New Park Medical College, April 1973, A.M. Jacobs and E. S. Kenney, Nuclear Engineering Department.

9. "Nuclear Engineering Applications in Medical Science," Isotope and Radiation Technology, 9, 4, pp. 485-499, 1972, W. A. Jester, G. L. Jackson, B. K. Lee, J. S. Burkle and D. Jarrell, Nuclear Engineering Department and Hershey Medical Center.

10. "A New Method of Dynamic Imaging with Medical and Industrial Applications," ANS Transactions 15, 1, 143-144, June 1972, E. S. Kenney and A. M. Jacobs, Nuclear Engineering Department.

11. "Activation Analysis of Heavy Metals in Surface Waters Using Ion Exchange Filter Papers and Cyanide Complexing," Transactions of the International Conference on Modern Trends in Activation Analysis, Paper No. M32, 1972, A. M. Kolaczkowski and W. A. Jester, Nuclear Engineering Department.

12. "Activation Analysis of Heavy Metals in Surface Waters Using Ion Exchange Filter Paper and Cyanide Complexing," Transactions of the American Nuclear Society, 15, 2, pp. 643-644, 1972, A. M. Kolaczkowski and W. A. Jester, Nuclear Engineering Department.

13. "The Development of a Coordinated Program in the Utilization of Radiation Techniques in Biomedical Studies," Final Report PSEF-142, B. K. Lee, Nuclear Engineering Department.

14. "Local Measurements Using Gamma Ray Fluctuations," Nuclear Science and Engineering, 49, pp. 188-201, 1972, F. E. LeVert and M. A. Schultz, Nuclear Engineering Department.

15. "Dynamic Radiography," Proceedings of American Industrial Hygiene Association, May 1973, K. L. Miller, W. A. Weidner, A. M. Jacobs, and E. S. Kenney, Hershey Medical Center and Nuclear Engineering Department.

16. "The Application of Post-Cutting Chip Activation Analysis to the Study of Tool Wear," Transactions of the American Nuclear Society, 15, 2, pp. 717-718, 1972, K. N. Prasad, W. A. Jester and F. J. Remick, Nuclear Engineering Department.

17. "Collection and Activation Analysis of Airborne Gunshot Residues," Transactions of the Second International Conference on Forensic Activation Analysis, Paper No. 9, 1972, W. B. Renfro and W. A. Jester, Nuclear Engineering Department.

18. "Collection and Activation Analysis of Airborne Gunshot Residues," to be published in Radioanalytic Chemistry, W. B. Renfro and W. A. Jester, Nuclear Engineering Department.

19. "Collection and Activation Analysis of Airborne Gunshot Residues," Transactions of the American Nuclear Society, 15, 2, pp. 718, 1972, W. B. Renfro and W. A. Jester, Nuclear Engineering Department.

20. "Sources of Water Pollution Established by Using a Neutron Activatable Tracer," Transactions of the American Nuclear Society, 15, 2, pp. 641-642, 1972, J. K. Schmotzer, W. A. Jester, R. R. Parizek and K. A. Uhler, Nuclear Engineering Department, Geology Department and Civil Engineering Department.

21. "Using Gamma Ray Ionization," Nuclear Technology, 17, pp. 38-48, 1973, M. A. Schultz, M. E. Crotzer and W. R. Knapick, Nuclear Engineering Department.

22. "Dynamic Radiography Exhibit," at meeting of Radiological Society of North America, Chicago, Nov. 1972, W. A. Weidner, K. L. Miller, A. M. Jacobs and E. S. Kenney, Hershey Medical Center and Nuclear Engineering Department

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).

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Department of Chemical Engineering
College of Engineering

Kline, Donald E., B.S., M.S., Ph.D.
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College of Earth and Mineral Sciences

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College of Engineering

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College of Agriculture

McMaster, Ira B., B.S.
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College of Engineering

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

Miller, Warren W., B.S., Ph.D.
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Mulay, Larman N., B.Sc., M.Sc., Ph.D.
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College of Earth and Mineral Sciences

O'Brien, John H.
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Penkala, John L., B.S.
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Pillay, Sivasankara, K. K., B.S., M.S., Ph.D.
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Pratt, William W., B.S., Ph.D.
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College of Science

Raupach, Dale C.
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College of Engineering

Riehl, John W., A.B., Ph.D.
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Robinson, Gordon E., B.S., M.S., Ph.D.
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College of Engineering

Roy, Della M., B.S., M.S., Ph.D.
Associate Professor
Materials Research Laboratory

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

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

Steel, William A., B.A., Ph.D.
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Department of Chemistry
College of Science

Suhr, Norman H., A.B., M.A.
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Department of Geosciences
College of Earth and Mineral Sciences

Tewksbury, Elmer J., B.S., M.S.
Research Associate
Department of Chemical Engineering
College of Engineering

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

Wickman, Frans E., Fil. kaud, Fil. lic., Fil. dr.H.C.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

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

Wood, Gene W., B.S., M.S., Ph.D.
Assistant Professor
School of Forest Resources
College of Agriculture

Zarkower, Arian, D.V.M, M.S., Ph.D.
Associate Professor
Department of Veterinary Science
College of Agriculture

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

College of Agriculture

Rightnour, T. A., Agronomy Department (undergraduate)

College of Earth and Mineral Sciences

DeSalvo, R., Material Sciences Department

Horn, H. A., Geosciences Department

Krupka, K. M., Geosciences Department

Villaume, J. F., Goesciences Department

College of Engineering

Bricklemyer, M. A., Nuclear Engineering Department

Cenko, M. J., Nuclear Engineering Department

Diab, S. S., Nuclear Engineering Department

Driscoll, D. C., Nuclear Engineering Department

Easly, A. J., Nuclear Engineering Department

Fjeld, R. A., Nuclear Engineering Department

Florek, D. J., Nuclear Engineering Department

Fuhrman, R. L., Chemical Engineering Department

Furtato, P., Nuclear Engineering Department

Grush, W. H., Nuclear Engineering Department

Jeffries, J. D. E., Nuclear Engineering Department

Lai, C. W., Chemical Engineering Department

Lee, B. W., Nuclear Engineering Department

Malamud, G. W., Chemical Engineering Department

Matchick, D. A., Nuclear Engineering Department

Moss, S. H., Nuclear Engineering Department

Neyman, J. N., Nuclear Engineering Department

Pasquini, L. A., Nuclear Engineering Department

Perez-Pita, V., Nuclear Engineering Department

Ray, P. K., Nuclear Engineering Department

Romaro, A. C., Nuclear Engineering Department

Rose, P. J., Nuclear Engineering Department

Sagliocca, G., Nuclear Engineering Department

Schmotzer, J. K., Nuclear Engineering Department

Sider, R. G., Nuclear Engineering Department

Tilley, D. G., Nuclear Engineering Department

Uhler, K. A., Civil Engineering Department

College of Human Development

Picciano, M. F., Division of Biological Health

College of Liberal Arts

de Mendoza, L. H., Anthropology Department

Manfredo, M. J., Anthropology Department (undergraduate)

Newman, L. S., Anthropology Department (undergraduate)

Pawson, I. G., Anthropology Department

Westlake, N. S., Anthropology Department (undergraduate)

College of Science

Blannett, J. D., Biology Department

Campbell, B. P., Microbiology Department

Eby, K. E., Microbiology Department

Emrick, R. J., Chemistry Department

Herritt, J. A., Physics Department

Hinkle, L. S., Biology Department

Houston, D. E., Physics Department

La Bodie, G. V., Microbiology Department

Miller, S. D., Microbiology Department

Mortensen, R. F., Microbiology Department

Pilione, L. J., Physics Department

Rakowski, J. A., Physics Department

Reed, J. P., Biology Department

Siegle, M. J., Microbiology Department

Stroud, W. C., Chemistry Department (undergraduate)

Vosbury, F. W., Chemistry Department (undergraduate)

Appendix B

FORMAL TOUR GROUPS

1972		
July 10	Huntingdon 6-7-8 Grade Science Classes	24
10	History Seminar (Huntingdon)	12
11	EOP Tour (PSU)	13
11	Radiation Environmental Institute (PSU)	25
25	EOP Tour (PSU)	25
Aug. 1	Upward Bound Students	68
1	Japan Production Management Study Team to USA	13
3	Geo. Sci. 303 and 498 (PSU)	47
15	Local Residents	10
21	Elementary Education Seminar 594 (PSU)	9
23	Bus. Adm. (PSU)	3
23	Physics 237 (PSU)	17
24	Explorer Scout Group	20
25	Snyder County 4-H Club	25
Oct. 9	Phy. Sci. 7 (PSU)	36
20	Glendale High School Science Club	68
26	Open House	420
28	Engineering Opportunity Day	70
30	Science Teacher's Symposium	36
31	Bucknell University	13
Nov. 2	West Perry High School	7
6	Physics 100 (PSU)	17

Nov.	7	Physics 100 (PSU)	40
	8	Wyomissing High School	13
	9	Physics 100 (PSU)	26
	10	Geo. Sci. 303 (PSU)	10
	14	Cub Scouts	10
	16	Daniel Boone Area High School	8
	16	Phy. Sci. 7	21
	24	Local Residents	7
	30	Sullivan County H.S. (Laporte, Pa.)	11
Dec.	7	Lower Dauphin High School	10
	12	Tyrone High School	27

1973

Jan.	23	Jersey Shore High School	23
Feb.	1	Ligonier High School	13
	5	U.S. Naval Reserve Unit 4-4	16
	15	Geo. Sci. 303 (PSU)	31
	16	Ferndale Area Middle School, Johnstown, Pa.	20
	22	ANS Student Branch Open House	49
	22	Port Matilda 6th Grade	47
	22	Juniata Area High School	83
	28	Chem. 527 (PSU)	19
	28	Bald Eagle High School (Physics)	38
Mar.	6	Phy. Sci. 7 (PSU)	81
	9	Berwick High School	11
	12	Ridgway High School	15
	13	Health Planning & Administration 102 (PSU)	16

Mar.	20	Kishacoquillas High School	36
	21	Kishacoquillas High School	19
	22	Elizabeth Forward High School	16
	28	Lewistown High School	19
	28	Chief Logan High School	20
	30	Titusville and Dunmore High Schools	11
	30	Punxsutawney High School	38
Apr.	4	Schuylkill Haven High School	34
	10	Greater Latrobe High School & Penns Valley H.S.	23
	10	Phy. Sci. 7 (PSU)	9
	12	Riverside and Pottsville High Schools	20
	17	Archbishop Kennedy High School and Hanover High School	14
	19	Hollidaysburg High School	25
	19	Penn Cambria High School	32
	24	Hopewell High School, Aliquippa, Pa.	14
	26	Penn Hills High School	8
	26	Kingston Central Catholic High School	7
	26	Science Seminar - Student Conference (PSU)	11
	27	Boyertown High School	41
	30	Nuc. E. 401 (PSU)	13
	30	Susquehanna University (Physics class)	4
May	1	Altoona Area High School	18
	1	Physics 100 (PSU)	59
	2	West Snyder High School	29
	2	PP&L Nuclear Coordinators	14
	3	Carlisle High School	16

May	3	Physics 100 (PSU)	36
	4	Waynesboro Area High School	12
	7	National Honor Society Students, Old Forge, H.S.	38
	8	Thomas Jefferson High School, Pittsburgh, Pa.	25
	9	Boy Scouts	11
	10	Geo. Sci. 303 (PSU)	11
	10	Schuylkill and Bellefonte High School	22
	11	Metallurgy 412 (PSU)	15
	11	Beattie Tech. School	12
	15	Penn Crest High School	34
	16	Boy Scouts	10
	16	PSU Students	9
	16	Microbiology 410 (PSU)	13
	17	Reading Central Catholic High School	8
	22	Ceramic Science 500 (PSU)	13
	23	Boy Scouts	11
	24	Pittsburgh Explorers Post 258	15
	24	Physics 237 (PSU)	32
	30	Park Forest Jr. High School 9th Grade, Social Studies	28
	31	Hamburg High School	10
June	4	Pine Glen Elementary School	20
	5	PP&L Nuclear Coordinators	14
	6	Sons of the American Revolution Tour	9
	6	Civil Engr. 471 (PSU)	13
	6	Air Pollution Group (PSU)	8
	27	4-H Club	35
			2,637