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

July 1, 1973 to June 30, 1974

Submitted to

United States Atomic Energy Commission

and

The Pennsylvania State University

by

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University Park, Pennsylvania

June 1974

Unclassified

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I. INTRODUCTION AND SUMMARY

The 19th 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(30-1)-1859 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.

Increased student enrollments in both the Nuclear Engineering Associate degree and Bachelor of Science degree programs will make a greater demand on the space, laboratory facilities, and staff at the PSBR. For this reason, additional space in the nearby Accelerator building is being obtained which will temporarily relieve the congestion at the PSBR.

The introduction of the Nuclear Engineering Associate degree and Bachelor of Science degree laboratories at the reactor facility continues to place an increased demand on the staff and facilities at the PSBR. As a consequence, efforts were made to improve the operational

efficiency of the PSBR by reducing the second shift operation as much as possible. This permits the staff to provide adequate attention to reactor operation when the preparation and conduction of the nuclear engineering laboratories are being made. Nevertheless, the actual reactor operation increased by 100 hours over last year's operation and experimenters irradiated more than twice as many samples for more than 6 times as many sample hours.

Over 2,300 visitors made a formal tour of the Facility and many high school science classes used the Facility to perform experiments. Of particular importance to the success of the high school program was the support provided by the Eastern Utilities Grant in the form of graduate student traineeships. Two graduate students supported by this grant helped coordinate and conduct the high school experiments.

New AEC rules and regulations are placing an increased work load on the reactor staff. A new major program, a reactor operator retraining program, has been initiated and 50 hours of reactor time has been deleted to permit conducting the retraining lectures. Another AEC requirement necessitating considerable staff time is that associated with implementing the new security rules and regulations. In general, the many new rules and regulations that are being established by the AEC for research reactors are requiring a significant fraction of the reactor staff and budget to implement.

Significant developments have occurred in the Radionuclear Applications Group this past year, particularly regarding the forensic research. A new method has been established for determining bullet trajectories by sampling Ba and Sb residues left in the wake of the

bullet. The "Film-Lift" procedure developed in this laboratory is now routinely used by the Pennsylvania State Police. Activation analysis and radioactive tracer techniques have been successfully employed to identify extraneous plaster on statues and to develop improved methods in biomedicine and hydrology.

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

A new fenceline monitoring system has been successfully field tested at the Oyster Creek Nuclear Power Plant.

Several departments of the University that do not use the reactor or Co-60 facility are finding an increased need for the nuclear detecting equipment at the PSBR.

An optimum design for a subcritical reactor for multiplying Cf-252 neutron sources has been effected. The design includes a central tube in the core for pneumatic tube irradiations.

For the fourth consecutive year, a four week institute in Nuclear Concepts was offered at the PSBR for Pennsylvania high school teachers.

A special three week course in Basic Nuclear Technology was given to a group of nonnuclear engineers from the Metropolitan Edison Company.

The pneumatic transfer system was converted to a closed cycle CO₂ gas operation further reducing the already small releases of radioactive gas to the environment. In addition, the water handling systems were modified to further reduce the small releases of liquid radioactive effluents to the environment to essentially zero.

The University Reactor Safeguards Committee met five 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.

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II. PERSONNEL

Faculty and Staff

**T. L. Flinchbaugh	- Reactor Operations/Education Specialist
**G. C. Geisler	- Research Associate
A. E. Hart	- Engineering Aide
**R. C. Houtz	- Reactor Supervisor
W. A. Jester	- Associate Professor
**S. H. Levine	- Professor
R. R. Mayers	- Engineering Aide (resigned November 73)
J. R. McKee	- Administrative Aide
**I. B. McMaster	- Research Assistant
**J. H. O'Brien	- Reactor Supervisor
**J. L. Penkala	- Research Assistant
K. K. Pillay	- Research Associate
K. N. Prasad	- Research Assistant
**D. C. Raupach	- Reactor Supervisor
**G. E. Robinson	- Associate Professor
*K. E. Rudy	- Engineering Aide-Mechanical Service Supervisor
**R. E. Totenbier	- Research Assistant
*D. S. Vonada	- Electronics Designer

Technical Service Staff

*G. L. Adams (part-time)	- Reactor Operator (resigned June 74)
W. A. Davy	- Custodian-Driver
R. L. Fisher	- Reactor Operator
J. P. Gauthier	- Custodian-Technician
R. O. Lowrey	- Machinist
*J. W. Martin (part-time)	- Reactor Operator
*W. C. Weadon (part-time)	- Reactor Operator (resigned June 74)

Clerical

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

Graduate Assistants and AEC Trainees

*R. H. Arnold	- AEC Trainee
*J. R. Bailey	- AEC Trainee
*J. A. Blakeslee	- AEC Trainee
M. A. Bricklemeyer	- Graduate Assistant

V. R. Burke	- Graduate Assistant
**M. J. Cenko	- AEC Trainee
T. J. Donlan	- Graduate Assistant
D. C. Driscoll	- Graduate Assistant
*G. W. Houston	- Graduate Trainee
R. A. Jabs	- Graduate Assistant
R. H. Klinetob	- Graduate Assistant
*J. A. Easley	- AEC Trainee
R. L. Kuis	- Graduate Assistant
B. W. Lee	- Graduate Assistant
M. A. Mann	- Graduate Assistant
D. G. Mosebey	- Graduate Assistant
S. A. Moss	- Graduate Assistant
*J. N. Neyman	- AEC Trainee
P. J. Rensen	- Graduate Assistant
*J. W. Rodell	- AEC Trainee
P. J. Rose	- Graduate Assistant
*G. J. Sagliocca	- AEC Trainee
*J. D. Seebald	- Graduate Trainee
R. G. Sider	- Graduate Assistant
E. G. Tourigny	- Graduate Assistant

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, Professor, Nuclear Engineering
 Dr. S. H. Levine, Professor, Nuclear Engineering and Director,
 Breazeale Nuclear Reactor
 Mr. E. J. Ney, Manager, Special Projects, Westinghouse Astronuclear
 Laboratory
 Dr. W. W. Pratt, Professor, Physics
 Dr. G. E. Robinson, Associate 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

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III. ADMINISTRATION

The permanent Facility Staff remained unchanged during the past year. Mr. W. C. Weadon and Mr. G. L. Adams, who had been employed as reactor operators (part time) while studying for a B.S. in Nuclear Engineering, left after graduating.

A group of AEC trainees (R. H. Arnold, J. R. Bailey, G. W. Houston and J. D. Seebald) completed the in-house operator training program and passed the AEC licensing examination. Mr. J. W. Martin, a Nuclear Engineering undergraduate, also completed this program and received his license.

Faculty members associated with the Facility who received promotions were Dr. E. S. Kenney, to Professor, and Dr. G. E. Robinson, to Associate Professor.

As detailed in Section VI, the Radionuclear Applications Laboratory was joined by Miss Ann Hart, Engineering Aide, and Dr. K. N. Prasad.

As usual, Facility Staff were involved in a variety of activities in addition to reactor operation. These activities, included teaching, advising students, committee membership and supervision of research. Specific activities are recorded in other sections of this report.

The following chart, Figure 1, shows the administrative organization of the Breazeale Nuclear Reactor Facility. Note that I. B. McMaster has been designated Facility Engineer.

Figure 1

ADMINISTRATIVE ORGANIZATIONAL CHART

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IV. FACILITY OPERATION

The recent introduction of the Nuclear Engineering Associate degree and Bachelor of Science degree laboratory courses is resulting in increasing demands for the assistance of the Reactor staff. To make staff personnel more available to provide such assistance, an effort was made during the past year to reduce second shift operation as much as possible without inconveniencing experimenters. Experiments utilizing the reactor under similar conditions were combined whenever feasible and second shifts, when no experiments were scheduled in advance, were canceled. The result was close to a 20% reduction in the number of 8 hour shifts.

The statistics in Tables 1 and 2 show an increase in utilization in every category. In spite of the reduction in hours available, the reactor was in operation over 100 hours more than during the previous year, enabling more experimenters to irradiate twice as many samples for 6 times as many sample hours. Most of the increase in number of samples and sample hours resulted from a regular use of a rotating sample irradiation container called the Merry-Go-Round (MGR). Since this irradiation facility utilizes the reactor at full power, a 20% increase in MWH of operation resulted. All of the MGR operation was for the Radionuclear Applications Laboratory.

In addition to the experimental load indicated, the reactor was utilized for more than 400 hours in several categories of reactor operator training, over 100 hours for various graduate and undergraduate

Table 1

BREAZEALE NUCLEAR REACTOR OPERATION DATA

June 1, 1972 - May 31, 1974

	<u>1972-1973</u>	<u>1973-1974</u>
A. Hours of Critical Time		
1. Hours Critical	1,347.60	1,451.16
2. Approaching Critical	279.00	260.80
3. Adjusting Fuel	72.92	57.24
B. Number of Pulses	179	241
C. Number of Square Waves	55	61
D. Energy Produced in MWH	851.12	1,019.25
E. Grams U ²³⁵ Consumed	43.82	52.48
F. Number of Scrams		
1. Planned as Part of Experiments	43	36
2. Unplanned - resulting from		
a. Operator Error	19	13
b. System Failure	6	5
G. Number of 8 hour Shifts	479	386

Table 2

BREAZEALE NUCLEAR REACTOR UTILIZATION DATA
(average per shift)

June 1, 1972 - May 31, 1974

	<u>1972-1973</u>	<u>1973-1974</u>
A. Number of Users	1.74	1.98
B. Samples or Experiments		
1. Number	4.53	10.34
2. Sample Hours	6.73	41.79
C. Reactor Usage (hours)		
1. Operating	2.81	3.75
2. Shutdown in Stand-by Condition	1.06	1.10
3. Reactor Operator Training	.88	1.09
4. Calibration and Maintenance	.43	.72

laboratory experiments, and approximately 50 hours for high school science class tours with demonstration type experiments. This education and training utilization is more fully explained in Section V of this report. Once again, the Facility provided formal tours to over 2,300 visitors during the year and again, most of these tours occurred during the busy Spring term.

In response to new requirements from the Atomic Energy Commission, another 50 hours of reactor time was set aside for staff retraining. The reactor was not operated during this time to allow for full attendance. Much of this time was used to familiarize the staff with recent facility changes.

During late December and early January, the annual fuel inspection and subsequent calibrations consumed 8 days of operation.

A week was set aside at the end of the Spring term for low power or subcritical experiments utilizing the reactor with the Cf 252 source instead of the normal source.

The pneumatic transfer system conversion to a closed cycle CO₂ gas operation was completed early in January. This conversion was made in an effort to reduce normally small amounts of Argon-41 released from the pneumatic transfer system to practically zero. Since January, over 500 sample irradiations were performed using the closed cycle system with essentially no release of radioactive gases.

Improvements to the waste water handling system were also completed during the past year. These improvements allow for greater efficiency in converting our radioactive liquid waste into makeup water for our pools and concentrated low level radioactive solids,

a form more easily handled for disposal. As a result of this work, the quantity of radioactive liquid effluents from the Facility has been reduced to essentially zero.

The Cobalt Facility statistics shown in Table 3 reflect an increase in utilization of available time for sample exposure when compared to the previous year. This occurred in spite of a marked decrease in the number of samples exposed and a slight decrease in the number of experimenters utilizing the facility. The increase in utilization of available time resulted from a general increase in the length of most exposures, rather than from a few longer term exposures.

One other area of the table showing a decrease is that labeled set-up time. This is time spent by the staff preparing samples for exposure and has decreased due to the fewer number of samples exposed.

The increases in the areas labeled total number of configuration changes and time adjusting Co-60 sources resulted mainly because of the needs of one experimenter who needed a much wider variation of exposure rates than generally obtainable from the four standard configurations.

Table 3
Cobalt-60 Operating Statistics
June 1, 1972 - May 31, 1974

	<u>1972-1973</u>	<u>1973-1974</u>
A. 1. Time adjusting Co-60 sources (hrs.)	4	10
2. Set-up Time	19	14
3. Total hours of sample runs	3,577	15,112
B. 1. Total number of samples	385	249
2. Total number of configuration changes	10	37
3. Total number of different experimenters	34	29
C. Per Day Averages		
1. Number of experimenters/day	.66	1.4
2. Number of samples/day	1.70	5.3
3. Hours of use/day/configuration	2.44	10.4
D. 1. Total Sample Hours	6,168 hrs.	42,854

Remarks:

1972-1973 statistics are based on 366 days and 4 configurations

1973-1974 statistics are based on 365 days and 4 configurations

Three A.E.C.L. sources moved to Hot Cell Number 1 in February 1971 for use by microbiology students are still in use. Seven runs were made during the past year for three different experimenters. This usage is not reflected above.

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V. EDUCATION AND TRAINING

A major program has been added this year to the long list of continuing training efforts conducted at the Breazeale Reactor. As of December 15, 1973, a requalification program for all licensed operating personnel was initiated. The requalification program consists of facility walkarounds, conducted by Mr. McMaster; procedure familiarization, handled by Mr. Totenbier; and classroom review of all topics suggested in Appendix A of 10 CFR Part 55, to be done by Mr. Flinchbaugh and Mr. Penkala. The program will then culminate in an A.E.C. type licensing examination in the fall of 1974 for all licensed operating personnel.

The most significant development in addition to the aforementioned requalification program has been the continued expansion of the undergraduate programs at the two year (technician) and the four year (bachelor) level in Nuclear Engineering. Along with this continued growth comes an ever increasing utilization of the training facilities and the staff operations personnel.

Through continued staff cooperation, the Breazeale Reactor and its laboratory facilities were made available to large numbers of undergraduate and graduate students in nuclear engineering course work.

The final term for nineteen candidates for associate degrees in Nuclear Engineering Technology was given at University Park with Breazeale Reactor staff members becoming involved as follows:

Nuc. E. 812, Nuclear Technology Laboratory, was taught by Mr. G. C. Geisler with assistance from Mr. R. C. Houtz and Mr. J. K. Schmotzer.

Former A.E.C. trainee Mr. M. J. Cenko taught the Nuc. E. 803 course, Elements of Nuclear Power Generation Reactor Technology Laboratory with assistance from Professor W. F. Witzig. Nuc. E. 814 was taught by Mr. J. L. Penkala with extensive assistance from Mr. T. L. Flinchbaugh. Mr. Penkala also acted as faculty advisor for the associate degree students.

It should be noted that as an integral part of the Nuc. E. 814 course, the special cooperation of senior reactor operators I. B. McMaster, R. E. Totenbier, D. C. Raupach, J. H. O'Brien, and R. C. Houtz made it possible for the nineteen associate degree candidates to accumulate a combined total of 256 man hours of reactor operations experience at the instrumentation and controls of the Breazeale Nuclear Reactor console.

The faculty and staff continued to be involved in the baccalaureate program with support given to Nuc. E. 200, 440, 441 and 430. Mr. R. C. Houtz assisted Dr. Diethorn in the Nuc. E. 200 laboratory. Mr. D. C. Raupach supported Dr. Kenney in the Nuc. E. 440 course while Mr. G. C. Geisler shared the Nuc. E. 441 responsibilities with Professor Schultz.

A most useful learning experience resulted for the seniors in Nuc. E. 430 and Nuc. E. 431 when they were given the opportunity to manipulate the controls of the Breazeale Reactor through a complete start-up and subsequent shutdown. This exercise was supervised by the staff senior operators.

The graduate program in Nuclear Engineering utilized the Reactor R Facility for the Nuc. E. 502 series of reactor laboratory courses.

During the fall, winter, and spring terms, Mr. D. C. Raupach rendered extensive assistance to Dr. Jester, Dr. Levine and Dr. Kenney who taught Nuc. E. 502A, 502B and 502C, respectively.

In all of the graduate and undergraduate courses which use the facilities here at the Breazeale Reactor, it has become standard procedure to seek the assistance of Mr. Douglas Vonada, staff electronic designer, in solving the multitude of electrical and electronics problems which arise throughout the academic year.

The A.E.C. Traineeship Program in Nuclear Engineering continued successfully during the past reporting period with the graduation of Messrs. J. A. Blakeslee, J. A. Easley, J. N. Neyman, J. W. Rodell and G. J. Sagliocca who all received Master of Science degrees in Nuclear Engineering. Upon graduation Mr. Easley accepted employment with General Public Utilities of Parsippany, New Jersey while Mr. Sagliocca and Mr. Rodell were employed by the Niagara Mohawk Power Corporation of Syracuse, New York. Mr. Blakeslee returned to the Pennsylvania Power and Light Company of Allentown, Pa. while Mr. Neyman joined Bechtel Corporation of San Francisco, California.

Further success in the Traineeship Program was encountered as first year trainees R. H. Arnold, J. R. Bailey, G. W. Houston and J. D. Seebald passed the A.E.C. reactor operator's licensing examination for the Breazeale Reactor and are now being used routinely in reactor operations.

The in-house Reactor Operator Training Program conducted by the staff of the Breazeale Reactor resulted in Mr. James A. Martin, an undergraduate student in Nuclear Engineering qualifying for an A.E.C.

operators license and Mr. Martin is also being used routinely in reactor operations.

For the fourth consecutive year, a four week institute in Nuclear Concepts was offered at the Breazeale Reactor for twenty-four Pennsylvania high school teachers. Members of the staff who made the program possible during August 1973 were Dr. W. A. Jester, Mr. T. L. Flinchbaugh, Mr. J. L. Penkala and graduate student David Tilley.

As in the past, the Pennsylvania secondary school teachers who participated in the Nuclear Concepts program were encouraged to return to the Breazeale Reactor with their students for a one day field trip. This resulted in 26 high school groups totaling 305 students visiting the Reactor for a day of experimentation with the Triga reactor, the neutron howitzer, the Cobalt-60 facility and the hot cells.

Mr. T. L. Flinchbaugh and Mr. J. L. Penkala handled the logistics involved with the high school groups visiting the reactor during the Fall term. At the same time A.E.C. trainees Jim Bailey and Bob Arnold were instructed in the means of scheduling the tours and conducting the experiments. Consequently, during the Winter and Spring terms Mr. Bailey and Mr. Arnold were responsible for the scheduling and experiments done by the visiting high school groups.

A special three week course in Basic Nuclear Technology was offered to a group of eight nonnuclear engineers from the Metropolitan Edison Company this past Spring term. Lectures were conducted twice a day by reactor staff members, G. C. Geisler,

T. L. Flinchbaugh, G. E. Robinson, and J. L. Penkala of the reactor staff and special lecturers F. J. Remick and E. S. Kenney of the Nuclear Engineering Department and R. W. Granlund of Health Physics, covering topics from basic nuclear physics through heat transfer. Senior reactor operators R. E. Totenbier, I. B. McMaster, D. C. Raupach, J. H. O'Brien and R. C. Houtz supervised each of the Met-Ed engineers through a minimum of four reactor start-ups and shutdowns during the special three week course.

Radioactive isotopes and four 2 hour reactor operation demonstrations were provided for fifty students in Dr. Miller's radiochemistry course, Chem. 405.

A group of students used the hot cell facilities to irradiate mice in a microbiology class, Immunology 410.

High school students from Bellefonte, Harrisburg, State College, Kane and Wyomissing, Pa. utilized the Cobalt-60 facility to irradiate various materials for a number of individual and class projects.

A study was conducted for Material Science 597, using the Cobalt-60 facility to determine the feasibility of using gamma irradiation for sterilizing materials used in biomedical applications.

And finally, to continue the policy of using the Breazeale Reactor Facility to provide information to any interested group, 2,324 visitors in organized groups were toured through the facilities.

Table 4

PARTICIPANTS IN REACTOR TRAINING PROGRAMS

<u>Name</u>	<u>Sponsor</u>	<u>Program</u>	<u>Started</u>	<u>Completed</u>
*R. H. Arnold	U.S.A.E.C.	Reactor Operator	September 1973	March 1974
*J. R. Bailey	U.S.A.E.C.	Reactor Operator	September 1973	March 1974
*G. W. Houston	U.S.A.E.C.	Reactor Operator	September 1973	March 1974
*J. W. Martin	Nuclear Reactor	Reactor Operator	September 1973	March 1974
*J. D. Seebald	U.S.A.E.C.	Reactor Operator	September 1973	March 1974
R. Benschel	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
J. Janiszewski	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
A. Karplus	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
G. A. Kunder	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
C. Randolph	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
E. Sheets	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
D. Trout	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
N. Williams	Metropolitan Edison	Research Reactor Operations	18 March 1974	5 April 1974
T. M. Beatty	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
A. D. Coveleskie	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
J. A. Damiano	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
R. E. Fischer	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
F. R. Flanegin	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
T. D. Folk	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
J. R. Gallik	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974

Table 4 (Continued)

<u>Name</u>	<u>Sponsor</u>	<u>Program</u>	<u>Started</u>	<u>Completed</u>
P. A. Hanchar	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
P. D. Hawk	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
E. F. Horne	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
D. C. Householder	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
K. C. Jones	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
S. A. Krupa	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
D. B. Mayhue	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
H. D. Milliron	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
M. C. Pudelski	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
G. C. Rodgers	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
D. G. Ward	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974
C. O. Weicht	Penn State University	Nuclear Engineering Technology	15 March 1974	22 May 1974

Table 5

HIGH SCHOOL NUCLEAR SCIENCE PROGRAM 1973-74

<u>High School</u>	<u>Instructor</u>	<u>No. of Students</u>
Pittsburgh Explorer Scouts	Mr. Howard	20
Wyomissing	Mr. Bell	8
Penn Hills	Ms. Szitas	6
Ligonier Valley	Mr. Mannion	12
Altoona	Mr. Beach	12
Sullivan County	Mr. DeWire	11
Daniel Boone	Mr. Tobias	17
Jersey Shore	Mr. Allen	12
Ridgway Area	Mr. Koos	9
Lebanon	Mr. McGinty	8
Northeast Bradford	Mr. W. S. Davis	6
Parkland	Mr. Eckensberger	4
Berwick	Mr. Foster	27
Upper Saint Clair	Mr. Greenway	25
Southern Fulton	Ms. Anderson	8
Riverside	Mr. Modzelesky	8
Penncrest	Dr. Good	17
Hollidaysburg	Mr. Rhodes	15
Dunmore	Mr. Gatto	5
North Schuylkill	Mr. Welker	5
Bishop O'Reilly	Sr. Hildegard	4
Smethport Area	Mr. Fetter	9
Pottsville	Mr. Naradko	4
Thomas Jefferson	Mr. Farrell	25
Harbor Creek	Mr. Peterson	11
Carlisle	Mr. Kauffman	15

TOTALS 26 groups, 305 participants

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VI. RADIONUCLEAR APPLICATIONS LABORATORY

This has been an extremely active and productive year for the personnel of the Radionuclear Applications Group, especially in the area of sponsored research. In addition, a continual growth in the capabilities of the laboratory has occurred.

In 1973, Miss Anne Hart joined the group as Engineering Aide, working primarily with the radionuclear forensic program under the direction of Dr. K. K. S. Pillay. In September of 1973, Dr. K. N. Prasad joined the group to supervise the renewed activities of the PSEF sponsored Nuclear Biomedical Research Program.

One of the highlights of the year from the Radionuclear Forensic Program was the adoption of the "Film-Lift" procedure by the Pennsylvania State Police for the detection of gunshot residues on human hands. This technique was developed at the Radionuclear Applications Laboratory and utilizes a cellulose acetate film to collect minute amounts of the residue from the skin for subsequent neutron activation analysis at the Breazeale Nuclear Reactor. During the Winter of 1974, Mr. Harry Fox III, a criminalist from the State Police Crime Laboratory, received three months extensive training in film lift analysis. This was followed by a two day training program in March 1974 for state law enforcement agency personnel to familiarize them with the technique and especially the procedures of using the film lift material in collecting samples from suspects and from victims of suicides involving firearms. As a result of these activities, the film-lift is now being used throughout the state.

Under the nuclear biomedical program, the most important accomplishment was the successful development of production and delivery procedures which have been accomplished for krypton-85m, which in animal tests appears to be a superior lung scanning agent compared to those currently being used in nuclear medicine. It is hoped that this radioisotope can be used in improving the diagnosis of lung disorders.

The hydrology project was brought to a successful conclusion during this year with the identification of two additional nonradioactive but neutron activatable tracers for tracing the movement of underground waters. The two were the iodide and the chloride ions. These, along with the previously identified bromide ion tracer, now provide hydrologists with three tracers which can be used simultaneously in underground water flow studies. A manual is being written describing the use of these tracers and will soon be published by the University's Institute for Research in Land and Water Resources.

A highlight of the fenceline monitoring project was the completion and successful field testing of the gas compression fenceline monitor at the Oyster Creek Nuclear Generating Station at Forked River, New Jersey. This system compresses atmospheric air to a pressure of 1500 psig around a NaI(Tl) spectroscopy detector. The background spectrum taken before compression is then subtracted leaving only the gas activity present in a previously calibrated geometry.

Dr. Levine has about completed the design for an optimum subcritical reactor irradiator using californium-252 neutron sources. These irradiators show future promise as being low cost irradiators which can be used in place of higher cost research reactors. Such irradiators would be especially useful in medical and crime laboratories.

Of the service activities of the laboratory, one of the most interesting was using gamma ray fingerprinting to provide the clues which enabled Professor John Cook of the Art Department to discover the original reproductive organs of a plaster statue entitled, "The Hewer," which he was reconditioning for placement in the University's new auditorium. It seems that many years ago that portion of the statue was plastered over. The gamma-ray fingerprinting showed that the plaster from the suspect region had a different trace element composition and thus a different origin than the plaster in the rest of the statue.

A growing area of service to the University seems to be occurring in requests for the use of radiation detection equipment in projects not utilizing the irradiation facilities of the Reactor. This is especially seen in the extensive use of the wide beta system by personnel of the biology department to determine ^{90}Y extracted from biological samples and the extensive use of the TMC 400 channel pulse height analyzer by personnel of the Poultry Science Department.

As a result of the many activities at the laboratory, there developed a shortage of available analyzer time on the two pulse height analyzer systems, i.e., the Nuclear Data Model 2200 and 4410

systems connected to the laboratories two high resolution Ge(Li) gamma ray detectors. Even the older TMC analyzer was in heavy demand. Thus, thanks to funds obtained from the Dean of the College of Engineering, a new pulse height analyzer (Northern Scientific Econ II with 2048 channels of memory) with a large (~50 cc) high resolution Ge(Li) detector was obtained to help alleviate this problem. This system is being set up in a new counting room being established in Room 103 of the Accelerator Building.

The Accelerator Building is adjacent to the Nuclear Reactor Facility and a number of rooms have been allotted because of overcrowding at the Reactor Facility. Plans are now underway for the establishment of a radiochemistry laboratory in Room 114 of the Accelerator Building to provide much needed space for the Radionuclear Applications Group.

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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 Auxiliary Radiation Sources such as 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. Fifty-four faculty members and fifty-one graduate students have used the Facility in the past year for research. This represents a usage by sixteen 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 utilization 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. Thermal Neutron Field Scattered by Simple Objects

Dr. A. M. Jacobs, Dr. E. S. Kenney and Graduate Student
C. A. Johannesmeyer of the Nuclear Engineering Department

In support of the development of the pseudo-hologram technique of neutron radiographic imaging, analytical methods of predicting thermal neutron scatter fields are being studied. The results are then tested relative to actual experiment configurations.

2. Reactor Power Imaging by Pseudo-Holographic Techniques

Dr. A. M. Jacobs, Dr. E. S. Kenney and Graduate Assistant
P. L. Rensen of the Nuclear Engineering Department

High-energy gamma rays (say greater than 8 Mev) and high-energy neutrons (greater than 1 Mev) represent carriers of fission distribution information in a nuclear reactor. This information must be translated into a pattern of reactor power distribution. The technique of pseudo-holographic imaging using coded apertures is being considered as a method of obtaining three-dimensional power distribution. The coded aperture must function as a translator of high-energy gammas or neutrons into suitable image producers such as ions or optical photons.

3. Pseudo-Holography Using Neutrons

Dr. A. M. Jacobs, Dr. E. S. Kenney and Graduate Assistant
P. J. Rose of the Nuclear Engineering Department

The concept of employing coded apertures to produce pseudo-holograms from radiation scattered by the intervals of optically opaque objects is being extended in this work to the use of thermal neutrons. The extremely high absorptive interaction rate with certain materials makes possible coded apertures of attractive resolution capabilities (Ca, a few thousandths of an inch). Three-dimensional radiography of hydrogenous material in metallic housing is one obvious application.

4. A Study of the Fast Neutron Spectrum Emanating from Selected Delayed Neutron Precursors

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

A chemical separation system has been set up to select bromine isotopes emanating from a neutron irradiated U-235 solution. This selection of Br which is a well known delayed neutron precursor

allows the study of the fast neutron spectrum of this element alone. The system is operational with delayed neutrons measured as to quantity and half life. Neutron spectrometry is proceeding using a fast neutron recoil proton proportional counter as the detector.

5. Perturbation Theory in TRIGA Core Management

Dr. S. H. Levine and AEC Trainee J. A. Easley of the Nuclear Engineering Department

A computer code, CORRUPT, using perturbation theory has been written for studying small changes of reactivity in the PSBR TRIGA core. The code has been used to compute reactivity worth curves for U-235 depletion and for fission product buildup in TRIGA fuel. Similar worth curves are utilized in the TRIGA Core Fuel Management Program, TRICOM, developed by Naughton, et al.; however, the worth curves provided by CORRUPT are an improvement over those originally developed. The new curves were substituted into TRICOM and TRIGA reactivities compared as computed with the different sets of curves and that measured experimentally. Although both sets of curves follow the measured core reactivities, the new curves provide a slightly improved comparison. The accuracy of the code was also verified by comparing the measured worth of a boron sample in the center of the core with that calculated by CORRUPT. CORRUPT calculated a reactivity worth of 15.66ϕ for the sample and measurement indicated a worth of $16.1\phi \pm 1\phi$.

6. Source Multiplication Studies Using a ^{252}Cf Neutron Source

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

A subcritical assembly has the ability to increase or multiply the number of neutrons emitted by a neutron source. The well-known subcritical multiplication, $M = 1/(1 - k_{\text{eff}})$, is an integral effect which does not indicate the spatial neutron multiplication and is only valid as the reactor nears critical. Actually, to study the subcritical multiplication of the source strength as well as the resultant neutron flux enhancement at certain positions in the subcritical assembly, an account must be made of the depletion of the fissile material, geometry of the assembly, multiplication factor of the system, and the energy and spatial distribution of the neutron source. An analytical program was performed to better understand this neutron multiplying process. Experiments using the ^{252}Cf neutron source in the TRIGA reactor were carried out to verify the analytical program. Absolute thermal flux were measured at different degrees of subcritical reactivity by activating bare and cadmium covered gold foils. Fast adjoint flux was also measured by moving the ^{252}Cf source in different positions of the subcritical core.

7. Fast Cross Section Measurement by Unfolding

Dr. S. H. Levine and Graduate Student J. K. Schmotzer of the Nuclear Engineering Department

The fast neutron spectrum in the PSBR is approximately defined by multi-group integral fluxes furnished by General Atomic. An activation method is being developed which will allow measurement of the shape and magnitude of the fast flux, $\phi(E)$, in and near the core.

By measuring the activity of a material activated with fast neutrons one obtains a numerical value for the expression

$$\alpha_i = \int_0^{\infty} \sigma_i(E) \phi(E) dE$$

where the subscript i refers to a particular reaction. If this is done for several different reactions whose cross section, $\sigma_i(E)$, are well known, then numerical methods known as unfolding may be used to obtain $\phi(E)$. A major portion of this project has been devoted to the development of an unfolding method which is superior to others described in the literature.

If the fast neutron spectra measured in different locations are sufficiently unique, then the expression for α_i may be written as

$$\alpha_i = \int_0^{\infty} \sigma_i(E) \phi_i(E) dE$$

where now various neutron spectra, $\phi_i(E)$, are known and it is the cross section, $\sigma(E)$, which is to be measured. The second part of this project will involve the unfolding of one or more unknown cross sections.

8. Fast Reactor Spectrum Assembly (FRSA)

Dr. S. H. Levine, Dr. W. F. Witzig, AEC Trainee L. A. Pasquini, Graduate Student D. J. Florek, Graduate Assistant S. S. A. Diab, AEC Trainee J. G. Seebald, AEC Trainee G. W. Houston and Graduate Assistant F. A. Wolfe of the Nuclear Engineering Department

This project involves the construction of an assembly to produce fast neutron spectra to that in the LMFBR using Pathfinder fuel, steel, and graphite. The assembly has been constructed; however, further safety analyses regarding structural integrity under dynamic loads is required. A fission disc has been designed to provide the incident fast flux on the assembly. A method for

"cladding" enriched foils is being devised to provide increased containment of fission products.

The fission disc will contain a stack of 94% enriched uranium metal foils. These foils will be hermetically sealed twice in a special container constructed from brass discs. Analyses of the fission products, temperatures, pressures, source strength and dose rates produced by the disc while it is being irradiated by thermal neutrons from the reactor has been calculated. Methods for measuring the fast spectrum are being studied.

9. Decay of ^{178}Hf

Dr. W. W. Pratt of the Physics Department

The electron capture decay of ^{175}Hf is known to populate at least three excited states in ^{175}Lu . There is not general agreement, however, concerning the spectrum of the deexcitation gamma rays. The gamma spectrum of ^{175}Hf is being measured here with special attention to the elimination of effects due to the competing activity of ^{181}Hf .

10. Decay of Long Lived Alpha Emitters

Dr. W. W. Pratt of the Physics Department

Among the heavy elements ($A > 200$) occurring in nature, it is well known that many are unstable with respect to alpha particle decay and appear to be stable only because of an extremely long half-life. Alpha decay has been observed in isotopes with half-lives up to 2×10^{15} years, and in one case 1.4×10^{17} years. In this region, however, the specific activity (disintegrations/second-gram) becomes so low as to render observation extremely difficult. It is for this reason that the radioactive decay of many of the heavy alpha emitters has not been observed to date. One example of particular interest is that of the heaviest known "stable" isotope, ^{209}Bi . The energy which would be released in the alpha decay of ^{209}Bi can be calculated from atomic mass data to be approximately 3 MeV and there is therefore no doubt that this isotope is radioactive. It would be of considerable interest to observe the decay of ^{209}Bi and to determine its half life. There are other similar cases in the region of the heavy elements which would similarly be of interest. A study is in progress in which the nuclear emulsion technique is used to search for alpha decay from long lived heavy isotopes.

11. Electric Monopole Transitions in ^{90}Zr

Dr. W. W. Pratt of the Physics Department

The decay of ^{90}Y is of particular interest since it results in the population of the first excited state of ^{90}Zr under conditions which are especially favorable for observing the 0^+-0^+ transition to the ^{90}Zr ground state. This transition has been studied by several workers with results which barely agree within the experimental errors of 15-25%. Greenberg and Deutsch have measured the positron and negatron spectra in a magnetic spectrometer and found a ratio of pair emission to beta emission $I(\pi)/I(\beta^-) = (3.6 \pm 0.9) \times 10^{-5}$. Yuasa has performed measurements with similar instrumentation, observing conversion electrons as well as positrons and negatrons, with the results: $I(\pi)/I(\beta^-) = (5.4 \pm 0.8) \times 10^{-5}$ and $I(\text{ce})/I(\beta^-) = (1.6 \pm 0.3) \times 10^{-4}$. Nessin et al. have observed the same transition by populating the ^{90}Zr state through inelastic proton scattering, using a magnetic spectrometer to measure the electron spectra. Their results give $I(\text{ce})/I(\pi) = 2.38 \pm 0.08$, to be compared with $1.6 \times 10^{-4}/5.4 \times 10^{-5} = 2.97 \pm 0.7$ obtained by Yuasa. In view of the extreme paucity of experimental data relating to electric monopole transitions, an attempt is in progress here to improve on the accuracy with which the intensities of the different deexcitation modes are known. Both the ce/β^- ratios and the π/β^- ratios are being measured using $^{90}\text{Sr} - ^{90}\text{Y}$ equilibrium sources. Conversion electrons are measured using a cooled $\text{Si}(\text{Li})$ detector with an x-ray gating requirement to reduce the continuum background. Pairs are observed by measuring coincidences between annihilation photons. It is hoped that experimental errors can be reduced to the point where a significant improvement in accuracy in both the ce/β^- and π/β^- ratios will result.

12. Energy Levels in ^{95}Nb

Dr. W. W. Pratt of the Physics Department

The low lying states of ^{95}Nb have been studied in the beta decay of $^{95}\text{Zr}^{4-6}$, the reaction $^{94}\text{Zr}(^3\text{He}, \text{d})^7$, and the reaction $^{96}\text{Mo}(\text{d}, ^3\text{He})^8$. Although the results of these measurements are in agreement regarding the ground state and the first excited state, there are discrepancies in the spins and parities assigned to the levels lying immediately above these. The beta decay measurements indicate states at 724 and 757 keV, both with $j^\pi = 7/2^+$; the $(\text{d}, ^3\text{He})$ measurements indicate one state at 770 keV with $j^\pi = 3/2^-$; while the $(^3\text{He}, \text{d})$ measurements give states at 728 keV ($j^\pi = 3/2^+$ or $5/2^+$) and at 799 keV ($j^\pi = 1/2^-$ or $3/2^-$). It is clearly of interest to determine whether there are only two states in this energy region, with spins and parities improperly assigned in either the beta decay or reaction experiments; or whether the apparent discrepancy is the result of closely spaced doublets with only one member being observed in each experiment. The latter possibility is being investigated in a study of the ^{95}Zr gamma ray

spectrum. High resolution Ge(Li) and Si(Li) detectors are used to search for weak transitions associated with the $(1/2, 3/2)^-$ and $(3/2, 5/2)^+$ states in ^{95}Nb which have not heretofore been observed in the decay of ^{95}Zr .

13. Gamma Ray Spectrum of $^{115\text{m}}\text{Cd}$

Dr. W. W. Pratt of the Physics Department

A recent study in another laboratory of the gamma ray spectrum of $^{115\text{m}}\text{Cd}$ has indicated 8 previously unreported transitions between levels in ^{115}Zn . A study is in progress here in which the gamma spectrum of $^{115\text{m}}\text{Cd}$ is being measured with a 40 cm³ Ge(Li) detector to determine whether or not the new transitions can be confirmed. The results of these measurements should serve to clarify the energy level structure of ^{115}Zn .

14. Gamma Ray Spectrum of ^{85}Sr

Dr. W. W. Pratt of the Physics Department

The electron capture decay of ^{85}Sr is known to lead predominantly to an excited state in ^{85}Rb with the subsequent emission of a 514 keV gamma ray. Several other accessible states in ^{85}Rb are known and there is conflicting evidence concerning their population in the decay of ^{85}Sr . A measurement of the gamma ray spectrum of ^{85}Sr is in progress in an attempt to resolve existing discrepancies in the electron capture branching ratios.

15. Radioactive Decay of $^{110\text{m}}\text{Ag}$

Dr. W. W. Pratt of the Physics Department

A recent study in another laboratory of the reaction $^{109}\text{Ag} (^3\text{He}, d)^{110}\text{Cd}$ has resulted in the observation of several new levels in ^{110}Cd and has led to the proposal of a revised energy level diagram for this isotope. A study of the decay of $^{110\text{m}}\text{Ag}$ recently carried out here is, in general, in excellent agreement with these results. Samples of high purity Ag metal were exposed to thermal reactions to produce $^{110\text{m}}\text{Ag}$. The gamma ray spectra were studied with a 40 cm³ Ge(Li) detector. Eleven gamma ray transitions, not previously established with certainty, were found; all of which support the recently proposed levels in ^{110}Cd .

16. A Study of Short Lived Isotopes Using a Pulsed Neutron Beam

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

Measurements are in progress in which a pulsed neutron beam is extracted from the reactor core and used to produce short lived activities in a target located within the beam. Current work is directed at optimizing the beam geometry and shielding to obtain a suitable signal to background ratio. The first application of this technique will be in a study of ^{24m}Na . This isomer has a 20 ms half life, a spin and parity of 1^+ and an excitation energy of 473 keV. It is produced by neutron capture in ^{23}Na . It decays primarily to the ^{24}Na ground state with the emission of a 473 keV gamma ray, although some evidence has been found for a weak beta ray transition to the ^{24}Mg ground state. The aim of the present work is to search for deexcitation gamma rays associated with beta decay to some of the excited states of ^{24}Mg . There are two such states known which are energetically accessible via allowed transition.

17. Thermal Neutron Induced Ternary Fission of Uranium-235

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

Ternary fission induced in ^{235}U by thermal neutrons has been studied with the aim of measuring the yields, energies and angular distributions of light nuclei with charge number greater than two. Uranium target nuclei were imbedded in small holes in the surface of a dielectric track detector. Measurements of the range, track etching rate and direction of emission of the light particles were used to identify the particles and to determine their yields, energies and angular distributions.

Thirteen events were observed which were interpreted as ternary fission. The total yield was found to be $(10 \pm 2) \times 10^{-5}$ per binary fission for particles in the mass range 9 - 32 amu. The kinetic energies of these particles ranged from 3.7 MeV to 16.8 MeV. The direction of emission of the light particles was found to be nonisotropic.

18. Na/K Ratios in Fluid Inclusions in Auriferous Quartz
Determined by Neutron Activation

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

The Na/K atomic ratios were determined for the fluid inclusions in fourteen quartz samples by neutron activation analysis. The quartz samples were taken from three gold-bearing veins in the O'Brien Mine in northwestern Quebec. The spatial locations and the ore grade at these locations were known for the analyzed samples. Measurement of ^{24}Na and ^{42}K activities was used to calculate the Na/K ratios. These samples were irradiated in the PSBR for 60 minutes at a neutron flux of $1.1 \times 10^{13} \text{ n cm}^{-2} \text{ sec}^{-1}$. A total of thirty-four irradiations were made. Hydrated antimony pentoxide (HAP) was used to selectively remove ^{24}Na in order to improve the analysis of ^{42}K . The Na/K atomic ratios for the fluid inclusions ranged from 0.87 ± 0.08 to 24.3 ± 4.1 . A vertical section of the samples from one of the veins showed a general increase in the Na/K ratios in the fluid inclusions with respect to depth with values ranging from 4.93 ± 0.52 at the 625 foot level to a value of 17.0 ± 3.8 at the 3,450 foot level. The Na/K ratios seemingly are a function of the sample location, the sample mineralization, and the filling temperature of the fluid inclusions in the quartz.

B. University Research Projects Utilizing the Radionuclear Applications Laboratory

1. 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.

Samples are being 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.

2. Partitioning of Several Rare-Earth Elements between an Aqueous Fluid and a Silicate Melt

Dr. C. W. Burnham and Research Assistant R. T. Flynn of the Geosciences Department

It is hypothesized that the partitioning of the rare earth elements will be a function of silicate liquid composition as well as fluid phase composition. This study is aimed at quantifying these effects and consequently furthering the understanding of rare earth distribution patterns in rocks. The partitioning of the particular rare-earth elements is examined via neutron activation analysis after reaction within an internally heated pressure vessel. The apparatus allows external control of pressure, temperature and hydrogen fugacity. Radioactive solutions of known concentrations are obtained from the PSBR and employed as part or all of the experimental fluid phase. Neutron activation analysis combined with autoradiography allows the experimenter to obtain a total rare-earth concentration and a qualitative idea of any concentration gradients within the sample.

Currently, experiments are in progress employing isotopes of La and Sm and synthetic silicate mixtures.

3. Gamma Ray Fingerprinting of Plaster Samples taken from a Sculpture Entitled "The Hewer"

Professor J. A. Cook of the Art Department, Dr. W. A. Jester, Graduate Assistant T. J. Donlan and Graduate Assistant P. L. Rensen of the Nuclear Engineering Department and University Health Physicist R. W. Granlund

A plaster statue entitled, "The Hewer," was being reconditioned for placement in the University's new auditorium. A portion of the statue was believed not to be part of the original statue. Using a portable x-ray machine, radiograph of the suspect portion of the statue was performed. The results were inconclusive. Plaster samples from the suspect area and portions believed to be part of the original sculpture were then taken for comparison by gamma ray fingerprinting. The samples were irradiated in the Breazeale Nuclear Reactor and the samples analyzed for their relative content of manganese, magnesium, vanadium, aluminum, calcium, sodium, and chlorine. The results showed that the samples taken from the suspect areas were considerably different than those taken from other areas of the statue. With this information, the suspect plaster was chipped away and the reproductive organs of the statue in their original form as created by the sculptor more than 70 years ago was found.

4. An Investigation of the Sulfur Contents in Asphalts and Asphaltenes

Dr. W. H. Gotolski and Graduate Assistant C. A. Ciesielski of the Civil Engineering Department and Dr. W. A. Jester of the Nuclear Engineering Department

During recent years much research has been performed in the asphalt field to determine the factors necessary to evaluate or predict the durability of an asphalt roadway. It is thought that deterioration occurs due to the hardening or increasing brittleness which generally accompanies the in-service life of an asphalt pavement. Hardening of an asphaltic pavement is confined to the asphalt cement. Any investigation of the hardening of an asphalt mix should concentrate on the changing properties of the asphalt cement. Some researchers have used chemical and physical tests to check asphalt hardening. In this study the object was to investigate the role of sulfur in asphalts and their asphaltenes. Three different asphalts were studied and aged artificially in a 140 F oven. Hardening measurements were made using viscosity and penetration measurements at times ranging from 0 to 112 days. The Modified Rostler chemical analysis method was used to determine asphaltenes.

A total of 216 specimens were irradiated and counted; six for each of the three asphalts and asphaltenes at the six testing periods.

A total of 72 sulfur standards were irradiated and counted; twelve for each of the six testing periods. Nuclear activation analysis was the method used to identify sulfur contents in the asphalts and asphaltenes. The ratio of the sulfur content in asphaltenes to the sulfur content in the asphalt was determined throughout the study. This ratio appeared to increase from time zero to about 14 days and seemed to level off. A similarity between this ratio and asphaltene content was noted.

This approach to evaluate trace elements in asphalts and asphaltenes and relationship to hardening shows promise.

5. Radiation Effects on SO_2 in Stack Gas Effluents

Dr. W. A. Jester, Dr. K.K.S. Pillay, Professor M. A. Schultz and Graduate Assistant R. H. Klinetob of the Nuclear Engineering Department

Work at PSU has indicated the possibility of removing SO_2 from stack gas by the use of ionizing radiation and electrostatic collection. This project attempts to establish the process for that removal by investigating the effect of various gaseous components, O_2 , H_2O , NO , N_2 , N_2O , C_xH_x , separately and in combination, on SO_2 in the presence of Co^{60} gamma rays. The Cobalt 60 Facility is being utilized as the source of radiation. The literature indicates that SO_2 reacts quickly with C_xH_x and NO_2 in the presence of γ -rays to form a sulfuric acid aerosol. This reaction will form a white powder if pushed to completion. This will require over 10^{10} R. The project currently has shown a 10% decomposition of pure SO_2 exposed to a dose of 10^8 R and a linear dose dependence. The reactions with mixtures is currently being investigated.

6. Evaluation of Silver Zeolite for the Collection and Detection of Radioactive Iodine from the Atmosphere

Dr. W. A. Jester, Dr. K. N. Prasad and Graduate Assistant V. R. Burke of the Nuclear Engineering Department

One of the major concerns of the AEC is the emission of radioactive iodines from nuclear power plants. Such iodine can readily enter the food chain including milk where it can expose the population, especially young children to thyroid doses. Because of this problem, the AEC in its "low as practicable" concept has set emission limits to such a low level that there currently exists no good method of detecting this minimum level in the environment. The object of this effort is to investigate the use of an iodine absorbing material, called silver zeolite as a basis for an air sampler which can concentrate the small amount of radioactive iodine out of a large volume of air for subsequent monitoring. The PSBR was used to produce ^{128}I for uses in the initial testing of this material.

7. Development of Neutron Activation Analysis and X-Ray Fluorescence Techniques for the Trace Element Analysis of Amniotic Fluid

Dr. W. A. Jester, Dr. K. N. Prasad, Graduate Assistant
T. J. Donlan and Graduate Assistant P. L. Rensen of the
Nuclear Engineering Department

The trace element analysis of amniotic fluid was undertaken after compliance with all the regulations that apply towards research involving human subjects. It was found that a purely instrumental technique using an x-ray detector (lithium drifted silicon) was not feasible with the equipment available. Therefore, other means had to be found for the analysis of prime interest which is copper in amniotic fluid. Sensitivity data from the literature indicates that x-ray fluorescence should be capable of utilization for this purpose. The analysis for long lived elements is being pursued through the expedient of allowing the high sodium activity that exists initially, to decay away.

8. Development of ^{85m}Kr as an Agent for Lung-Scanning Using Krypton Gas in Clathrate for Neutron Irradiation

Dr. W. A. Jester, Dr. K. N. Prasad, Graduate Assistant
T. J. Donlan and Graduate Assistant P. L. Rensen of the
Nuclear Engineering Department, Dr. J. S. Burkle of the
York Hospital and Dr. G. L. Jackson of the Harrisburg
Hospital

The radionuclide ^{85m}Kr has several desirable characteristics for lung scanning when compared with ^{133}Xe , which is the agent that currently finds most widespread use. The most abundant photon from the decay of ^{85m}Kr has an energy of 150 Kev which is considered to be the optimum energy for lung scanning. The photon energy from ^{133}Xe is 81 Kev. The purpose of this research was to investigate all the relevant properties of ^{85m}Kr for lung scanning and make a comparison with ^{133}Xe . A novel approach was attempted to make ^{85m}Kr using neutron irradiation of natural krypton in hydroquinone clathrate. Thus, the normal problems attendant on irradiation of a gas were completely avoided and it was found that the clathrate was an ideal medium from the points of view of purity, irradiation stability and ease of handling. It was demonstrated that the levels of ^{85m}Kr activity required for lung scanning could be generated in approximately 1 gm. of clathrate irradiated for approximately 8 hours in the central thimble of the PSBR.

The results of this research has led to two important conclusions. Dose rate measurements made with irradiated krypton have shown that its use for lung scanning could lead to the radiation dose rate delivered to the lungs being as low as one quarter of that caused by ^{133}Xe . The shorter half-life of ^{85m}Kr ($T_{1/2} = 4.4$ hours) also causes the post scanning dose to all

personnel involved to be lower as well. An animal experiment was performed at the Harrisburg Hospital, using a dog, to compare the imaging characteristics of the two isotopes. It was shown that the image quality in lung scanning was superior for ^{85m}Kr than ^{133}Xe .

The only disadvantage of ^{85m}Kr arises from the logistical problems caused by its short half-life. It is anticipated that transportation would be the major cost component if the isotope is adapted on a relatively large scale. However, if it is possible to show that ^{85m}Kr could significantly add to the diagnostic potential of lung scanning, this factor may not prove to be a major hurdle.

9. Relation of Zinc Concentration in Hair to Learning Deficiency in Children

Dr. W. A. Jester, Dr. K. N. Prasad, Graduate Assistant T. J. Donlan and Graduate Assistant P. L. Rensen of the Nuclear Engineering Department and Dr. G. L. Jackson of the Harrisburg Hospital

Zinc has been found to play a key role in many aspects of human physiology. A research project was undertaken to investigate the possible connection between abnormal zinc metabolism and learning deficiency in children. The zinc in the hair of children with a learning deficiency was compared with that in other groups of people.

The hair samples obtained were from 24 children with a learning deficiency and their relatives. Some samples from non-relatives were also obtained. The procedure for analysis consisted of washing in ethyl ether, encapsulation in quartz, irradiation in the reactor, post-irradiation preparation of sample and gamma spectroscopy with a Ge(Li) detector.

The samples were divided into four groups and the results of the analyses intercompared among them. The groups were: (a) The patients with a learning deficiency, (b) their relatives and (c) their siblings and (d) non-relatives. It was found that: (a) there is no significant difference between the relatives as a group (including siblings) and non-relatives, and (b) there is a significant difference between the patients and their sibling relatives. Thus, there is a strong indication that lower zinc concentration in hair can be related to learning deficiency in children.

10. The Development and Testing of a Gas Compression Fence Line Monitor for the Detection of Radioactive Gases Released from Nuclear Reactors

Dr. W. A. Jester, Dr. K. N. Prasad and Graduate Assistant
R. H. Jabs of the Nuclear Engineering Department

The new AEC "as low as practicable" guide for the operation of light water cooled nuclear power reactors places the emission limits for the radioactive noble gas fission products such that the dose rate at the plant boundary does not exceed 10 millirems annually. This limit is less than one tenth the natural radioactive background. To date, the gaseous effluent detection systems available to such plants can only monitor the gross airborne activity. The detection system being developed in this project will utilize on line gamma ray spectroscopy to identify both the identification and the concentration of these radioactive gases.

To improve detection efficiency, air samples will be compressed into a pressure vessel which is essentially a 12-inch diameter sphere containing a well into which a 4-inch diameter by 4-inch thick NaI(Tl) spectroscopy detector is inserted. In this arrangement, the detection sensitivity goes up directly proportional to the pressure. Thus, at its operation pressure of 1500 psig, the system should give a sensitivity of about two orders of magnitude larger than that at atmospheric pressure.

Construction of the system has been completed including an all weather shelter for the system and an elaborate electronic temperature control system, both of which are required to maintain stability and safety of the radiation detector. A sophisticated instrument panel has been constructed for control and monitoring the system. Upon the completion of the system in February of this year it was taken to the Oyster Creek Nuclear Generating Station for field testing. It was able to collect and monitor the stack plume for fission gases. It was also used to monitor Argon-41 in and around the reactor bay of the BNR.

11. Identification and Evaluation of Water Traces Amenable to Post-Sampling Neutron Activation Analysis

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

The project utilized activation analysis procedures to analyze a number of natural water samples for trace element concentrations. This data was then utilized to select likely artificial tracers. These were then evaluated in soil slurry tests and soil column tests to determine their ability to survive in the environment. Large scale field testing is now in progress using two of the tracers selected in this work.

12. Water Tracer Study of Discharge from Limestone Mine

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

This project is utilizing activation analysis procedures to evaluate ground water movement in the vicinity of a large limestone mine. Water pumped from the mine is being traced to determine the amount which recirculates back to the mine. Two tracers are being utilized. This project will provide a full-scale trial for these two tracers ($\text{Br}^- + \text{I}^-$).

13. Land Disposal of Contaminated Lime Wastes from SO_2 Scrubbers

Dr. G. W. McKee, Graduate Student R. A. Peiffer and Undergraduate T. A. Rightnour of the Agronomy Department, Dr. W. A. Jester and Mr. D. C. Raupach of the Nuclear Engineering Department

Sulfur dioxide scrubbed 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. Neutron activation analysis is being employed to investigate the relative amounts of such potential pollutants. To date the following elements of interest have been identified in these samples - aluminum, manganese, molybdenum, potassium, sodium, and arsenic. Eight other elements have also been identified.

14. Skeletal Metabolism

Dr. W. J. Mueller and Graduate Assistant P. Mazur of the Poultry Science Department and Post Doctoral Fellow M. Mazurkiewicz

Influences of bone fracture, parathyroid hormone and other hormones on skeletal bone flow are being studied. Prelabeled (^{169}Yb , ^{51}Cr , ^{85}Sr) vinyl microspheres (15 μ diameter) were injected via the pulmonary vein into the left ventricle of the heart in laying hens. The microspheres leave the heart and lodge in small arterioles throughout the body in proportion to the blood flow supplying the various tissues and organs.

The influence of various physiological states and hormonal levels on specific organ blood flow can be measured by successive injections of differently labeled microspheres in the same experimental animal.

Resolution of the individual gamma spectra (Yb, Cr, Sr) from various bone tissue samples required the use of a multichannel gamma spectrophotometer and computer program. This instrument was provided by the Breazeale Nuclear Reactor Facility.

In addition, due to the large number of samples generated by this research, the gamma spectrometer was interfaced with a Packard autogamma sample changer. This apparatus allowed automatic spectrum analysis of up to 100 samples and this capability enabled more extensive studies to be planned and conducted.

15. History of Biologically Active Trace Elements in the Environment

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

There is abundant new evidence indicating that the growth, health, and well-being of all living beings are determined, among other things, by the amounts and proportions of various trace elements to which they are exposed. The present condition of a human being is a product of his total environmental history as it has affected the actions of his inherited genetic code. Similarly, every plant has a unique and continuously changing environment, although since plants are fixed in one spot, their environmental change is principally in time. Thus, the knowledge of the changes in a plant over a period of time is a unique indicator of environmental changes that happened around the plant. This principle was used in analyzing the history of several biologically active trace elements in the geographical region of The Pennsylvania State University campus.

Investigations conducted at Penn State using sections of several 25 to 30 year old trees have demonstrated the potential for a unique data source of past records on trace elements in the environment. The tree sections used in this investigation were collected from the Penn State campus during 1972 (spring and summer) and included several flowering cherry, yellow locust, and an oak tree. The data from dendrochronological measurements and neutron activation analysis has demonstrated that during the quarter of a century, the environmental concentrations of zinc, mercury, and silver in the environment of University Park changed by factors of 2, 100 and 1000 respectively, while some of the other elements such as chromium, iron, and cobalt remained unchanged during this period. The detailed analyses included the determination of Se, Hg, Cr, Hf, Ag, Fe, Zn, Co, Sb and La.

While these investigations have demonstrated the possibilities of measuring the pollution history of trace elements using dendrochronological measurements and neutron activation analysis, these studies also indicate that there exist potentials for developing a unique global monitoring system for radioactive fallouts, toxic metals and other biologically active environmental contaminants using these principles.

16. Distribution Patterns of Firearm Discharge Residues

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

When a firearm is discharged, the projectile leaving the barrel carries with it some of the discharge residues and this gets distributed along the trajectory of the bullet. As the bullet leaves the barrel at a high speed, it sets up a wave front which extends out from the nose of the bullet. This condition creates an area of lower pressure immediately in its wake. In addition, due to the rifling action within the gun barrel, the projectile is discharged with a tangential velocity component. The combination of these two conditions creates an area in the wake of the bullet which carries along some of the firearm discharge residues. These residues are spewed out along the trajectory by the spinning bullet while it moves forward. The unique nature of the distribution of these residues between the gun and the target and its possible applications in criminalistics were discovered during investigations conducted at the Nuclear Engineering Department of The Pennsylvania State University.

Numerous test firings conducted during this investigation have demonstrated that the gunshot residues deposited on surfaces below the trajectory of the bullet have certain distinct features characteristic of the firearm and the ammunition used, the distance between the firearm and the target and the design features of the firearm itself. Experimentally, these patterns are developed by collecting residues from the floor of a test facility using moist filter paper squares (15 x 15 cms) and determining the concentrations of barium and antimony, which are characteristic of gunshot residues. The analyses of the samples are done non-destructively using (n, γ) products ^{139}Ba and $^{122\text{m}}\text{Sb}$ and by high resolution gamma ray spectrometry. During test firings using different types of firearms and ammunitions, 45 samples were collected after each firing from predetermined points along the ground-line parallel to the trajectory. The analyses of the barium and antimony contents of these samples are employed to develop distribution patterns of gunshot residues.

Systematic studies conducted so far suggest that under ideal conditions, the gunshot residue patterns from the scene of a crime can provide valuable information regarding (a) the trajectory of

the bullet, (b) the approximate distance between the firearm and the target, (c) the caliber of the bullet and (d) some of the physical features of the firearm used in the commission of the crime.

17. Neutron Activation Analysis of Hair as a Forensic Evidence

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

In most of the investigations involving crimes of violence, hair may be found at the scene of the crime, on the criminal, on weapons and instruments or on the victim. When hair is found at the scene of the crime, various questions are raised:

(1) Is the material actually hair? (2) Does it come from humans? (3) Does the hair come from furs or from animals? (4) What part of the body does the hair come from? and (5) Does the hair come from a particular person? The answers to some of these questions can be obtained from morphological examinations and others are hard to answer with any certainty.

During the 1960's there has been a sudden upsurge of interest in the possible use of trace element analysis of human hair by neutron activation as a forensic evidence. Some overly optimistic evaluations made during the 1960's have been due to limitations of the analytical technology available at that time and due to the limited knowledge about the variations of trace elements in human hair.

The investigations done at Penn State during the last two years attempted a somewhat different approach compared to all other hair analysis studies done so far. The principle of the method being explored is to use multiple neutron activation analysis using equipments and facilities conforming to the present state of technology. In addition, this investigation has developed practical methods of isolating hair from its surface contaminants and determining independently nearly 25 trace elements in both the hair and hair-wash samples. While most of the trace elements in the hair matrix derives from biological processes within a person, the surface contaminants of the hair can characterize the environmental exposures (occupational, cosmetic aids, etc.) of an individual. Analyzing these samples independently offers a better potential to compare hair samples collected from the scene of a crime with those obtained from known sources (suspects or victims).

18. Ultra Trace Metals in Biological Media

Dr. K.K.S. Pillay of the Nuclear Engineering Department
Dr. T. H. Risby and Teaching Assistant J. J. Dulka of
the Chemistry Department, Dr. L. N. Zimmerman and Dr. P.
Kolenbrander of the Microbiology Department

Extensive research efforts are underway to study the effects of trace metals (in the parts per billion range) on bacteria, in particular, bacillus substillus, and streptococcus, in an interdepartmental research program at The Pennsylvania State University. The first of these, bacillus substillus, a sportulating organism, is capable of causing problems in the canning industry. The present work is to determine the possible effects of essential trace metals and their concentrations on the growth rate of vegetative cells, sportulating cells and metals incorporated in the spores themselves. With the study of streptococcus, similar trace metal dependence was related to cell growth, as well as enzymatic activity and extrachromosomal elements associated with the cell.

The primary method used in the analysis is atomic absorption, while neutron activation analysis was employed to qualitatively determine the various trace elements present in these microorganisms and the growth media. Multiple neutron activation followed by extensive gamma ray spectrometric measurements were employed to determine the presence of Cu, Mn, Na, Cl, Al, Ca, Br, Sc, Zn, Au, As, La, Sb, Fe and Mo. Some of these metals have been chosen for extensive investigation of the role of ultra trace metals on bacteria using atomic absorption techniques.

19. Gold Seed Irradiation

Dr. J. A. Stryker, Health Physicist K. L. Miller,
Associate Health Physicist D. W. Campbell of the Hershey
Medical Center and Dr. W. A. Jester and Mr. D. C. Raupach
of the Nuclear Engineering Department

Small gold "seeds" which had been received from the Hershey Medical Center were doubly encapsulated in polyethylene tubing and then heat sealed. The samples were irradiated by placing them adjacent to the reactor core. After having been irradiated the samples were analyzed in the Radionuclear Applications Laboratory to determine the presence of any trace amounts of contaminants. The activity of the sample was then determined as a function of irradiation time, reactor power level and the position of the sample at the core face during irradiation.

These irradiations were done as preliminary investigations in order that the staff of the PSBR can perform irradiation of gold seeds when they are needed for use at the Hershey Medical Center.

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

1. Polymetization of Phosphazenes

Dr. H. R. Allcock, Graduate Assistant W. Cook, Graduate Assistant G. Y. Moore and Graduate Assistant L. Smeltz of the Chemistry Department

Solid state polymerization of cyclophosphazenes was attempted using Cobalt-60 radiation.

2. Detection of Microorganisms in their Natural Habitat

Dr. L. E. Casida, Jr., Graduate Assistant D. P. Labeda and Graduate Assistant D. L. Balkwill of the Microbiology Department

Electron microscopy techniques have been developed that allow one to detect and study microorganisms in situ in soil without having to isolate or culture them in the laboratory. Certain terrestrial (or even entraterrestrial) soils that one might wish to study might be potentially dangerous because of their possible content of pathogenic microorganisms. Nevertheless, the microflora of these soils could be studied safely if the soil could be first sterilized then viewed by electron microscopy providing that the sterilization procedure did not destroy the structural integrity of the microbial cells. Heat, chemical, and radiation sterilization methods were evaluated. Of these, the chemical and ^{60}Co (6 megarads) sterilizations have achieved the goal.

3. Studies of Marine Leukemia Virus-Induced Immuno Suppression

Dr. W. S. Ceglowski, Graduate Assistant M. J. Siegel, Research Assistant G. U. La Badie and Undergraduate B. P. Campbell of the Microbiology Department

Infection of susceptible strains of mice with certain murine viruses results in a leukemia-like disease, the outstanding feature of which is an increase in spleen weight. A marked defect in certain parameters of the immune response accompanies this infection. For example, mice infected with Friend leukemia virus (FLV) prior to or simultaneously with immunization, show a depression in their ability to form antibody to sheep red blood cells. The mechanism whereby this immunologic response is suppressed is not clearly understood. However, it has been determined that this immunosuppression does not occur at the level of antibody forming cells, but rather at the level of the antigen sensitive precursor cells.

Two of these precursor cells are the thymus derived lymphocytes (T cells) and the bone marrow derived lymphocytes (B cells). Although B cells are the precursors to the antibody forming cells, they must first interact with antigen specific T cells before antibody can be produced. The mechanism of this interaction is unclear, but these cellular roles have been well established.

The present investigation was undertaken to characterize the interaction between thymus derived and bone marrow derived lymphocytes. Studies were performed to determine the ability of this cellular interaction to reconstitute an immune response in lethally irradiated syngeneic mice. More particularly, the effect of FLV on the ability of T and B cells to reconstitute immune competence was of primary interest.

4. Neutralization and Precipitation in Acid Mine Waters under Gamma Radiation

Dr. F. B. Dacheille of the Geochemistry and Mineralogy Department and Dr. H. L. Lovell, Director of Mine Drainage Research

Treatment of acid mine waters involves the handling of very great volumes of a gelatinous precipitate, primarily hydrated boric oxides. The necessary neutralization and oxidation processes are most economically done with hydrated lime and aeration. An attempt was made to try to influence the nature of the precipitate during these processes by conducting them in gamma radiation fields available at the Cobalt-60 Facility. Any changes in nucleation and crystallite growth that would lead to more rapid settling and easier dehydration of the complex precipitates could be of very great practical and economic value to the coal mining and other industries and governmental agencies faced with the acid mine water problem.

The results did not show any significant improvement of precipitation and dehydration in experiments scaled to the volumes to be dealt with in practice.

5. Krypton-85 Waste Control-Storage as Hydroquinone Clathrate

Dr. W. S. Diethorn and Graduate Assistant R. Shimko of the Nuclear Engineering Department

The purpose of this work is to determine the feasibility of storing, temporarily or permanently, ^{85}Kr in the form of the krypton clathrate of hydroquinone.

Nuclear fuel reprocessing plants routinely discharge large amounts of radioactive ^{85}Kr ($t_{1/2} = 10.7$ yr.) to the atmosphere. The amount discharged to the atmosphere by nuclear reactors is much smaller. The atmosphere ^{85}Kr inventory is 50 megacuries,

delivering at present a dose of 10^{-2} - 10^{-3} mrads/year to the world population. By 1985, the dose will rise by a factor of 30 if the projected growth in fuel reprocessing is realized. Permanent storage of this gas is the only solution to this world-wide problem of atmospheric contamination.

The cage-like structure of beta hydroquinone, a common organic compound (mp = 172°C), can accommodate large amounts of rare gas, forming the so-called clathrate of hydroquinone. When every cage is filled, the gas content is 60 STP cm^3 of rare gas per gram of clathrate. Clathrates containing argon, krypton, and xenon are easily prepared by cooling a solution of hydroquinone pressurized with the rare gas. It is believed that the hydroquinone clathrate should be investigated because of the compact storage it can provide for ^{85}Kr . For example, the annual output of ^{85}Kr from a 300 tonne/year reprocessing plant is about one megacurie or 24 STP ft^3 of ^{85}Kr gas. In the form of solid hydroquinone clathrate, this gas occupies about $1/3 \text{ ft}^3$.

This program will include studies of:

- 1) the synthesis of the clathrate from krypton and dilute mixtures of krypton in air
- 2) the resistance of the clathrate to radiation damage from ^{85}Kr decay

The radiation damage experiments are being carried out in the Cobalt-60 Facility for irradiation times up to one year.

6. Dynamic Radiography Applied to a Study of Heart Dynamics and Condition

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

One medical application of dynamic radiography is the imaging of the dynamics and condition of myocardial and aorta surfaces. Mechanical models of the heart-lung interface have been used to develop the technique.

Cardiac studies with living dogs are currently in progress at the Hershey Medical Center.

7. The Application of a Four Channel Dynamic Radiograph to Two-Phase Flow Measurements

Dr. E. S. Kenney, Dr. A. M. Jacobs and AEC Trainee
G. Sagliocca of the Nuclear Engineering Department

In previous published research, a two-channel dynamic radiograph was used to obtain density perturbations in a two-phase-flow system. By constructing a four channel system, a correlative between any two selected points in a two-phase-flow system can be obtained. As a result, using penetrating radiation as the interrogating tool, flow velocities and profiles are obtainable throughout modest diameter flow vessels. Radiation scattering changes in the presence of bubbles and using collimated detectors conventional cross-correlation methods allows point to point comparisons in a quantitative fashion.

8. Fresnel Zone Plate Imaging of Scattered Radiation (x-ray)

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

The absence of a lens for penetrating radiation has reduced the imaging possibilities severely. The idea of using coded apertures to produce pseudo-holograms has been introduced into radiation imaging by others, but this work is the first to use scattered radiation in a manner analogous to optical light. The work to date indicates promise of increased aperture size compared to a pin hole camera and tomographic capabilities. The method demonstrates the ability to "see" into opaque objects with both source and observer being on the same side of the light.

9. Atomic Beam Scattering from Clean Crystal Surfaces

Dr. D. R. Frankl and Graduate Assistant J. A. Meyers
of the Physics Department

Clean surfaces were prepared by cleavage of single crystal samples in ultra-high vacuum. To improve perfection of cleavage, crystals are gamma-irradiated. This produces point defects which pin the dislocations and prevent plastic deformation.

10. Charging Airborne Particulate Matter Using Ionizing Radiation and Electric 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

It is believed that a particle charging scheme utilizing ionizing radiation and electric and magnetic fields may have application to air pollution problems. A mathematical model has been developed to predict particle charging as a function of ion generation rate and applied electric field. This model indicates optimum combinations of electric field and ion generation rate for maximum charging of particles. Preliminary experiments in one of the hot cells has partially verified the ion distribution portion of the mathematical model. Experiments also suggest use of beta source for maximum utilization of emitted energy.

11. Immunological Aspects of Coal Miner's Pneumoconiosis

Dr. R. L. Naeye and Medical Student R. H. Davis of the Hershey Medical Center

It is the purpose of this project to determine if coal miners develop a cell-mediated immunologic reaction to coal dust or other substances in the mine atmosphere.

To date, lymphocyte transformation tests on blood samples from approximately 40 underground coal miners have been performed. These tests involve cell cultures in which suspensions of coal dust, or certain other antigens, to the lymphocytes from the miners' blood are introduced.

The Cobalt-60 Facility was used to irradiate the coal samples, thereby sterilizing them and rendering the dust suitable for cell culture purposes. Each sample absorbed at least 3×10^6 rads.

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

Dr. G. E. Robinson, AEC Trainee J. N. Neyman and AEC Trainee R. H. Arnold 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 heated surface. A pool boiling system has been constructed in one of the "hot cells." Isolated bubble growth from a heated wire immersed in Freon 12 is being investigated. A comparison of the wire temperature to initiate boiling with and without Co-60 radiation present is being made. The influence of saturated versus subcooled liquid is also being investigated.

13. Resistivity Measurements of Particulate Matter under the Influence of a Gamma Field

Professor M. A. Schultz and AEC Trainee J. W. Rodell of the Nuclear Engineering Department

In electrostatic precipitates, the efficiency of collection falls off drastically if the particulate matter being collected has high resistivity. This fall off occurs when the resistivity is above 10^{10} ohm cms. In conventional precipitators additives are sometimes injected into the flue gas to reduce the resistivity. This step is particularly necessary when low sulfur coal is burnt.

In the electrostatic precipitation device under development at Penn State, gamma rays are used to ionize the gas instead of a corona wire. The question then arises as to how the resistivity of the collected material will behave under the influence of high gamma fields.

An experimental set-up was made using the Cobalt-60 Facility. A fixture was designed that approximated the standard resistivity measuring fixture specified by the ASME. Various materials such as Portland cement, powdered glass, high resistivity fly ash, etc. were measured for resistivity changes under the influence of high gamma fields. These materials with initial very high resistivities all showed far lower resistivities in the gamma fields, usually being considerably less than 10^{10} ohm cms. Consequently, the gamma induced electrostatic precipitator should be suitable for their stack gas collection.

14. Tunneling Resonances in Dimethylacetylene

Dr. W. A. Steel, Dr. J. W. 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 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

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

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

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.

15. Laser Window Coatings

Dr. K. Vedam and Graduate Assistant M. Lovette of the Physics Department, Dr. B. E. Knox of the Material Sciences Department and Post Doctoral Scholar E. C. Beahm

In preparation of anti-reflective coatings for laser windows, coatings transparent at 10.6 μm are deposited on potassium chloride. The Cobalt-60 Facility was used to irradiate the potassium chloride substrates to increase hardness before deposition of coatings.

16. Immunological Response to Inhaled Antigens

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

The objectives are to determine and test procedures for quantitatively estimating immunologic responses in animals given antigen by aerosol and to determine the effects of environment and age on the various parameters of immunologic reactivity. This work includes the exposure of mice to toxic particulates, which they inhale. Such animals are next checked for their ability to respond to aerosol exposures with bacteria, by producing antibodies and antigen reactive cells. One technique used to check the immunologic competence of mice is to reconstitute gamma-irradiated, syngeneic mice with lymphocytes from experimental animals and follow this with antigenic stimulations.

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:

State Organizations

The Pennsylvania State Police

"Film-Lift" Techniques and Gunshot Residue Analysis

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

One of the accomplishments of the radionuclear forensic investigations at Penn State during the last two and a half years was the development of a new procedure to collect evidence samples for forensic neutron activation analysis. The work done at the PSBR has now completed exhaustive tests to determine the potentials of the new procedures called "Film-Lift" techniques. Numerous rounds of test firings using a variety of firearms and ammunitions have clearly established that film-lift techniques are extremely convenient for field use, while these methods are capable of efficiently collecting gunshot residues from human body surfaces for neutron activation analysis.

Having demonstrated the unique features of the sample collection method and multielement analysis for the detection of gunshot residues, these procedures were introduced to the Pennsylvania State Police. Evidence samples are being collected and analyzed using these new methods by trained personnel from the state police.

In addition to introducing the new procedures to the State Police, an evidence collection kit has been designed and assembled. This kit called the "Film-Lift Kit" is now assembled in large quantities by the Nuclear Engineering Department and is made available to the Pennsylvania State Police.

Conestoga Senior High School

Measurement of Organochlorine Pesticides in the Aquatic Food Chain of Valley Creek (Chester County)

Dr. R. Heister and Student D. R. Midgley, Student P. A. Balderston and Student R. Glasser of Conestoga Senior High School, Dr. W. A. Jester of the Nuclear Engineering Department and Dr. J. D. Sink of the Department of Animal Science

This research represents a senior biology/science project conducted by students at Conestoga Senior High School. The study focuses on the progressive concentration of organochlorine pesticide residues throughout the different levels of the food web in Valley Creek. Samples included bottom mud, algae, benthic organisms, and fish were taken above and below the Knickerbocker landfill and in a down stream pond. The three sampling sites were selected to determine the effect of landfill on total pesticide concentration in the area. The samples were collected by the students, delivered to Dr. Sink who did the extraction, and then Dr. Jester who did the neutron activation analysis. The data were then forwarded to the students at Conestoga Senior High School for analysis and summary

Industrial Organizations

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.

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VIII. THESES, PUBLICATIONS AND REPORTS

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

Theses

1. "An Investigation of the Sulfur Contents in Asphalts and Asphaltenes," C. A. Ciesielski, Ph.D. Thesis, 1974, Civil Engineering Department, Dr. W. H. Gotolski, Thesis Advisor.
2. "A Fission Disc Assembly Using Highly Enriched Uranium Foils," S. S. A. Diab, M.S. Paper, 1974, Nuclear Engineering Department, Dr. S. H. Levine, Paper Advisor.
3. "Perturbation Theory in TRIGA Core Management," J. A. Easley, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. S. H. Levine, Thesis Advisor.
4. "The Effect of Carbon Inhalation on the Immune Response of Mice to Escherichia coli Aerosol," K. E. Eby, Ph.D. Thesis, 1973, Veterinary Science Department, Dr. A. Zarkower, Thesis Advisor.
5. "Mathematical Model of a Particle Charging Scheme Utilizing Ionizing Radiation and Electric and Magnetic Fields," R. A. Fjeld, M.S. Thesis, 1973, Nuclear Engineering Department, Dr. S. H. Levine and Dr. R. J. Heinsohn, Thesis Advisors.
6. "Construction of the Fast Reactor Spectrum Assembly," D. J. Florek, M. Eng. Paper, 1973, Nuclear Engineering Department, Dr. W. F. Witzig, Paper Advisor.
7. "⁴He Atomic Beam Scattering from Clean Surfaces of Silicon, Germanium, and Lithium Fluoride," D. E. Houston, Ph.D. Thesis, 1973, Physics Department, Dr. D. R. Frankl, Thesis Advisor.
8. "Nuclear Safety and Biological Dose Rate Calculations for The Pennsylvania State University's Fast Reactor Spectrum Assembly (FRSA), L. A. Pasquini, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. S. H. Levine, Thesis Advisor.
9. "Thermal Neutron Induced Ternary Fission of Uranium-235," L. J. Pilione, Ph.D. Thesis, 1973, Physics Department, Dr. W. W. Pratt, Thesis Advisor.

10. "Resistivity Measurements of Particulate Matter under the Influence of a Gamma Field," J. W. Rodell, M.S. Thesis, 1974, Nuclear Engineering Department, Professor M. A. Schultz, Thesis Advisor.
11. "The Application of the Four Channel Dynamic Radiograph to Two-Phase Flow Measurements," G. Sagliocca, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. E. S. Kenney, Thesis Advisor.
12. "Effects of Radiation on Krypton Release from the Krypton Clathrate of Hydroquinone," R. Shimko, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. W. S. Diethorn, Thesis Advisor.
13. "The Interaction Between Thymus Derived and Bone Marrow Derived Lymphocytes from Friend Leukemia Virus Infected Mice," M. J. Siegel, M.S. Thesis, 1973, Microbiology Department, Dr. W. S. Ceglowski, Thesis Advisor.
14. "Dynamic Radiography - Imaging the Motion of a Surface," D. G. Tilley, M.S. Thesis, 1973, Nuclear Engineering Department, Dr. A. M. Jacobs, Thesis Advisor.

Publications, Reports, and Oral Presentations

1. "Ultra Trace Metals in Bacterial Systems," 9th Mid-Atlantic Regional Meeting of the American Chemical Society, April 1974, Wilkes-Barre, Pa., J. J. Dulko, T. H. Risby, Chemistry Department, P. Kolenbrander and L. N. Zimmerman, Microbiology Department.
2. "TRIGA Reactor Perturbation Studies," to be presented at the ANS Conference on Research, Test, and Training Reactors, August 1974, J. A. Easley and S. H. Levine, Nuclear Engineering Department.
3. "Charging Airborne Particulate Matter in High Concentrations using Radiation and Magnetic Fields," Proceedings of the Industry Applications Society (IEEE), Annual Meeting, October 8-11, 1973, Milwaukee, Wisconsin. R. A. Fjeld, Nuclear Engineering Department, G. W. Malamud, Chemical Engineering Department, R. J. Heinsohn, Mechanical Engineering Department and S. H. Levine, Nuclear Engineering Department.
4. "Reflection of ^4He Atomic Beams from Clean LiF Surfaces," Physics Review Letters 31, 298, July 30, 1973, D. E. Houston and D. R. Frankl, Physics Department.

5. "The Development of an Environmental Monitoring System for the On-Line Detection of Airborne Radioactive Gases," Transactions of the American Nuclear Society, 18, 1974, R. H. Jabs and W. A. Jester, Nuclear Engineering Department.
6. "Dynamic Radiography as a Technique of Imaging Biological Flows," Proceedings of the International Symposium on Holography in the Biomedical Sciences, 1973, A. M. Jacobs and E. S. Kenney, Nuclear Engineering Department.
7. "Pennsylvania Nuclear Science Program (A significant Public Education Program)," Transactions of the American Nuclear Society, 18, 1974, W. A. Jester, W. S. Diethorn, Nuclear Engineering Department and J. J. McDermott.
8. "Environmental Impact of Electrical Power Generation (A New Educational Minicourse)," Transactions of the American Nuclear Society, 18 1974, W. A. Jester, W. F. Witzig, Nuclear Engineering Department, and J. J. McDermott.
9. "Neutron Diffraction Intensities from Vibrating Double-Crystal Systems," Nuclear Instruments and Methods (in press), E. S. Kenney, J. D. E. Jeffries, A. M. Jacobs, Nuclear Engineering Department.
10. "Coating Science and Technology - The Development of Anti-Reflective Coatings for Infrared Laser Windows," Third Conference on High Power Infrared Laser Windows, Air Force Cambridge Research Laboratories, November 1973, B. F. Knox, Material Sciences Department and K. Vedam, Physics Department.
11. "Activation Analyses of Heavy Metals in Surface Waters using Ion Exchange Filter Papers and Cyanide Complexing," Journal of Radioanalytical Chemistry, 16, 21, (1973), A. M. Kolačzkowski and W. A. Jester, Nuclear Engineering Department.
12. "Soil Sterilization Effects on in situ Indigenous Microbial Cells in Soil," Canadian Journal of Microbiology (ready for submission) 1974. D. P. Labeda, D. L. Balkwill, and L. E. Casida, Jr., Microbiology Department.
13. "Fine Structure Survival for Indigenous Soil Microorganisms Subjected to Soil Sterilization," American Society for Microbiology, May 1974, D. P. Labeda, D. L. Balkwill, and L. E. Casida, Jr., Microbiology Department.
14. "Atomic Beam Scattering from Clean Alkali Halide Surfaces," 2nd International Conference on Solid Surfaces, Kyoto, Japan, March 1974 (to be published in Japanese Journal of Applied Physics), J. A. Meyers, D. E. Houston and D. R. Frankl, Physics Department.

15. "Distribution Patterns of Firearm Discharge Residues," Transactions of the American Nuclear Society, 18, pp. 61-62, 1974, K. K. S. Pillay, D. C. Driscoll, B. W. Lee and W. A. Jester, Nuclear Engineering Department.
16. "New Method in the Collection and Analysis of Gunshot Residues as a Forensic Evidence," Journal of Forensic Sciences (in press), K. K. S. Pillay, W. A. Jester, Nuclear Engineering Department and H. A. Fox III, Pennsylvania State Police.
17. "New Methods in the Collection and Analysis of Gunshot Residues," 165th National Meeting of the American Chemical Society, Chicago, Illinois, August 1973, K. K. S. Pillay, W. A. Jester, Nuclear Engineering Department and H. A. Fox III, Pennsylvania State Police.
18. "A Modified Approach to Forensic Activation Analysis of Hair," Transactions of the American Nuclear Society, 18, p. 62, 1974, K. K. S. Pillay, S. H. Moss, M. A. Bricklemeyer and W. A. Jester, Nuclear Engineering Department.
19. "The Application of Post-Cutting Chip Activation Analysis to the Study of Tool Wear," Nuclear Technology, (in press), K. N. Prasad, W. A. Jester and F. J. Remick, Nuclear Engineering Department.
20. "Radioactive Decay of ^{110m}Ag ," Journal of Inorganic and Nuclear Chemistry, 36, 1199 (1974), William W. Pratt, Physics Department.
21. "A New Technique for Unfolding Foil Activation Data," Transactions - Annual 1974 Northeastern American Nuclear Society Student Conference, March 1974, p. 32, J. K. Schmotzer, Nuclear Engineering Department.
22. "Ground Water Tracing with Post-Sampling Activation Analysis," Journal of Hydrology, Vol. 20, pp. 217-236, (1973), J. K. Schmotzer, W. A. Jester, Nuclear Engineering Department and R. R. Parizek, Geology Department.
23. "An Improved Technique for Unfolding Foil Activation Data," Transactions of the American Nuclear Society, 18, p. 370, 1974, J. K. Schmotzer and S. H. Levine, Nuclear Engineering Department.
24. "Scattered X-Ray Holography using Fresnel Zone Plates," Penn State Engineer, April 1974, R. G. Sider, Nuclear Engineering Department.
25. Pseudo-Holography using Scattered X-Rays, Nature, 518, in press, R. G. Sider, E. S. Kenney and A. M. Jacobs, Nuclear Engineering Department.

26. "Dynamic Radiography - An Evaluation of Mechanical Motion of the Heart by Analyzing Scattered Radiation during Flouroscopy," Investigative Radiology (in press), W. A. Weidner and K. L. Miller, Hershey Medical Center, A. M. Jacobs, E. S. Kenney and D. G. Tilley, Nuclear Engineering Department.
27. "The Na/K Ratio of Fluid Inclusions in Pegmatitic Quartz and its Genetic Implications. A Study by Neutron Activation Analysis," Lithos, 6, 373, 1973, R. A. Horn and F. E. Wickman, Geosciences Department.
28. "Effect of Carbon and Silica on the Immune Response," Seminar, Cornell University, October 1973, A. Zarkower, Veterinary Science 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).

Allcock, Harry R., B.Sc., Ph.D.
Professor
Department of Chemistry
College of Science

Beahm, Edward C., B.S., M.S., Ph.D.
Post-Doctoral Scholar
Materials Research Laboratory

Bellis, Edward D., B.S., M.S., Ph.D.
Professor
Department of Biology
College of Science

Burkle, Joseph S., B.A., M.D.
Clinical Assistant
Department of Nuclear Medicine
York Hospital
University of Maryland

Burnham, C. Wayne, B.A., M.S., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Campbell, Dale W., B.S., M.S.
Associate Health Physicist
Hershey Medical Center

Casida, Lester E., Jr., B.S., M.S., Ph.D.
Professor
Department of Microbiology
College of Science

Ceglowski, Walter S., B.S., M.S., Ph.D.
Associate Professor
Department of Microbiology
College of Science

Cook, John A., B.A., M.F.A.
Professor
Department of Art
College of Arts and Architecture

Cooper, Edwin L., B.S., M.S., Ph.D.
Professor
Department of Biology
College of Science

Dachille, Frank B., Ch.E., Ph.D.
Associate Professor
Department of Geosciences
College of Earth and Mineral Sciences

Diethorn, Ward S., B.S., M.S., Ph.D.
Professor
Department of Nuclear Engineering
College of Engineering

Flinchbaugh, Terry L.
Reactor Supervisor, Nuclear Reactor
Department of Nuclear Engineering
College of Engineering

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

Geisler, George C., B.S. M.S.
Research Associate
Department of Nuclear Engineering
College of Engineering

Gotolski, William H., B.S., M.S., Ph.D., P.E.
Professor
Department of Civil Engineering
College of Engineering

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

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

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

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

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

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

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

Knox, Bruce E., B.S., M.S., Ph.D.
Associate Professor
Department of Materials Science
College of Earth and Mineral Sciences

Kolenbrander, Paul, B.S., M.S., Ph.D.
Assistant Professor
Department of Microbiology
College of Science

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

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

McKee, Guy W., B.S., M.S., Ph.D.
Professor
Department of Agronomy
College of Agriculture

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

Miller, K. L., B.S., M.S.
Health Physicist
Hershey Medical Center

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

Naeye, Richard L., M.D.
Professor
Pathology Department
Hershey Medical Center

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

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

Pillay, Sivasankara, K.K., B.S., M.S., Ph.D.
Research Associate
Department of Nuclear Engineering
College of Engineering

Prasad, Kadambi N., B.E., M.S., Ph.D.
Research Assistant
Nuclear Engineering Department
College of Engineering

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

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

Riehl, John W., A.B., Ph.D.
Associate Professor
Department of Chemistry
College of Science

Risby, Terence H., L.R.I.C., D.I.C., Ph.D.
Assistant Professor
Chemistry Department
College of Science

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

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

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

Sink, John D., B.S., M.S., Ph.D.
Professor
Department of Animal Science
College of Agriculture

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

Stryker, John A., M.D.
Associate Professor of Radiotherapy
Hershey Medical Center

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

Vedam, Kuppuswami, B.Sc., M.Sc., Ph.D.
Professor
Department of Physics
College of Science

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

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

Zimmerman, Leonard N., B.S., M.S., Ph.D.
Professor
Department of Microbiology
College of Science

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

College of Agriculture

Eby, K. E., Veterinary Science Department

Miller, S. D., Veterinary Science Department

Peiffer, R. A., Agronomy Department

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

College of Earth and Mineral Sciences

Flynn, R. T., Geoscience Department

Krupka, K. M., Geoscience Department

College of Engineering

Arnold, R. H., Nuclear Engineering Department

Bricklemeyer, M. A., Nuclear Engineering Department

Burke, V. R., Nuclear Engineering Department

Ciesielski, C. A., Civil Engineering Department

Diab, S. S. A., Nuclear Engineering Department

Donlan, T. J., Nuclear Engineering Department

Driscoll, D. C., Nuclear Engineering Department

Easily, J. A., Nuclear Engineering Department

Fjeld, R. A., Nuclear Engineering Department

Florek, D. J., Nuclear Engineering Department

Houston, G. W., Nuclear Engineering Department

Jabs, R. H., Nuclear Engineering Department

Johannesmeyer, C. A., Nuclear Engineering Department

Klinetob, R. H., Nuclear Engineering Department

Lee, B. W., Nuclear Engineering Department
Malamud, G. W., Chemical Engineering Department
Moss, S. H., Nuclear Engineering Department
Neyman, J. N., Nuclear Engineering Department
Pasquini, L. A., Nuclear Engineering Department
Ray, P., Nuclear Engineering Department
Rensen, P. L., Nuclear Engineering Department
Rodell, J. W., Nuclear Engineering Department
Rose, P. J., Nuclear Engineering Department
Sagliocca, G., Nuclear Engineering Department
Seebald, J. G., Nuclear Engineering Department
Shimko, R., Nuclear Engineering Department
Tilley, D. G., Nuclear Engineering Department
Uhler, K. A., Civil Engineering Department
Wolfe, F. A., Nuclear Engineering Department

College of Science

Balkwill, D. L., Microbiology Department
Campbell, B. P., Microbiology Department (undergraduate)
Cook, W., Chemistry Department
Dulka, J. J., Chemistry Department
Emrich, R. J., Chemistry Department
Herritt, J. A., Physics Department
Hinkle, L. S., Biology Department
Labeda, D. P., Microbiology Department
Lorette, M., Physics Department
Meyers, J. A., Physics Department

Moore, G. Y., Chemistry Department

Pilione, L. J., Physics Department

Siegel, M. J., Microbiology Department

Smeltz, L., Chemistry Department

Hershey Medical Center

Davis, R. H., Medical Student

APPENDIX B
FORMAL GROUP TOURS

1973

July	2	Huntingdon Middle School Students	55
	16	High School Science Advisors	48
	17	Chambersburg Area High School Students	8
	17	High School Science Advisors	11
	18	High School Science Advisors	10
	23	Risks of Nuclear Engineering (P.S.U.)	8
	24	Free University and High School Science Teachers	16
	25	Upward Bound Students (P.S.U.)	12
	31	Fire Safety Conference Members	17
Aug.	2	Boy Scouts of Jersey City, New Jersey	24
	14	Pa. Power & Light Company Coordinators	9
	16	Physics 237 (P.S.U.)	13
Sept.	13	Nuclear Engineering Seminar	11
	24	Science Technology and Society (P.S.U.)	11
Oct.	2	Society of Manufacturing Engineers	3
	10	Dairy Science (P.S.U.)	19
	11	Northwest Area High School National Honor Society	29
	12	Heidelberg College (Ohio)	6
	16	Physics 100 (P.S.U.)	34
	17	Physics 100 (P.S.U.)	10
	18	Physics 100 (P.S.U.)	15

Oct.	23	Bucknell University Students	7
	29	Introduction to Environmental Health (P.S.U.)	7
	31	Microbiology (P.S.U.)	8
	31	Physical Science 7 (P.S.U.)	13
Nov.	1	Geological Science 303 (P.S.U.)	20
	5	Physical Science 7 (P.S.U.)	9
	5	Junior Science and Humanities Symposium	20
	7	Explorer Post (Pittsburgh)	23
	12	Physical Science 7 (P.S.U.)	23
	13	Engineering 5 (P.S.U.)	5
	14	Wyomissing and Penn Hills High Schools	13
	16	Edenburo Sixth Grade	9
	20	Ligonier Valley High School	14
	21	Daniel Boone High School	19
	29	Special Education Class (P.S.U.)	6
Dec.	5	Representatives of the Governor's Justice Commission and Reg. Police Department	8
	6	Bucknell University Students	5
	11	Altoona Campus	14
	12	Sullivan County High School	12
<u>1974</u>			
	8	Engineering 11 Seminar (P.S.U.)	14
	17	Industrial Engineering 319 (P.S.U.)	17
	18	Biophysics 10 (P.S.U.)	23
	24	State College group	8
	29	Physics 101 (P.S.U.)	56
	31	Physics 101 (P.S.U.)	25

Feb.	7	Geological Science 303 (P.S.U.)	32
	7	Jersey Shore High School	12
	12	Physics 237 (P.S.U.)	30
	13	Public Affairs Leadership Program	24
	14	Ridgway Area High School	10
	21	Open House - National Engineers' Week (P.S.U.)	33
	25	Engineering 5 (P.S.U.)	18
	27	Nuclear Engineering 200 (P.S.U.)	10
March	7	Cub Scouts	12
	8	Nuclear Engineering Class (P.S.U.)	7
	13	Shippensburg State College	38
	14	Bradford and Lebanon High Schools	15
	15	Huntingdon High School	68
	19	Central Pennsylvania Chapter of the National Association of Accountants	24
	19	Society of Engineering Science	11
	21	Upper St. Clair High School	24
	22	American Nuclear Society Student Conference (P.S.U.)	54
	26	Bishop O'Hare High School	44
	27	Nuclear Engineering 401 (P.S.U.)	18
	28	Monroeville and Parkland High Schools	14
	29	Eco Action (P.S.U.)	29
April	2	Penncrest High School	10
	2	Physics 100 (P.S.U.)	27
	4	Berwick High School	27
	4	Physics 100 (P.S.U.)	43
	5	Churchill Area High School	45

April	8	Elkland High School	48
	9	Organization of Town Independent Students	18
	18	Southern Fulton High School	10
	18	Riverside High School	6
	19	Fulbright Scholars	21
	19	Lewistown-Granville High School	17
	19	Cambria High School	100
	23	Hollidaysburg High School	5
	23	Columbia High School	41
	24	Metallurgy 412 (P.S.U.)	6
	24	Biology 436 (P.S.U.)	13
	24	Agricultural Engineering Club (P.S.U.)	24
	25	Bishop O'Reilly, North Schuylkill and Dunmore High Schools	15
	26	State College Area High School	116
May	2	Geological Science 303 (P.S.U.)	22
	2	Thomas Jefferson High School	23
	6	Association for Field Services & Teachers Education	7
	6	Microbiology 410 Immunology (P.S.U.)	6
	7	Kishacoquillas High School	64
	8	Pa. Rural Electric Association	19
	9	Harbor Creek High School	19
	10	Penn Cambria High School	32
	10	Pittston Area High School	33
	14	Physics 237 (P.S.U.)	17
	16	Carlisle High School	16
	17	Lemont Sixth Grade	62
	30	Fairmount Avenue Fifth Grade	62

June	1	Graduating Seiors and Guests (P.S.U. Nuclear Engineering)	25
	13	Harrisburg Hospital School of Nuclear Medicine	11
	26	Extension Agents, Home Economists, 4 H Leaders	45
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		TOTAL	2,324