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RADIATION SCIENCE AND ENGINEERING CENTER

COLLEGE OF ENGINEERING

THIRTY-EIGHTH ANNUAL PROGRESS REPORT

AUGUST 1993

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THIRTY-EIGHTH ANNUAL PROGRESS REPORT

PENN STATE RADIATION SCIENCE AND ENGINEERING CENTER

July 1, 1992 to June 30, 1993

Submitted to:

United States Department of Energy

and

The Pennsylvania State University

By:

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TABLE OF CONTENTS

TABLES

FIGURES

P

R

E

F

A

C

E

PREFACE

Administrative responsibility for the Radiation Science and Engineering Center (RSEC) resides in the Department of Nuclear Engineering in the College of Engineering. Overall responsibility for the reactor license resides with the Senior Vice President for Research and Dean of the Graduate School. The reactor and associated laboratories are available to all Penn State colleges for education and research programs. In addition, the facility is made available to assist other educational institutions, government agencies and industries having common and compatible needs and objectives, providing services that are essential in meeting research, development, education and training needs.

The Thirty-Eighth Annual Progress Report (July 1992 through June 1993) of the operation of The Pennsylvania State University Radiation Science and Engineering Center is submitted in accordance with the requirements of Contract DE-AC07-76ID01570 between the United States Department of Energy and EG&G Idaho, Incorporated, and their Subcontract C88-101857 with The Pennsylvania State University. This report also provides the University administration with a summary of the utilization of the facility for the past year.

Numerous individuals are to be recognized and thanked for their dedication and committment in this report, especially Terry Flinchbaugh who edited the report and Lisa Large who typed it. Special thanks are extended to those responsible for the individual sections as listed in the Table of Contents and to the individual facility users whose research summaries are compiled in Section XI.

INTRODUCTION

P
E
R
S
O
N
N
E
L

I. INTRODUCTION

The 92-93 academic year marked the first complete year when the Radiation Science and Engineering Center was operated by the second generation staff. In the previous five years, the original staff from the late '50s gradually retired and replacements were selected and trained. The new staff rose to the occasion by first replacing the reactor control system and then moving into research and education thrusts highlighted by the following specific examples:

* During the first year of operation of the new digital control system, the staff built and programmed a local area network to broadcast information to experimenters and emergency re-entry points. The performance record for the new control system was outstanding.

* RSEC staff were participants in a major advanced reactor control demonstration study jointly funded by EPRI and NSF.

* DOE awarded the RSEC $40,617 with $21,870 additional university matching for improved instrumentation for research and operations.

* A facility is under construction to evaluate cold neutron source materials in a joint project with the physics and nuclear engineering departments, sponsored by the Argonne National Laboratory Intense Pulsed Neutron Source.

* The RSEC staff is working with Westinghouse personnel of the Bettis Laboratory, improving neutron radiography techniques to study thermal hydraulics at high heat flux.

* The dark room was upgraded and image processing equipment was enhanced to improve resolution of neutron radiographs.

* The flux spectrum of the fast neutron irradiation facility was carefully characterized using threshold foil irradiations and spectra unfolding techniques.

* The Low Level Radiation Monitoring Laboratory began large scale testing of radon in water and also began studies of doses from naturally occurring radioactivity in artificial joints.

* Educational programs remained a major thrust with programs for high school classes, high school science teacher workshops, and challenging programs for groups of student scholars.

* Licensed reactor operators all passed a NRC-administered license requalification examination with outstanding scores. Also, the RSEC staff was commended in audits by Nuclear Regulatory Commission inspectors.

II. PERSONNEL

Julia Goodfellow resigned her position as environmental analyst in the LLRML on August 1, 1992. Maurice Peagler assumed that position on August 26, 1992. Maurice had been employed at the LLRML in a full-time wage payroll position.

Jana Lebiedzik was hired into a full-time wage payroll position in the LLRML on August 31, 1992. Part-time wage payroll help during the year was provided by Joy Moncil and Brett Kellerman.

Robert Gould was reclassified from a Project Assistant staff position to a Research Assistant faculty position on September 1, 1992.

Pam Stauffer, head secretary, took a temporary personal leave of absence for one year beginning January 1, 1993. Pam has been working two days a week during this time. Lisa Large has received a temporary promotion for assuming Pam's duties three days a week. Arlene Stewart was promoted from a wage payroll secretary to staff assistant III position for one year beginning January 4, 1993.

Eric Hannold resigned as reactor operator intern on January 4, 1993 following the completion of his undergraduate mechanical engineering degree. David Miller was hired as a reactor operator intern on January 11, 1993.

Dale Raupach, who had retired from his staff position during the previous reporting year, resigned his wage payroll position on January 29, 1993.

Timi Narehood resigned her position as Administrative Assistant IV in the Nuclear Engineering Department on June 1, 1993 and was replaced by Cathy Kowalske.

Tom Gillen was employed in a part-time wage payroll position to assist the reactor staff in characterizing the flux spectrum of the fast neutron irradiation facility.

Clerical and staff positions were combined under a new SPEC job classification system, giving the former clerical employees new job titles.

TABLE I

Personnel

	Faculty and Staff	Title
	H. M. Boyle	Supervisor, Low-Level Radiation Monitoring Lab
**	P. G. Boyle	Reactor Supervisor/Nuclear Education Specialist
**	M. E. Bryan	Electronic Designer/Reactor Supervisor
	G. L. Catchen	Associate Professor
	T. Daubenspeck	Reactor Supervisor/Reactor Utilization Specialist
**	C. C. Davison	Reactor Supervisor/Nuclear Education Specialist
**	T. L. Flinchbaugh	Operations and Training Manager
	J. E. Goodfellow (resigned)	Environmental Analyst
	R. Gould	Research Assistant
**	E. Hannold (resigned)	Reactor Operator Intern
**	D. E. Hughes	Senior Research Assistant/Manager of Engineering Services
	W. A. Jester	Professor
	C. J. Kowalske	Administrative Assistant
	L. D. Large	Staff Assistant V
**	D. R. Miller	Reactor Operator Intern
	M. Q. Peagler	Environmental Analyst
*	K. E. Rudy	Operational Support Services Supervisor
**	E. J. Sipos	Reactor Operator Intern
	A. Z. Stewart	Staff Assistant III
	P. J. Stauffer	Staff Assistant VII
**	B. D. Vergato	Reactor Operator Intern
**	M. H. Voth	Associate Professor/Director

* Licensed Operator
** Licensed Senior Operator

Technical Service Staff

J. E. Armstrong	Mechanic-Experimental and Maintenance
R. L. Eaken	Machininst A

Wage Payroll

T. Gillen
B. Kellerman
J. Lebiedzik
J. Moncil
D. Raupach

Penn State Reactor Safeguards Committee

W. S. Diethorn	Professor, Nuclear Engineering, Penn State (retired)
E. W. Figard	Supervisor of Maintenance, Pennsylvania Power and Light Susquehanna Steam Electric Station
R. W. Granlund	Health Physicist, Intercollege Research Programs and Facilities, Penn State
D. E. Hughes	Senior Research Assistant, Penn State Radiation Science and Engineering Center
P. Loftus	Manager, Product Licensing, Westinghouse
J. H. Mahaffy	Assistant Professor, Nuclear Engineering, Penn State
G. E. Robinson	Chairman, Associate Professor, Nuclear Engineering, Penn State
M. J. Slobodien	Radiological Controls Director, General Public Utilities
P. E. Sokol	Associate Professor, Physics, Penn State
M. H. Voth	Ex officio, Director, Penn State Radiation Science and Engineering Center

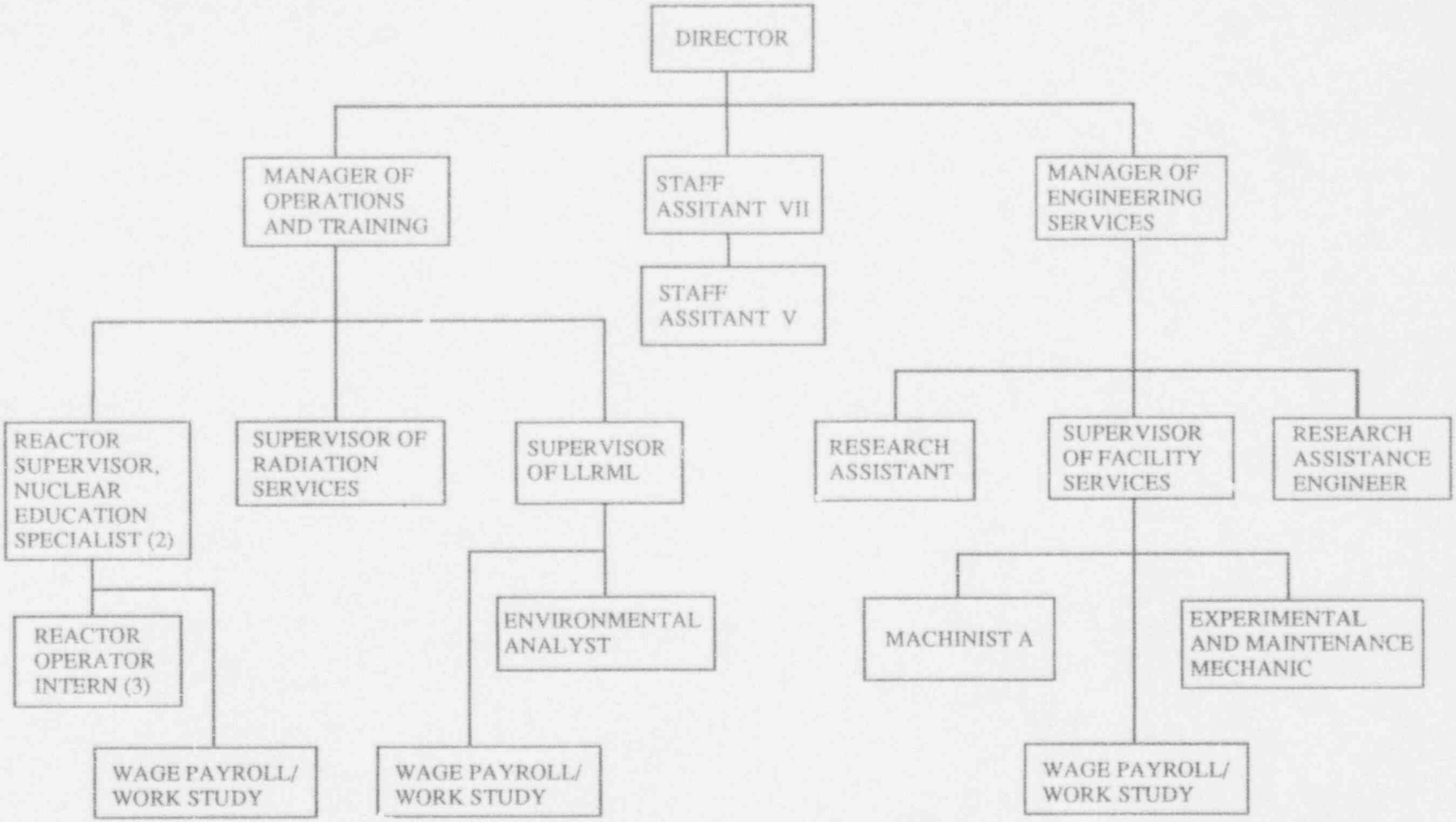

FIGURE 1 RSEC Organization Chart

REACTOR OPERATIONS

III. REACTOR OPERATIONS

Research reactor operation began at Penn State in 1955. In December of 1965 the original core, which operated at a maximum power level of 200 KW, was replaced by a more advanced TRIGA core, capable of operation at 1000 KW. The present core may also be operated in a pulse fashion in which the power level is suddenly increased from less than 1 KW to up to 2000 KW for short (milliseconds) periods of time. TRIGA stands for Training, Research, Isotope Production, built by General Atomic Company.

Utilization of the PSBR falls into three major categories:

Educational utilization is primarily in the form of laboratory classes conducted for graduate and undergraduate degree candidates and numerous high school science groups. These classes will vary from the irradiation and analysis of a sample to the calibration of a reactor control rod.

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

Training programs for Reactor Operators and Reactor Supervisors are offered and can be tailored to meet the needs of the participants. Individuals taking part in these programs fall into such categories as PSBR reactor staff and power plant operating personnel.

The PSBR core, containing about 7.5 pounds of Uranium-235, in a non-weapons form, is operated at a depth of approximately 18 feet in a pool of demineralized water. The water provides the needed shielding and cooling for the operation of the reactor. It is relatively simple to expose a sample by merely positioning it in the vicinity of the reactor at a point where it will receive the desired radiation dose. A variety of fixtures and jigs are available for such positioning. Various containers and irradiation tubes can be used to keep samples dry. Three pneumatic transfer systems with different neutron levels offer additional possibilities.

In normal steady state operation at 1000 kilowatts, the thermal neutron flux available varies from approximately 1×10^{13} n/cm^2/sec at the edge of the core to approximately 3×10^{13} n/cm^2/sec in the central region of the core.

When using the pulse mode of operation, the peak flux for a maximum pulse is approximately 6×10^{16} n/cm^2/sec with a pulse width of 15 msec at 1/2 maximum.

Support facilities include a machine shop, electronic shop, laboratory space and fume hoods.

STATISTICAL ANALYSIS

Tables 2 and 3 list Reactor Operation Data and Reactor Utilization Data-Shift Averages, respectively, for the past three years. In table 2, the Critical time is a summation of the hours the reactor was operating at some power level. The Subcritical time is the total hours that the reactor key and console instrumentation were on and under observation, less the Critical time. Subcritical time reflects experiment set-up time and time spent approaching reactor criticality. Fuel movement hours reflect the fact that there were minimal fuel movements made this year.

The Number of Pulses reflects demands of undergraduate labs, researchers and reactor operator training programs. Square waves are used primarily for demonstration purposes for public groups touring the facility, researchers and reactor operator training programs.

The number of Scrams Planned as Part of Experiments reflects experimenter needs. The scrams from Personnel Action were a result of operator error. The unplanned scram resulting from Abnormal System Operation was due to a pneumatic transfer system operational problem. It should be pointed out that a scram shuts down the reactor before a safety limit is reached.

Table 3, Part A, Reactor Usage, indicates Hours Critical and Hours Subcritical, and also Hours Shutdown such as for instruction or experimental setup. Occasionally a component failure prohibits reactor operation. The necessary repair time is included in Reactor Usage as Reactor Not Available to reflect total reactor utilization on a shift basis.

Part B gives a breakdown of the Type of Usage in Hours. The Nuclear Engineering Department and/or the Reactor Facility receives compensation for Industrial Research and Service, and for Industrial Training Programs. University Research and Service includes both funded and non-funded research, for Penn State and other universities. The Instruction and Training category includes all formal university classes involving the reactor, experiments for other university and high school groups, demonstrations for tour groups and in-house reactor operator training.

Part C statistics, Users/Experimenters, reflect the number of users, samples and experimenters per shift. Part D shows the number of eight hour shifts for each year.

INSPECTIONS AND AUDITS

During October of 1992, Robert R. Walston, Nuclear Engineer, U.S. Department of Energy, conducted an audit of the PSBR. This fulfilled a requirement of the Penn State Reactor Safeguards Committee charter as described in the PSBR Technical Specifications. The reactor staff has implemented changes suggested by that report, all of which exceed NRC requirements.

During October of 1992, a Nuclear Regulatory Commission (NRC) routine inspection was conducted of activities authorized by the materials license 37-00185-05 for the Cobalt-60 facility. No items of non-compliance were identified.

During February of 1993, a NRC routine inspection was conducted of activities authorized by the reactor R-2 license. No items of non-compliance were identified.

During April of 1993, a NRC routine inspection was conducted of health physics activities as they relate to the reactor R-2 license. No items of non-compliance were identified.

TABLE 2

Reactor Operation Data
July 1, 1990 - June 30, 1993

		90-91	91-92	92-93
A.	Hours of Reactor Operation			
	1. Critical	521	431	635
	2. Subcritical	334	541	404
	3. Fuel Movement	5	37	8
B.	Number of Pulses	111	90	77
C.	Number of Square Waves	74	68	60
D.	Energy Release (MWH)	318	210	391
E.	Grams U-235 Consumed	16	11	20
F.	Scrams			
	1. Planned as Part of Experiments	36	24	20
	2. Unplanned - Resulting From			
	a) Personnel Action	5	2	2
	b) Abnormal System Operation	3	7	1

TABLE 3

Reactor Utilization Data
Shift Averages
July 1, 1990 - June 30, 1993

	90-91	91-92	92-93
A. Reactor Usage			
1. Hours Critical	2.1	1.7	2.5
2. Hours Subcritical	1.3	2.1	1.6
3. Hours Shutdown	1.9	1.7	1.6
4. Reactor Not Available	0.0	0.7	0.1
TOTAL HOURS PER SHIFT	5.3	6.3	5.8
B. Type of Usage - Hours			
1. Industrial Research and Service	0.8	0.8	0.9
2. University Research and Service	2.1	1.5	2.3
3. Instruction and Training	1.2	1.4	1.1
4. Industrial Training Programs	0.1	0.0	0.0
5. Calibration and Maintenance	1.1	2.4	1.4
6. Fuel Handling	0.0	0.1	0.1
C. Users/Experiments			
1. Number of Users	2.4	2.8	2.7
2. Pneumatic Transfer Samples	0.5	0.7	0.7
3. Total Number of Samples	2.5	2.4	3.1
4. Sample Hours	2.2	1.5	2.7
D. Number of 8 Hour Shifts	247	255	250

GAMMA IRRADIATION FACILITY

IV. GAMMA IRRADIATION FACILITY

The University, in March of 1965, purchased 23,600 curies of Cobalt-60 in the form of stainless steel clad source rods to provide a pure source of gamma rays. In November of 1971, the University obtained from the Natick Laboratories, 63,537 curies of Cobalt-60 in the form of aluminum clad source rods. These source rods have decayed through several half-lives, leaving a July 1, 1993 approximate total of 4,200 curies.

In this facility, the sources are stored and used in a pool 16 feet by 10 feet, filled with 16 feet of demineralized water. The water provides a shield which is readily worked through and allows great flexibility in using the sources. Due to the number of rods and size of the pool, it is possible to set up several irradiators at a time to vary the size of the sample that can be irradiated, or vary the dose rate. Experiments in a dry environment are possible by use of either a vertical tube or by a diving bell type apparatus.

The Cobalt-60 facility is designed with a large amount of working space around the pool and has two laboratory rooms equipped with work benches and the usual utilities.

Maximum exposure rates of 158 KR/Hr in a 3" ID tube and 92 KR/Hr in a 6" ID tube are available as of July 1, 1993.

Efforts continue to obtain 10,500 curies of Cobalt-60 in the form of 15 source rods from Battelle National Labs. The sources will be donated to Penn State. One of the current storage casks was modified and a third storage cask was built to accommodate dry storage of the additional sources.

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

TABLE 4

Cobalt-60 Utilization Data
July 1, 1990 - June 30, 1993

	90-91	91-92	92-93
A. Time Involved (Hours)			
1. Set-Up Time	215	185	171
2. Total Sample Hours	14,277	12,549	10,975
B. Numbers Involved			
1. Samples Run	756	740	684
2. Different Experimenters	30	35	35
3. Configurations Used	3	3	4
C. Per Day Averages			
1. Experimenters	0.8	0.6	0.8
2. Samples	3.04	2.97	2.75

EDUCATION AND TRAINING

V. EDUCATION AND TRAINING

During the past year, the Penn State RSEC was used for a variety of educational services; in-house training, formal laboratory courses and many continuing education programs and tours.

In-house reactor operator requalification during November of 1992 consisted of an oral examination on abnormal and emergency procedures given by T. L. Flinchbaugh and an operating test given by M. E. Bryan. In January of 1993, the NRC administered a requalification written exam and operating test to D. E. Hughes, M. H. Voth and K. E. Rudy. All three successfully passed the exams. The other nine licensed staff also took the written exam to fulfill the in-house requalification requirement for 1993.

Staff member Patrick Boyle, a licensed reactor operator, was granted his senior operator license by the NRC in January of 1993. Dave Miller joined the staff in January of 1993 as an operator intern and was granted a senior reactor operator license in June of 1993.

The seventh session of the Pennsylvania Governor's School for Agricultural Sciences was held at Penn State's University Park campus during the summer of 1992. Sixty-four high school scholars participated in the five week program at Penn State. The Governor's School for Agricultural Sciences includes introduction and experience in many different agricultural disciplines. There are several parts of the program which are considered "core courses". The core courses are fundamental instruction given to all participants. "Radioisotope Applications in Agricultural Research" is one of the core courses in the program. The core course (normally eight hours) was shortened to six hours due to time and conflicting program constraints. The program was conducted at Penn State's RSEC by Candace Davison of the RSEC staff. Guy Anderson and Joy Moncil assisted in the teaching sessions. Hermina Boyle, Supervisor of the Low-Level Radiation Monitoring Laboratory, provided a session on detection of radiation in the environment including radon gas. The students performed a series of experiments focusing on the fundamentals of radiation interaction and principles of radioisotope applications. These experiments included a demonstration of a cloud chamber; penetrating ability of alpha, beta and gamma radiation; half-life calculation and gamma ray spectroscopy. The importance of statistics in taking data and other applications of radioactive materials in research were discussed. The students were also given a tour of the reactor facility.

The Nuclear Concepts and Technological Issues Institute (NCTII) was conducted from July 6-31, 1992 at the University Park campus. The Nuclear Concepts program was designed to prepare secondary science educators to teach the basics of nuclear science, radiation, and applications and is offered as a special topics course in nuclear engineering (NUCE 497B). The program was developed in 1970 and has been conducted every summer since that time. Twenty-six secondary science teachers including one Energy Technology Project Staff person participated in the program.

Support for the program included funding for fourteen participants through a grant from the National Science Foundation. Sponsorship of the other twelve participants was provided by Chem-Nuclear Systems Inc., Duquesne Light Company, Edison Electric Institute, General Electric Company, Gilbert Commonwealth, Limerick and Peach Bottom Community Education Program (through the Philadelphia Electric Company), New York State Electric and Gas Company, the American Nuclear Society and various school districts. Materials were obtained from the U.S. Department of Energy, USCEA, ANS and other sources. General Electric Company donated many educational materials to the course including a full-size Chart of the Nuclides and booklet to each participant. Oxford Instruments Inc. provided a loan of educational counting equipment and hosted the evening reception for participants and sponsors.

The institute was coordinated by Candace Davison and was conducted through Penn State's Continuing Education Office. Joseph Bonner presented the fundamental nuclear science lectures. Other instruction was provided by Nuclear Engineering department personnel and Rodger Granlund, University Health Physicist. Guest speakers from government, research institutions and industry provided expertise for the technical and issues sessions. Guest speakers included Ms. Carol Hanlon from the U.S. Department of Energy, Office of Civilian Radioactive Waste Disposal and Management, Dr. Robert Meyer from Chem-Nuclear Systems Inc., Mr. John Redding from General Electric Company, Mr. Doug Ekeroth from Westinghouse Electric Corporation, Dr. Grafton Chase retired professor from the Philadelphia College of Pharmacy and Science, Dr. Ralph Mumma distinguished professor of environmental quality at Penn State, Mr. Jeff Schmidt from the PA Sierra Club and Dr. Warren Witzig professor emeritus of nuclear engineering.

Laboratory experiments are an important aspect of the institute as the teachers are able to have hands-on experience with radioactive materials. The laboratories were conducted at the RSEC under the direction of the RSEC and Health Physics personnel. Guy Anderson, a chemistry teacher from the Bald Eagle Area School District, was in charge of the laboratories and was assisted by Craig Munnell, a physics teacher from Bellefonte HS. Both teachers are graduates of the Nuclear Concepts program. The laboratory experiments and demonstrations included: characteristics of ionizing radiation, radionuclide handling, neutron activation of Indium, complex decay of Silver-110 and Silver-108, neutron radiography and the approach to critical experiment. Discussion and problem solving sessions, a tour of Medical Applications including an MRI, and a visit to either Three Mile Island Unit 1 (a PWR) or Susquehanna Steam Electric Station (a BWR) were included in the schedule.

Evaluations from the participants were very positive concerning the course. As in previous institutes, the participants in NCTII were encouraged to return with their students for a day of experiments at the RSEC. Two follow-up programs were conducted for past participants of the Nuclear Concepts course during the month of May to address topics of interest in depth. One of the sessions was held as part of the American Nuclear Science Teachers Association meeting at the U.S. Nuclear Regulatory Commission and the Smithsonian Institution in Washington D.C. and the other session on applications of Radiation and Medicine was held at Penn State's Milton S. Hershey Medical Center.

The University Reactor Sharing Program is sponsored by the U.S. Department of Energy. The purpose of this program is to increase the availability of the university nuclear reactor facilities to non-reactor owning colleges and universities. The main objectives of the University Reactor Sharing program are to strengthen nuclear science and engineering instruction and to provide research opportunities for other educational institutions including universities, colleges, junior colleges, technical schools and high schools.

Experiments were conducted at the RSEC for students from Juniata College and Lock Haven University.

A total of 551 students and teachers from 24 high schools and 2 colleges came to the RSEC for experiments and instruction. (see Table 5). Candace Davison and Lois Lunetta were the main instructors for the program. Other instruction and technical assistance for experiments were provided by Eric Sipos, Thierry Daubenspeck, Dan Hughes and Joy Moncil.

The RSEC staff and facilities provided educational opportunities along with a tour for student and teacher workshops, many of which were conducted as part of a larger program on campus through Penn State Continuing Education Programs. The student programs included: the Kodak BEST (Business, Science, Engineering and Technology) program, the SEE the Future program, the Atoms Scholars program and the Upward Bound program for minority and "at risk" students.

Twenty-four teachers from the Harrisburg area participated in a full day of experiments as part of the course "Exploring the Nuclear Option". Seventeen teachers toured the facility as part of the Renaissance in Engineering Week (RENEW) program. Thirty-nine teachers from the Enter-2000 program received instruction and toured the facility to learn more about nuclear energy and related careers.

Faculty member Robert Edwards and graduate assistant Mike Power hosted two high school students for two half-days of pulsing experiments using the reactor. The students were participating in the two-week Penn State Summer Space Academy Program sponsored by NASA.

In addition to the full or half-day programs with experiments, educational tours were conducted for students, teachers and the general public. All groups, including the reactor sharing groups, who toured the facility are listed in Appendix B. The RSEC operating staff and Nuclear Engineering Department conducted 101 tours for 2,242 persons.

Involvement of the reactor personnel and the role of the reactor in educational programs was recognized this past year when Candace Davison, also president of the American Nuclear Science Teachers Association, was invited to present several talks on precollege nuclear science programs for students and teachers and the impact on career decisions. The presentations were presented at the American Chemical Society in Washington, D.C., the American Association of Physics Teachers Western PA Chapter meeting at Indiana University of Pennsylvania and the High Level Radioactive Waste Management Conference in Las Vegas, Nevada.

The RSEC was used by several Nuclear Engineering and other courses during the year.

Semester		Course	Instructor	Students	Hours
Summer	1992	NucE 497B-Nuclear Concepts	C. C. Davison	28	8
Summer	1992	NucE 444-Nuclear Reactor Operations	D. E. Hughes	3	15
Summer	1992	Food Science 313-Process Plant Product	R. B. Beelman	33	3
Fall	1992	NucE 420-Radiological Safety	E. S. Kenney	16	2
Fall	1992	NucE 451-Reactor Physics	R. M. Edwards W. A. Jester	20	77
Spring	1993	NucE 450-Radiation Detection and Measurement	M. H. Voth W. A. Jester	23	12
Spring	1993	NucE 505-Reactor Instrumentation and Control	R. M. Edwards	8	6
Spring	1993	Entomology 456-Insect Pest Management	A. Hower	10	2
Summer	1993	SciEd 497-Exploring the Nuclear Option	C. C. Davison	24	4
Summer	1993	NucE 450-Radiation Detection and Measurement (Westinghouse)	M. H. Voth W. A. Jester	27	24

In February of 1993, a total of 42 University Police Services personnel were given training and retraining sessions by C. C. Davison at the RSEC to ensure familiarity with the facilities and to meet Nuclear Regulatory Commission requirements.

During the past year, the RSEC operating staff has maintained reactor operator competence and safe facility operation through training and requalification. The RSEC and continuing education staffs have disseminated knowledge directly to the general public through tours and indirectly through programs such as Nuclear Concepts for high school teachers. Many educational opportunities have been provided to students in university courses both nuclear and non-nuclear.

TABLE 5

University Reactor Sharing Program
College and High School Groups
1992-1993 Academic Year

Those who came to the RSEC for experiments received instruction on the basics of radiation and nuclear energy and received a tour of the facility. All groups either conducted the approach to critical experiment or saw a demonstration with the reactor. Most groups also did one of the other experiments listed below.

Gamma Ray Spectroscopy
Neutron Activation and Complex Decay of Silver
Barium-137m Decay or Silver Decay
Neutron Activation Analysis
Relative Stopping Powers for α, β and γ in Air, Aluminum and Lead

Month		School and Teacher	Number of Students & Teachers
October	19	Clearfield County Teachers	7
November	4	Twin Valley HS Doug Mountz	55
	9	Berwick HS Jeff Snyder	12
	13	Teacher Workshop	7
	16	Johnsonburg/Kane High School JoAnn Castle IU-9	17
December	2	Wyomissing High School Charles Bell	4
	7	Greensburg - Salem HS Cheryl Harper	18
	14	Carlisle HS Robert Barrick, Kenneth Egolf	44
January	15	Jersey Shore High School James Allen	16
February	18	State College HS	26
March	1	State College HS Sara Bresler	12
	17	Daniel Boone High School Larry Tobias	15
	29	Redland HS Jo Becker	15
April	5	Mt. Union HS Janet Whitaker, Suzanne Brown	20
	12	Northern Bedford Yvette Blair	31
	14	Carmichael High School Pat Gibson	23
	16	St. Mary's High School William Scilingo	25

TABLE 5

University Reactor Sharing Program
College and High School Groups
1992-1993 Academic Year
(Continued)

Month		School and Teacher	Number of Students & Teachers
April	16	Ridgway HS Ernest Koos	18
	19	Loyalsock HS John Gernan	23
	21	Juniata College Norm Siems	6
	28	Harborcreek HS Dave Sidelinger	12
May	3	Muncy HS Harold Shrimp, Larry Grieco	35
	10	Dallastown HS Mark Ilyes	8
	18	Danville HS Michael McDevitt, Deb Slattery	27
	19	Somerset HS Jon Critchfield	27
	24	Warren HS Dan Giffin	11
	24	State College HS Marguerite Ciolkosz	11
June	2	Lock Haven University	2
	16	Williamson HS Bob Burket	24

NEUTRON BEAM LABORATORY

VI. NEUTRON BEAM LABORATORY

The Neutron Beam Laboratory (NBL) is one of the experimental facilities that is a part of the RSEC. A well collimated beam of neutrons, thermalized by a D_20 thermal column, is passed into the NBL for use in non-destructive testing and evaluation. Work now being done utilizes a Real Time Neutron Image Intensifier, by Precise Optics, Inc., for real time radiography. The beam is also being used for static neutron radiography and neutron attenuation studies, and flash radiography utilizing pulsing. There is also equipment available to digitize the real time radiography images for image processing.

The NBL was established partially with funds from the U.S. Department of Energy with matching funds from the University to:

1. Educate students and the public on an important use of neutrons from a research reactor,

2. Establish a demonstration center, "Neutrons in Action," to show that their use is beneficial to mankind, and

3. Expand the use of neutron radiography in research, both as a tool for improving the development of U.S. industrial products and to develop new information in other fields of science and engineering.

Bettis Atomic Power Laboratory purchased time to utilize the neutron beam laboratory to evaluate two phase flow during the past year and the project continues. We continue to have funded service work utilizing the beam to measure neutron attenuation of boraflex materials that have seen service in fuel storage pools.

Dhushy Sathianathan, assistant professor of Engineering Graphics, has recently completed a new photography lab to facilitate the development and analysis of static neutron radiographs. A project has been started to enhance the quality and intensity of the neutron beam entering the NBL. This project is being partially funded with funds from the U.S. Department of Energy and matching funds from the University. It is expected that the project will be completed in the next year.

RADIONUCLEAR APPLICATIONS

LABORATORY

VII. RADIONUCLEAR APPLICATIONS LABORATORY

Personnel of the Radionuclear Applications Laboratory provide consulting and technical assistance to those University research personnel who wish to utilize some type of radionuclear technique in their research. The majority of these research projects involve neutron activation, but the staff is able to provide services in radioactive tracer techniques, radiation gauging, radiation processing, and isotope production for laboratory, radionuclear medicine and industrial use.

Laboratory personnel continue to supply support for the operation of the RSEC doing analysis of water, air monitor filters and other samples. During the past year, thermal and fast neutron dosimetry measurements were made in a variety of regularly used irradiation facilities.

Approximately 164 irradiations of semiconductors were performed during the past year for several electronic companies. Laboratory personnel prepared each set of devices for irradiation, calculated the 1-MeV Silicon Equivalent fluence received, determined the radioisotopes produced in the devices, packaged and shipped the devices back to the companies. In addition to semiconductors, analyses were performed for a variety of other industrial customers.

Analyses of samples were performed for Penn State students and faculty members who had samples to be analyzed but did not have the time to learn how to perform the analysis. In addition to providing analyses services, short instructional sessions were provided to persons wishing to perform their own analyses of their samples.

During the past year, the ND66 computer system located in Room 4 stopped working. This system had been in use since the early 1980's and had occasionally shown some signs of not working properly. The multichannel analyzer-PC computer system purchased last year and located in the reactor bay was moved to Room 4 and hooked up to the detector. Unfortunately, with this move, we no longer have the capability of acquiring a spectrum and printout in the reactor bay. A second multichannel analyzer-PC computer system purchased last year has been in service in Room 2A.

Progress has been made in learning how to use the software on the new multichannel analyzer-PC computer systems, but additional work is needed to better understand the capabilities of the programs. A graduate student has been assigned to write a user's guide that will be easily understandable.

The benchmarking of the reactor neutron energy spectrum following ASTM procedures is complete. A final report from Sandia National Laboratories confirmed our results making the RSEC a "certified" facility for radiation hardening work. We are attempting to purchase fission foils for any similar future work to replace those on loan from Sandia. This project has raised some very interesting issues concerning gamma radiation damage to radhard devices which will be explored in the future as funding is available.

In May of 1993, a two-day workshop was conducted for three members of the reactor staff of the Armed Forces Radiobiological Research Institute (AFRRI). Training was conducted in areas of sample preparation and positioning, radiation counting, fluence determination and the associated quality assurance issues.

LOW LEVEL RADIATION MONITORING LABORATORY

VIII. LOW LEVEL RADIATION MONITORING LABORATORY

The staff of the Low Level Radiation Monitoring Laboratory (LLRML) provides analytical and environmental monitoring services to community water suppliers, private laboratories, utilities and researchers at the University. Since July 1, 1992, the LLRML personnel have analyzed samples from 37 laboratories representing 257 different public water systems. Mack Labs, Incorporated of Pittsburgh, PRC Environmental Labs of Sinking Springs, Mahaffey Labs of Grampian, and SSM Labs of Pittsburgh have joined the LLRML clientele since July 1992.

The LLRML has begun several new projects. Howmedica of New Jersey has requested gamma, gross alpha and gross beta analyses of materials used in producing femoral heads in hip-joint replacements. The LLRML, in cooperation with the reactor facility, began analyses based on the work of graduate student Abdul Dulloo of enriched Lithium samples for Isotec Incorporated of Ohio. The LLRML has begun supplying American Inspection Agency of Bath, Pennsylvania with long-term electret devices for testing radon in homes in the Allentown/Bethlehem area.

The LLRML has expanded its participation in the Environmental Protection Agency's (EPA) Environmental Radioactivity Laboratory Intercomparison Studies Program to include Strontium-89, Strontium-90, and Tritium analyses and has successfully passed these checks. The LLRML is planning to add Natural Uranium and Gamma analyses to the list of ongoing EPA cross-check programs and is looking forward to increasing its number of certified analyses. The LLRML is currently certified via the EPA program by the Pennsylvania Department of Environmental Resources (PA DER) to perform gross alpha, gross beta, radium-226 and radium-228 analyses on drinking water. This past year the LLRML has applied for and received certification in the State of New Jersey for the above listed drinking water analyses.

In addition to the above listed analyses, the LLRML is certified via the EPA National Radon Measurement Proficiency Program to test for radon using activated charcoal canisters and both short and long term electret devices. Both Maurice Peagler and Hermina Boyle have passed the RMP exam for radon test operators and will be listed in the next posting of EPA certified radon testing labs/individuals. They join William Jester, the lab's technical advisor, in this category.

The LLRML has updated data management in several key areas. Control charts are now handled exclusively through an Excel format. Sample log-ins, radon testing kits, sample disposal schedules, rad waste disposal and various equipment calibrations have been converted from the Microsoft Chart program to Excel. Joy Moncil continues to work to incorporate all the LLRML drinking water sample data into a comprehensive Excel data base. Scheduled completion date for this project is December 1993.

THE ANGULAR CORRELATIONS LABORATORY

IX. THE ANGULAR CORRELATIONS LABORATORY

The Angular Correlations Laboratory has been in operation for approximately 7 years. The laboratory, which is located in Room 116 and Room 4 of the RSEC, is under the direction of Professor Gary L. Catchen. The laboratory contains two spectrometers for making Perturbed Angular Correlation (PAC) measurements. One apparatus, which has been in operation for seven years, measures eight coincidences concurrently using cesium fluoride detectors. A second spectrometer was acquired two years ago, and it measures four coincidences concurrently using barium fluoride detectors. The detectors and electronics provide a nominal time resolution of 1 nsec FWHM, which places the measurements at the state-of-the-art in the field of Perturbed Angular Correlation Spectroscopy.

Currently, Penn State has a unique research program that uses PAC Spectroscopy to characterize technologically important electrical and optical materials. This program represents the synthesis of ideas from two traditionally very different branches of chemistry, materials chemistry and nuclear chemistry. Although the scientific questions are germane to the field of materials chemistry, the PAC technique and its associated theoretical basis have been part of the fields of nuclear chemistry and radiochemistry for several decades. Two federal agencies, the National Science Foundation and the Office of Naval Research, are sponsoring this program.

The PAC technique is based on substituting a radioactive probe atom such as either ^{111}In or ^{181}Hf into a specific site in a chemical system. Because these atoms have special nuclear properties, the nuclear (electric quadrupole and magnetic dipole) moments of these atoms can interact with the electric field gradients (efgs) and hyperfine magnetic fields produced by the extranuclear environment.

Static nuclear electric quadrupole interactions can provide a measure of the strength and symmetry of the crystal field in the vicinity of the probe nucleus. In the case of static interactions, the vibrational motion of the atoms in the lattice is very rapid relative to the PAC timescale, i.e., 0.1-500 nsec. As a result, the measured efg appears to arise from the time-averaged positions of the atoms, and the sharpness of the spectral lines reflects this "motional narrowing" effect. In contrast to static interactions, time-varying interactions arise when the efg fluctuates during the intermediate-state lifetime. These interactions can provide information about defect and ionic transport. The effect of the efg fluctuating in either strength or direction, which can be caused, for example, by ions "hopping" in and out of lattice sites, is to destroy the orientation of the intermediate state. Experimentally, this loss of orientation appears as the attenuation or "smearing-out" of the angular correlation. And, often a correspondence can be made between the rate of attenuation and frequency of the motion that produced the attenuation.

Magnetic hyperfine interactions, which can be measured in ferromagnetic and paramagnetic bulk and thin-film materials, are used to study the effects of defects and lattice distortions in metal and semiconducting structures that have nominal cubic symmetry. The general approach is to measure the magnetic hyperfine interaction in a material with few defects. The cubic symmetry requires that the electric quadrupole interaction vanishes. When either defects or distortions are produced, a quadrupole interaction arises that attenuates the usually-well-defined magnetic interactions. Thus, the analysis of this attenuation can provide information, for example, about the type of defect that produced the quadrupole interaction.

Current Activities

During the last several years, the PAC technique has been used to investigate phase transitions and local ordering in ferroelectric perovskites such as lead titanate and barium titanate. These

compounds and other related materials are widely used as dielectric materials for capacitors, piezoelectric transducer materials, and thin-film elements for random access memories. Static nuclear quadrupole interactions measured in these materials have provided new information about displacive (paraelectric-to-ferroelectric) phase transitions such as the critical behavior of the (titanium-site) electric field gradient at temperatures near the transition temperature. In particular, since few of the ABO_3 perovskites have been investigated, similar measurements need to be performed on $KNbO_3$, $KTaO_3$, and similar materials. The primary objective is to observe critical effects near the ferroelectric-to-paraelectric transition temperatures in several of these compounds. Specifically, the theory of critical pheonomena provides an appropriate context in which to interpret the critical exponents that describe the power-law temperature dependence of the nuclear-quadrupole-interaction parameters at temperatures very close to the critical temperature. Ultimately, measurements of critical phenomina in ferroelectric crystals can be compared to the results of similar measuremetns on other kinds of highly-correlated crystals such as ferromagnetics. These comparisons could lead to a more fundamental understanding of the crystal instabilities that give rise to the phase transitions. The office of Naval Research has been funding this project.

Another important area of research in electronic materials is the characterization of chemical interactions on molecular-beam-epitaxy (MBE) produced surfaces. In principle, the PAC technique can measure the strength and symmetry of the chemical bonding of the ^{111}In probe atom on MBE-produced surfaces of gallium arsenide and other III-V materials. Currently, electron scattering is the predominant technique that is used to evaluate the morphology of MBE-produced III-V surfaces. But, these measurements do not provide any detailed, microscopic information about for example, the effects of step edges and kinks on the chemical bonding of impinging atoms on these surfaces. The PAC technique, which would use the ^{111}In probe could be used to measure these effects. Moreover, during the last decade, a German group has shown that PAC measurements on Cu and CuIn surfaces under ultrahigh vacuum are feasible and that the measurements do provide information about chemical bonding on MBE-produced surfaces. A project of this type requires a collaboration between an expert in MBE-produced surfaces and an expert in PAC spectroscopy. Penn State has such an expert; namely, Professor David L. Miller of the Department of Electrical and Computer Engineering. The Electronic Materials and Processing Research Laboratory (of the College of Engineering) has a large state-of-the-art Varian MBE machine. But, to dope the MBE-produced surfaces, a small, dedicated ultrahigh vacuum chamber has been added to the existing MBE system. This chamber is used to dope IV-V surfaces with ^{111}In; and because it is separated from the main MBE chambers, the main chamber cannot become contaminated. After surfaces are doped, PAC measurements are performed while the surfaces are maintained under ultrahigh vacuum. During the past year, the separate chamber and the PAC spectrometer have been placed into operation. Currently, experiments are being performed using this new experimental capability. The National Science Foundation has been funding this project.

NUCLEAR MATERIALS ENGINEERING LABORATORY

X. NUCLEAR MATERIALS ENGINEERING LABORATORY

The Nuclear Materials Engineering Laboratory has two heavily shielded hot cells with master-slave manipulators for the remote handling of highly radioactive materials viewed directly through thick leaded-glass windows. Equipment is provided for impact testing, tensile testing, hardness testing, fracture toughness testing, fatigue testing, creep testing, corrosion testing, metallographic examination, positron annihilation studies, light microscopy and electron microscopy. Research has focused on plant life extension for nuclear power reactors.

RADIATION SCIENCE & ENGINEERING CENTER RESEARCH

XI. RADIATION SCIENCE AND ENGINEERING CENTER RESEARCH UTILIZATION

Research continues to be the major focus of the RSEC. A wide variety of research projects are currently in progress as indicated on the following pages. The University oriented research projects are arranged alphabetically by department in Section A. Theses, publications, papers and technical presentations follow the research description to which they pertain. In addition, Section B lists other university and industrial research utilizing the facility.

The reporting of research information to the editor of this report is at the option of the researcher, and therefore the research projects in sections A and B are only representative of the research at the facility. The projects described involved 1 technical presentation, 10 reports, 6 papers, 20 publications, 1 patent pending, 8 masters' theses, 15 doctoral theses and 1 bachelor's thesis. The examples cited are not to be construed as publications or announcements of research. The publication of research utilizing the RSEC is the prerogative of the researcher.

Appendix A lists all university, industrial and other users of RSEC facilities, including those listed in sections A and B. Names of personnel are arranged alphabetically under their department and college or under their company or other affiliation. During the past year, 64 faculty and staff members, 33 graduate students and 6 undergraduate students have used the facility for research. This represents a usage by 16 departments or sections in 4 colleges of the University. In addition, 64 individuals from 37 industries, research organizations or other universities used the RSEC facilities.

A. PENN STATE RESEARCH UTILIZING THE FACILITIES OF THE RADIATION SCIENCE AND ENGINEERING CENTER

Chemistry Department

THE SYNTHESIS AND CHARACTERIZATION OF ANIONIC POLY(ORGANOPHOSPHAZENE) HYDROGELS

Participants: H. R. Allcock
A. A. Ambrosio

Service Provided: Gamma Irradiation

The surface of a polymeric implant influences the tissue response toward the implant and hence, determines the biocompatibility of the polymer. Previous studies have shown that polymers with hydrophilic surfaces exhibited improved biocompatibility. Moreover, materials with negatively charged surfaces showed enhanced blood compatibility. Thus, the goal of this project is to synthesize and evaluate anionic poly(organophosphazene) hydrogels for potential applications in the biomedical field. A series of poly[(methoxyethoxyethoxy)(sodium carboxylato)phosphazenes] with varying ratios of the cosubstituents have been synthesized. Blends of the corresponding homopolymers were also prepared and subsequently crosslinked by gamma irradiation. Preliminary tests have shown that the swelling of the crosslinked blends in aqueous solutions was pH dependent. Further characterization is in progress.

Doctoral Thesis:

Ambrosio, A. A., and H. R. Allcock, advisor. The Synthesis and Characterization of Poly(organophosphazenes) for Biomedical Applications. In progress.

Chemistry Department

STEREOCONTROLLED POLYMERIZATION OF DIENE MONOMERS WITHIN A TRIS(O-PHENYLENEDIOXY)CYCLOTRIPHOSPHAZENE TUNNEL CLATHRATE

Participants: H. R. Allcock
G. K. Dudley
E. N. Silverberg

Service Provided: Gamma Irradiation

The inclusion and polymerization of the diene monomers 2,3-dimethyl butadiene, isoprene, trans-piperylene, trans-2-methyl-1,3-pentadiene, 4-methyl-1,3-pentadiene, chloroprene, 1,3-cyclohexadiene, 2,3-dimethyl butadiene-co-isoprene, isoprene-co-trans-piperylene and isoprene-co-butadiene within the tunnels of clathrates formed by tris(o-phenylenedioxy) cyclotriphosphazene have been achieved. The polymerizations were accomplished by ^{60}Co γ-irradiations. All the polymers obtained by this technique resulted from 1,4-addition. Specifically 1,4-trans poly(dimethyl butadiene), 1,4-trans poly(isoprene), isotactic 1,4-trans poly(trans-piperylene), isotactic 1,4-trans poly(trans-2-methyl-1,3-pentadiene), 1,4-trans poly(4-methyl-1,3-pentadiene), 1,4-trans poly(chloroprene), atactic 1,4 poly(cyclohexadiene), 1,4-trans

poly(isoprene/dimethyl butadiene), 1,4-trans poly(isoprene/trans-piperylene), and 1,4-trans poly(isoprene/butadiene) were formed. The stereoregularity is explained in terms of monomer packing arrangements in the tunnels.

Doctoral Thesis:

Dudley, G. K., and H. R. Allcock, advisor. Novel Synthesis of Diene Polymers. In progress.

Publication:

Allcock, H. R., G. K. Dudley and E. N. Silverberg. Stereocontrolled Polymerization of Diene Monomers within a Tris (o-phenylenediory) cyclotriphosphazene Tunnel Clathrate. Submitted to *Macromolecules*.

Chemistry Department

SYNTHESIS OF NOVEL COMPOSITES WITH POLY(ORGANOPHOSPHAZENE) NETWORKS

Participants: H. R. Allcock
C. S. Reed
P. W. Brown
K. Tenhuisen

Service Provided: Gamma Irradiation

Composites utilizing a poly(organophosphazene) network and hydroxyapatite as the inorganic matrix comprise a new class of materials. The poly(organophosphazenes) considered are poly[bis(methoxyethoxyethoxy)phosphazene], poly[bis(monomethylamine)phosphazene], poly[bis(carboxylatophenoxy)phosphazene], and poly[bis(p-sulfonicphenoxy)phosphazene]. These polymers are water-soluble and intrinsically hydrothermally and thermo-oxidatively stable. The inorganic precursors used in the formation of hydroxyapatite are tetracalcium phosphate (TetCP) and dicalcium phosphate dihydrate (DCPD). Composites of varies ratios of polymer to hydroxyapatite have been prepared and examined.

Doctoral Thesis:

Reed, C. S., and H. R. Allcock, advisor. Advanced Applications of Poly(organophosphazenes). In progress.

Chemistry Department

STEREOCONTROLLED POLYMERIZATION WITHIN A CYCLOPHOSPHAZENE CLATHRATE TUNNEL

Participants: H. R. Allcock
E. N. Silverberg
G. K. Dudley

Service Provided: Gamma Irradiation

The inclusion and ^{60}Co γ-ray initiated polymerization of vinylic and acrylic monomers within the clathrate-tunnels formed by tris(o-phenylenedioxy)cyclotriphosphazene is described. Methacrylonitrile, methacrylic acid, ethyl acrylate, butyl acrylate, hexyl acrylate, allyl methacrylate, vinyl acetate and vinyl anisole monomers were included by direct contact imbibition. Varying degrees of stereoregularity were obtained from the inclusion polymerization of the monomers listed above. For example, poly(methacrylonitrile) synthesized within the host adduct showed an enhanced isotactic microstructure. Another aspect of clathrate-mediated polymerization is that no radiation cross-linked material was obtained for polymers derived from the acrylates and methacrylonitrile, in contrast to the corresponding radiation-induced bulk polymerizations. The copolymer, poly(vinyl acetate-co-methyl acrylate), was also prepared using the inclusion polymerization method.

Doctoral Thesis:

Silverberg, E. N., and H. R. Allcock, advisor. Phosphazene Clathrate Systems. In progress.

Publication:

Allcock, H. R., E. N. Silverberg and G. K. Dudley. Stereocontrolled Polymerization within a Cyclophosphazene Clathrate Tunnel. Submitted to *Macromolecules*.

Chemistry Department

POLY(ORGANOPHOSPHAZENES) CONTAINING ALLYL SIDE GROUPS: CROSSLINKING AND MODIFICATION BY HYDROSILYLATION

Participants: H. R. Allcock
D. E. Smith
Y. B. Kim

Service Provided: Gamma Irradiation

Poly(organophosphazenes) containing 4-allyloxyphenoxy and 4-(4'-allyloxy-phenyl)phenoxy side groups were synthesized. These polymers were crosslinked thermally and by UV and γ radiation. It was proposed that the allyl group could be used as a functional site for further chemical modification. Hydrosilylation reactions were first investigated using a small molecule model compound, pentaphenoxy mono 4-allyloxy phenoxy cyclotriphosphazene. Heptamethyltrisiloxane and dimethylethoxysilane underwent hydrosilylation reactions with the model compound. The dimethylethoxy silane group underwent hydrolysis and self-condensation reactions in the presence of acid. Hydrosilylation of high polymers containing unsaturated side groups resulted in poly(organophosphazenes) with terminal dimethyl siloxane grafts. Control of the reactant ratios allowed siloxane-containing polymers to be synthesized with residual unsaturated sites to facilitate crosslinking by the previously mentioned methods.

Chemistry Department

SYNTHESIS AND CHARACTERIZATION OF NOVEL POLY(ORGANOPHOSPHAZENE) INTERPENETRATING POLYMER NETWORKS

Participants: H. R. Allcock
K. B. Visscher

Service Provided: Gamma Irradiation

The synthesis and characterization of novel Interpenetrating Polymer Networks (IPN) composed of poly(organophosphazenes) and organic or inorganic polymers is investigated. The phosphazene polymers form the cross-linked polymer matrix of the IPN within which the organic or inorganic monomers are polymerized. The phosphazene polymers may be cross-linked by exposure to ^{60}Co γ-radiation or UV radiation which cross-link the polymers either through a double bond or by loss H-SiOEt. These IPNs are characterized by ^{1}H NMR, ^{31}P NMR and FT-IR spectroscopy, DSC and electron microscopy-TEM and SEM.

Doctoral Thesis:

Visscher, K. B., and H. R. Allcock, advisor. Polyphosphazene Alloys: Polymer Blends and Interpenetrating Polymer Networks. In progress.

Publication:

Allcock, H. R., and K. B. Visscher. Synthesis and Characterization of Novel Poly(organophosphazene) Interpenetrating Polymer Networks. In progress for *Chemistry of Materials.*

Chemistry Department

SYNTHESIS AND CHARACTERIZATION OF POLYPHOSPHAZENE/POLY(SILOXANE) BLENDS AND IPNS

Participants: H. R. Allcock
K. B. Visscher

Service Provided: Gamma Irradiation

In this paper, we describe the synthesis and characterization of poly(organophosphazene)/poly(siloxane) blends and IPNs. These materials may be miscible or immiscible depending on intermolecular interactions between the constituent materials. IPNs are constructed so that the constituents are in more intimate contact with each other than they are in the blends. This more intimate contact may increase the possiblity of miscibility and intermolecular interactions between the component materials. The blends and IPNs have been characterized by NMR and IR spectroscopy, DSC and electron microscopy.

Doctoral Thesis:

Visscher, K. B., and H. R. Allcock, advisor. Polyphosphazene Alloys: Blends and Interpenetrating Polymer Networks. In progress.

Publication:

Allcock, H. R., and K. B. Visscher. Synthesis and Characterization of Polyphosphazene/Poly(siloxane) Blends and IPNs. In progress for *Chemistry of Materials.*

Chemistry Department

SYNTHESIS AND CHARACTERIZATION OF ION COMPLEXING POLYPHOSPHAZENE INTERPENETRATING POLYMER NETWORKS

Participants: H. R. Allcock
K. B. Visscher

Service Provided: Gamma Irradiation

The synthesis of several ion-complexing interpenetrating polymer networks composed of polyphosphazenes and coordinative organic polymers is reported. Full, sequential IPNs were prepared from poly[bis . (2-methoxyethoxy)ethoxy)phosphazene], poly[bis(propyloxyben. ate)phosphazene] and several organic polymers including poly(acrylic acid), poly(sulfonic aci. sodium salt), poly(diundecylenylphosphinate) and poly((p-methylimino diacetoxy)styrene). These materials were characterized by NMR and IR spectroscopy, differential scanning calorimetry (DSC), and transmission electron microscopy (TEM). The metal-complexed IPNs were anlayzed by electron microscopy and x-ray microanalysis.

Doctoral Thesis:

Visscher, K. B., and H. R. Allcock, advisor. Polyphosphazene Alloys: Blends and Interpenetrating Polymer Networks. In progress.

Publication:

Allcock, H. R., and K. B. Visscher. Synthesis and Characterization of Ion Complexing Polyphosphazene Interpenetrating Polymer Networks. In progress for *Chemistry of Materials*.

Chemistry Department

REACTIONS OF POLY[BIS(2-(2-METHOXYETHOXY)ETHOXY) PHOSPHAZENE] UNDER BASIC, NEUTRAL AND ACIDIC CONDITIONS

Participants: H. R. Allcock
K. B. Visscher

Service Provided: Gamma Irradiation

The response of poly[bis((methoxyethoxy)ethoxy)phosphazene] (MEEP) to hydrolytic conditions is reported. Both cross-linked and uncross-linked MEEP were exposed to a variety of aqueous media including acids and bases of different concentrations including HCl, H_2SO_4, HNO_3, H_3PO_4, NaCl, $NaHCO_3$, Na_2CO_3 and NaOH. The polymer is stable for long periods in contact with neutral or (basic?) media, but undergoes hydrolysis under acidic (basic?) conditions. Hydrolysis products were analyzed using ^1H and ^{31}P NMR spectroscopy, FT-IR spectroscopy and gel permeation chromatography (GPC).

Doctoral Thesis:

Visscher, K. B., and H. R. Allcock, advisor. Polyphosphazene Alloys: Blends and Interpenetrating Polymer Networks. In progress.

Publication:

Allcock, H. R., and K. B. Visscher. Reactions of Poly[bis(2-(2-methoxyethoxy)ethoxy) phosphazene] Under Basic, Neutral and Acidic Conditions. In progress for *Chemistry of Materials.*

<u>Geosciences Department</u>

GEOCHEMISTRY AND PETROLOGY OF PRECAMBRIAN MATIC ROCKS FROM SERRA DOS CARAJERÓ BRAZIL

Participants: D. H. Eggler
J. B. Teixeira

Services Provided: Neutron Irradiation and Radiation Counters

The rare-earth elements (REE), along with Hf, Th, Ta, U, Cs and Sc are measured by instrumental neutron activation analysis. Here a 500 mg sample of pulverized rock is irradiated for five hours in a series of 24 samples per run. Gamma-ray spectra of the decaying radionuclides are measured after a few days and recalculated to elemental concentrations.

The element concentrations are used to evaluate some petrological parameters for the samples concerned. The ultimate aim is to study the magma genesis and its evolution, along with the magmatic rocks generated during this process.

Doctoral Thesis:

Teixeira, J. B., and D. H. Eggler, advisor. Geochemistry and Petrology of Precambrian Matic Rocks from Serra Dos Carajeró, Brazil. In progress.

<u>Geosciences Department</u>

NATURE AND ORIGIN OF DIATREME-DIKE ASSOCIATIONS, EAST-CENTRAL MONTANA

Participants: D. P. Gold
A. G. Doden

Services Provided: Neutron Irradiation and Radiation Counters

The present research is part of a Ph.D. project investigating igneous rocks from central Montana. An important goal of this research is to investigate the chemical compositions of bulk rock samples. Neutron irradiation methods have been used to determine the concentrations of rare earth elements, U, Sc, Ta, Ce, and others not obtainable by conventional whole-rock analytical techniques. Acquisition of these data will provide an important basis for properly characterizing the igneous rocks and evaluating their source regions, genesis, and relationships to other igneous rocks in central Montana.

The part of this research conducted at the Breazeale Nuclear Reactor has proceeded with two batches of samples irradiated in February of 1993, followed by three appropriate counting sessions for each batch. The final raw counting data were later determined from the energy spectra and these data are presently being converted to parts per million element concentrations as the final step in the process.

Doctoral Thesis:

Doden, A. G., and D. P. Gold, advisor. Nature and Origin of Diatreme-Dike Associations, East-Central Montana. In progress.

Paper:

Doden, A. G., and D. P. Gold. Unusual Carbonate Dikes and Lamprophyres of Porcupine Dome, East-Central Montana. Geological Society of America, Program with Abstracts, Annual Meeting, 1992.

Industrial Engineering

THE DEVELOPMENT OF THE METHODOLOGY FOR THE OPTIMIZATION OF NEUTRON OPAQUE PENETRANTS FOR USE IN THE EVALUATION OF MANUFACTURING DAMAGE IN MONOLITHIC AND COMPOSITE MATERIALS

Participants: C.O. Ruud
D. F. Poeth, II

Services Provided: Neutron Radiography, Radiation Counters, Laboratory Space, Machine Shop and Flux Monitoring

The purpose of this thesis research was to develop the methodology for the optimization of neutron opaque penetrant fluids for the detection of internal manufacturing process damage in monolithic and composite materials. In this context, internal damage was defined as damage that exists principally in the body of the part, but which may also extend to the part surface. This required a rigorous theoretical and empirical investigation of neutron opaque contrast enhancing penetrants. An emphasis was placed on modeling an idealized penetrant.

Flaws or defects in products may occur during any manufacturing fabrication process. Casting, rolling, and heat treating are all operations which may introduce imperfections in monolithic components. For composite materials, chip forming operations such as machining, drilling, milling, or sawing have all been shown to have a high probability of damaging the component by introducing flaws and defects.

Internal damage in composite and monolithic components is not generally visible using common NDT inspection procedures. Without the ability to evaluate internal damage, it is impossible to accurately verify the useability of the component. It is also more difficult to evaluate and control the part manufacturing process.

This investigation consisted of a theoretical analysis of contrast enhancing penetrants, neutron-matter interactions, and fracture mechanics relevant to neutron radiographic inspection. This analysis evaluated the fundamental physical properties of contrast enhancing penetrant fluids. This phase of the investigation resulted in mathematical equations which represented the optimum characteristics of contrast enhancing penetrants.

Potential penetrant systems were evaluated by estimating their neutron cross section using experimental and analytical techniques. The mathematical model was verified by experimentally measuring the neutron cross section for several fluids using the Breazeale Nuclear Reactor neutron radiography facility.

Doctoral Thesis:

Poeth, D. F., and C. O. Ruud, advisor. The Development of the Methodology for the Optimization of Neutron Opaque Penetrants for Use in the Evaluation of Manufacturing Damage in Monolithic and Composite Materials. 1993.

Publication:

Poeth, D. F., and C. O. Ruud. Options in Nondestructive Testing of Components and Printed Circuit Boards. *Electronic Manufacturing*, March 1990.

Technical Presentation:

Poeth, D. F. Presentation on Neutron Radiography presented at the Nondestructive Test and Evaluation Showcase, The Pennsylvania State University, October 1991.

Metals Science and Engineering

AUTORADIOGRAPHY OF BORON CONTAINING STEEL

Participants: M. D. Irwin
L. J. Cuddy
P. R. Howell

Service Provided: Neutron Irradiation

A phenomenon known as superhardenability has been observed in thermomechanically processed steels since around 1979. The current study is an investigation of this hardenability enhancement mechanism. Several production heats have been studied and enhanced hardenability has been achieved by processing according to methods reported in the literature as requirements for superhardening. The heats varied in composition and deoxidation practice. It was found as a result of Jominy testing and continuous-cooling transformation studies, that the critical event in achieving this hardenability enhancement is a delay in formation of bainite. The observed hardenability enhancement in these steels appears to be the result of a "boron effect." Autoradiography results have confirmed that the boron distribution in the superhardened steel is identical to that seen in a steel hardened by means of the boron effect. The possibility that some type of particle pinning mechanism may be contributing to the hardenability enhancement has been investigated using carbon-extraction replication and transmission electron microscopy.

Master's Thesis:

Irwin, M. D., L. J. Cuddy and P. R. Howell, advisors. Superhardenability and the Boron Effect. In progress.

Paper:

Irwin, M. D., J. B. Breedis, P. R. Howell and L. J. Cuddy. Superhardenability and the Boron Effect. To be presented at the 1993 Fall meeting of the ASM/TMS, Pittsburgh, PA.

Sponsors: Standard Steel and Ben Franklin Partnership Program $55,000

Metals Science and Engineering

STRUCTURE DETERMINATION OF Al_9Co_3Ce

Participants: E. R. Ryba
R. Poduri

Services Provided: Neutron Irradiation and Neutron Activation Analysis

The crystal structure of an alloy of suspected composition Al_9Co_3Ce, is being explored using x-ray diffraction. While the lattice parameters and space group have been found, it is difficult to determine the atomic portions within the unit cell. A literature survey revealed that the alloy Ga_9Co_3Nd had the same space group and lattice parameters as the alloy in question, and hence, the guess that the composition of the alloy is Al_9Co_3Ce. Verification would greatly help the effort to determine the atomic portions. Since the alloy is very brittle, other methods of determining composition (like EDS etc.) cannot easily be used. Neutron activation analysis is being used to identify Al, Co and Ce composition.

Master's Thesis:

Poduri, R., and E. R. Ryba, advisor. X-ray Crystal Structure Determination of an Al Co Ce Alloy. In progress.

Mineral Science and Engineering

CONTINENTAL PLEISTOCENE IMPACT SPHERULES

Participant: B. Phelps

Services Provided: Neutron Irradiation, Radiation Counters and Neutron Activation Analysis

Continental spherules have been found which exhibit many similar and some very unique characteristics to spherules identified from ocean and polar sediments. The objective of this work is to characterize and quantify the chemical composition and map in cross-section the constituents of the spherules.

The characterization, quantification, and mapping of the chemical makeup of the spherules will be done using a two-pronged approach. First, the electron microprobe in the Mineral Constitution Laboratory will be used to analyze for elemental oxides and complete the mapping of these constituents. Second, it is important to verify the presence of iridium which cannot be quantified by the electron microprobe. For this work, neutron activation analysis, which has detection limits of 0.00002 ppm for iridium, will be utilized using the facilities of the Radiation Science and Engineering Center. The results of the search for iridium will also be anlayzed for a suite of additional elements that have been reported in the literature for ocean and polar spherules.

Northeast Watershed Research Center

NITROGEN DYNAMICS IN THE NEAR-STREAM ENVIRONMENT

Participants: R. Schnabel
C. Montgomery

Services Provided: Neutron Irradiation and Neutron Activation Analysis

Poorly-drained soils on floodplains contain environments favorable for ground water cleanup before it discharges into streams. Plant uptake and identification are processes which remove nitrogen from discharging groundwater. The level of cleanup depends on watershed characteristics defining flow dynamics and process intensity. Spiking the system with Br aids in mass balance calulations and process identification. Currently completed one year of a three-year study.

Nuclear Engineering

MECHANICAL PROPERTIES OF BORATED STAINLESS STEEL TO BE USED IN SPENT FUEL RACK ASSEMBLIES

Participants: A. J. Baratta
J. He

Services Provided: Neutron Irradiation, Hot Cell Lab, Radiation Counters, Machine Shop, Low Level Monitoring Lab and Electronics Shop

The purpose of this project is to perform test and analysis of the mechanical properties of several types of borated stainless steels manufactured by Carpenter Technology Corporation. Test specimens in either neutron irradiated or unirradiated conditions are used to investigate potential neutron irradiation effects on the mechanical properties of the borated steels. The application of these steels is to make spent fuel storage channel boxes. It is thought that neutron irradiation in the designated application may embrittle the material, especially in the presence of a significant amount of boron which would produce helium upon neutron interactions. Helium is an agent assisting void growth. So the exact effect of neutron irradiation on the mechanical properties of borated stainless steels is both fundamentally interesting and practically important. The study attempts to resolve most of these concerns and present corresponding recommendations for the intended applications.

The project includes various tests of life-size steel storage channel boxes made of borated steels. Channel box testing is done by compression in one of the following ways: lateral flattening, lateral compression in diagonal direction, or axial compression. Tensile test is performed by mechanically pulling and breaking round tensile bars. JIc toughness test is performed by pulling and breaking fatigue precracked compact tension specimens. Load, displacement and various other information is recorded in a X-Y-Y' plotter and aquired into computer storage to be analyzed for important parameters of mechanical properties of the materials. Tests are conducted for various temperature conditions and on samples irradiated by various levels of neutron fluences and on unirradiated samples in order to give a conservative estimation of changes in mechanical properties which may occur in the postulated worst accident scenarios in the intended applications. Currently, the project is about complete with the remaining JIc toughness tests being performed. It is expected that the tests will be completed by mid June and a full report and a publication can be submitted by the end of the summer.

Doctoral Thesis:

He, J., and A. J. Baratta, advisor. Mechanical Properties of Borated Stainless Steel to be Used in Spent Fuel Rack Assemblies. In progress.

Sponsor: Carpenter Technology

Nuclear Engineering

INVESTIGATING BONDING SITE SYMMETRY IN EPITAXIAL GROWTH USING PERTURBED-ANGULAR-CORRELATION (PAC) SPECTROSCOPY

Participants: G. L. Catchen
J. M. Adams
J. Fu
D. L. Miller

Services Provided: Angular Correlations Lab and Laboratory Space

The objective of this project is to measure chemical-bonding effects on GaAs surfaces using Perturbed-Angular-Correlation (PAC) spectroscopy. The primary experimental apparatus is located in Electrical Engineering West. At the PSBR facility, we are using a radiochemical laboratory for the purposes of preparing Cu foils doped with radioactive ^{111}In → ^{111}Cd, which is the PAC probe used for these experiments. In the EE West laboratory, the ^{111}In-doped foils are placed in an effusion source that is part of an ultrahigh vacuum chamber in which GaAs crystals are grown by molecular beam epitaxy (MBE). The effusion source is used to deposit a small number of ^{111}In atoms (10^{11}-10^{12}) onto GaAs surfaces that were prepared in a different part of the MBE system. After the ^{111}In probe atoms are deposited on the GaAs surface, the surface is moved to an isolated region of the ultrahigh vacuum system where a PAC spectrometer is located external to the system. In this region, PAC measurements are performed on the ^{111}In-doped GaAs surface.

Doctoral Theses:

Adams, J. M., and G. L. Catchen, advisor. Bonding Site Symmetries of ^{111}In Dopants on GaAs Surfaces Measured by Perturbed-Angular-Correlation Spectroscopy. In progress.

Fu, J., and D. L. Miller, advisor. Characterization of GaAs Surfaces Using PAC Spectroscopy and Other Techniques. In progress.

Papers:

Adams, J. M. (presenter), J. Fu, G. L. Catchen and D. L. Miller. New Technique to Dope GaAs Crystals with the ^{111}In → ^{111}Cd PAC Probe. American Chemical Society National Meeting, Washington, DC. August 23-28, 1992.

Fu, J. (presenter), J. M. Adams, G. L. Catchen and D. L. Miller. Perturbed Angular Correlation of ^{111}In → ^{111}Cd on GaAs Surfaces. Materials Research Society Meeting, Symposium W: Atomic Scale Imaging of Surfaces and Interfaces, Boston, MA. November 29-December 5, 1992.

Publication:

Adams, J. M., J. Fu, G. L. Catchen and D. L. Miller. New Technique to Dope GaAs Crystals with the ^{111}In → ^{111}Cd Probe for Perturbed-Angular-Correlation Spectroscopy. *Applied Physics Letters*, 61, 2668-2670.

Sponsor: National Science Foundation $75,000

A STUDY OF $PbTiO_3$ AND $PbZrO_3$ USING PERTURBED ANGULAR CORRELATION (PAC) SPECTROSCOPY

Participants: G. L. Catchen
D. Esh
E. F. Hollinger
T. M. Rearick
R. L. Rasera

Services Provided: Neutron Irradiation, Angular Correlations Lab, Laboratory Space and Isotope Production

Perturbed Angular Correlation (PAC) spectroscopy was performed on the ferroelectric perovskite $PbTiO_3$ and the antiferroelectric perovskite $PbZrO_3$. The $^{181}Hf/^{181}Ta$ PAC probe was substituted into the Ti and Zr sites at concentrations of less than 0.10 atomic percent. Nuclear-electric-quadrupole interactions were measured on phase-pure samples over a temperature range from 290 to 773 K.

In $PbTiO_3$, the electric-field-gradient component, V_{zz} has a value of about 14 x 10^{17} V/cm^2 at room temperature. At temperatures well below the transition temperature T_c, V_{zz} is nearly constant but does decrease slowly. Near T_c, it decreases rapidly to a value of about 0.25 x 10^{17} V/cm^2. V_{zz} is nearly constant over the temperature range above the phase-transition point. The asymmetry parameter, η, is constant over the temperature range approaching T_c. Near T_c, it increases to substantially larger values. The linebroadening parameter, δ, is non-zero up to temperatures close to T_c. δ then increases rapidly to large values above T_c. The parameters V_{zz}, η, and δ, when examined over the full range of temperatures, appear to have a temperature dependence similar to those for $KNbO_3$ and $BaTiO_3$. However, near T_c the behavior of V_{zz}, η, and δ in $PbTiO_3$ seems to be somewhat different than $BaTiO_3$.

In $PbZrO_3$, the electric-field gradient component V_{zz} remains nearly constant with a value of about 4.5 x 10^{17} V/cm^2 over the temperature range below T_c. Near T_c, a second interaction becomes increasingly important, and V_{zz} for this interaction is much smaller in magnitude. The asymmetry parameter, η, is large at temperatures below T_c. Above T_c, η has values that are close to zero. The linebroadening parameter, δ, increases from constant small values below T_c to large values above T_c. At low temperatures, a high-frequency interaction is dominant. Near T_c, a low-frequency interaction becomes increasingly important. Above T_c, the low-frequency interaction dominates. These results indicate that the phase transition in $PbZrO_3$ appears to be very similar in nature to the phase transition in $PbTiO_3$, which is well known to be a first-order transition.

Bachelor's Thesis:

Esh, D., and G. L. Catchen, advisor. A Study of $PbTiO_3$ and $PbZrO_3$ Using Perturbed-Angular-Correlation (PAC) Spectroscopy. 1993.

Paper:

Catchen, G. L. (presenter), E. F. Hollinger and J. M. Adams. Search for Critical Effects in ABO_3 Perovskites Measured by Perturbed-Angular-Correlation (PAC) Spectroscopy. The Eighth International Meeting on Ferroelectricity, NIST, Gaithersburg, MD. August 8-13, 1993.

Publication:

Catchen, G. L., E. F. Hollinger, J. M. Adams and R. L. Rasera. Initial Search For Critical Effects in $KNbO_3$, $PbTiO_3$, $BaTiO_3$, and $PrAlO_3$ Using Perturbed-Angular-Correlation (PAC) Spectroscopy. Submitted to *Ferroelectrics*. February 1993.

Sponsor: Office of Naval Research $69,000

Nuclear Engineering

INITIAL SEARCH FOR CRITICAL EFFECTS IN $KNbO_3$, $PbTiO_3$, $BaTiO_3$, AND $PrAlO_3$ USING PERTURBED-ANGULAR-CORRELATION (PAC) SPECTROSCOPY

Participants: G. L. Catchen
E. F. Hollinger
J. M. Adams
R. L. Rasera

Services Provided: Neutron Irradiation, Angular Correlations Lab and Laboratory Space

Perturbed-Angular-Correlation (PAC) spectroscopy has been used to measure nuclear-electric-quadrupole interactions at the Ti sites in $PbTiO_3$ and $BaTiO_3$, at the Nb site in $KNbO_3$, and at one of the metal-ion sites in $PrAlO_3$. Specifically, we submitted the $^{181}Hf \rightarrow ^{181}Ta$ PAC probe into these crystals at 0.01 - 0.01 at. % of the metal ion concentration. The primary objective was to search for critical effects by measuring the temperature dependence of the metal-ion-site electric-field-gradient (EFG) parameters, V_{zz}, η, and δ at temperatures very close to the ferroelectric-to-paraelectric transition temperature T_c. For $KNbO_3$ and $BaTiO_3$, the exponent β, derived from the power-law dependence of V_{zz} on the reduced temperature, falls into the range of values 0.2 - 0.4 that are expected for three-dimensional, highly-correlated crystals. For $PbTiO_3$, we did not observe a continuous decrease in V_{zz} as the temperature approached T_c. Instead, as the temperature increases, the fraction of probes that experience a very-low-frequency interaction characteristic of the cubic phase increases, and the fraction that experience a high-frequency interaction characteristic of the tetragonal phase decreases. This result suggests that the transition for $PbTiO_3$ has more first-order character. However, for these three compounds, the experimental temperature control was not optimal. As a result, the measured V_{zz} values represent temperature averages over $\approx$ 1 K, and this situation limits further interpretation of the V_{zz} temperature dependences. For $PrAlO_3$, at temperatures near T_c, the temperature dependences of the EFG parameters show no large changes. This result does not suggest an unique explanation, since the probe-site substitution is not known. In addition, all four of the perovskites exhibit anomalies either in the EFG asymmetry or in the lineshape, or in both. These anomalies could be attributed in part to the effects of defects.

Master's Thesis:

Hollinger, E. F., and G. L. Catchen, advisor. Critical Effects in ABO_3 Perovskites Measured by Perturbed-Angular-Correlation Spectroscopy. In progress.

Publication:

Catchen, G. L., E. F. Hollinger, J. M. Adams and R. L. Rasera. Initial Search for Critical Effects in $KNbO_3$, $PbTiO_3$, $BaTiO_3$ and $PrAlO_3$ Using Perturbed-Angular-Correlation (PAC) Spectroscopy; submitted to *Ferroelectrics*. February 1993.

Sponsor: Office of Naval Research $69,000

Nuclear Engineering

COMBINED MAGNETIC-DIPOLE AND ELECTRIC-QUADRUPOLE HYPERFINE INTERACTIONS IN RARE-EARCH ORTHOFERRITE

Participants: G. L. Catchen
T. M. Rearick
J. M. Adams

Services Provided: Neutron Irradiation, Angular Correlations Lab and Laboratory Space

Perturbed-Angular-Correlation (PAC) spectroscopy was used to measure combined nuclear-magnetic-dipole and nuclear-electric-quadrupole interactions in rare-earth orthoferrite (REO) ceramics, $RFeO_3$ (R = La, Pr, Nd, ..., Lu). The rare-earth orthoferrites are canted antiferromagnets that have orthorhombically-distorted perovskite structures. Using the $^{111}In \rightarrow {}^{111}Cd$ probe, the PAC measurements were made over a temperature range from laboratory temperature through the antiferromagnetic-to-paramagnetic transitions (740 - 620 K) and at or near 800 K. In the heavier REOs, the $^{111}In \rightarrow {}^{111}Cd$ probe substitutes primarily into the rare-earth sites; and in the lighter REOs, it can substitute into both the Fe and the rare-earth sites. At the rare-earth sites, the probe undergoes a high-frequency electric-quadrupole interaction that is shifted in energy by a weak magnetic-dipole interaction. The direction of the associated magnetic hyperfine field is nearly perpendicular to the principal z-axis of the electric-field-gradient (EFG) tensor. The magnitude of this field is small, and it may be produced by transferred spin density. In the heavier REOs, the rare-earth-site EFGs are nearly axially symmetric; and, as the rare-earth atomic number decreases, the EFG asymmetry increases. At the Fe sites, the probe undergoes a strong magnetic-dipole interaction that is shifted in energy by a low-frequency electric-quadrupole interaction, which involves very asymmetric EFGs. For $PrFeO_3$, as an example, the strong magnetic-dipole interactions could be attributed to the presence of a supertransferred hyperfine field, in which spin density is transferred via Fe-O-^{111}Cd bonds. The predictions of a quantum-chemistry theory agree within a factor of two with the magnitude of this field. The direction of this field makes an angle of approximately 40° with the principal z-axis of the EFG. For $NdFeO_3$, similar results were obtained.

The results of these experiments indicate that combined interactions can be measured in highly-distorted crystals and that they can be analyzed. Moreover, these results indicate that PAC spectroscopy can provide new information about the magnitudes and directions of supertransferred hyperfine fields, which can be used as benchmarks for theoretical calculations.

Publication:

Rearick, T. M., G. L. Catchen and J. M. Adams. Combined Magnetic-Dipole and Electric-Quadrupole Hyperfine Interactions in Rare-Earth Orthoferrite Ceramics. *Physical Review B* 48: 224-238. 1993.

Nuclear Engineering

METAL CONCENTRATIONS IN PEAT

Participants: T. Daubenspeck
M. Vile
R. K. Wieder

Services Provided: Neutron Irradiation, Radiation Counters and Neutron Activation Analysis

Neutron Activation Analysis was looked at as a possible method of determining metal concentrations in peat collected from polluted and pristine regions. Differentiation between samples was possible, with 14 metals identified.

Master's Thesis:

Vile, M. A., and R.K. Wieder, advisor. Metal Concentrations in Peat. In progress.

Nuclear Engineering

INVESTIGATION OF HISTORIC ST. MARY'S CITY HUMAN REMAINS USING NEUTRON ACTIVATION ANALYSIS

Participants: T. Daubenspeck
D. Raupach
M. Moore
H. Miller
S. D. Hurry

Services Provided: Neutron Irradiation, Radiation Counters and Neutron Activation Analysis

Three lead coffins at the Historic St. Mary's City contain the remains of three Maryland colonists buried there 300 years ago. Archaeologists think one coffin may contain the remains of Philip Calvert, youngest son of Sir George Calvert, the first Lord Baltimore. Philip, the colony's first chancellor, died in 1682. The other two coffins are thought to contain the remains of Philip's wife and child. The remains of the woman are the best preserved 17th-century remains ever found in North America.

The RSEC has worked with Mark Moore of the Armed Forces Radiobiology Institute in assisting archaeologists at Historic St. Mary's City. Neutron Activation Analysis (NAA) has been used in an attempt to match the coffin lead with lead samples whose English sources are known. NAA has also been used to determine elemental content of body hair; one aspect of this work involves determining if part of the remains is human hair or a wig. NAA is also being used to try to determine the identity of a crystalline residue on the human remains.

Nuclear Engineering

TRITIUM CONTAMINATION OF METALS

Participants: W. S. Diethorn
A. R. Dulloo

Services Provided: Neutron Irradiation, Radiation Counters, Laboratory Space, Machine Shop, Isotope Production and Electronics Shop

Tritium contamination of equipment creates problems in waste control, radiological safety and tritium accountability at large tritium-processing facilities in the U.S. The purpose of this study is to investigate tritium distribution in materials of interest to the tritium-processing industry.

Recoil injection and diffusion-charging will be used to impregnate materials with tritium, and the tritium distribution resulting from these two methods of impregnation will be compared. The effects of factors such as grain size and sensitization on the tritium distribution will also be investigated.

Doctoral Thesis:

Dulloo, A. R., and W. S. Diethorn, advisor. An Experimental Study of the Distribution of Recoil- and Diffusion-Charged Tritium in Metals. In progress.

Sponsor: EG&G Mound Applied Technologies, fourth year.

Nuclear Engineering

UNDERGRADUATE LABORATORY ON REACTOR EXPERIMENTS

Participants: R. M. Edwards
J. A. Turso
M. E. Bryan
D. E. Hughes

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, Reactor Instrumentation and Support Staff

The Nuclear Engineering 451 course is the second of two required 3 credit laboratory courses. Each weekly laboratory exercise usually consists of 2 lectures and one laboratory session conducted. The first course (NucE 450) covers radiation instrumentation and measurement and is conducted in the 2nd semester of the junior year. By the beginning of the senior year, the students have already covered the LaMarsh reactor theory book including reactor point kinetics. The 451 course then emphasizes experiments using the instrumentation that was covered in the first course and is divided into two (more or less) equal "tracks". These tracks can be coarsely described as TRIGA and non-TRIGA experiments and each is the major responsibility of a different professor. The non-TRIGA track includes 3 graphite pile, 2 analog simulation, and 1 power plant measurement experiment.

In 1992, the TRIGA track included:

1. Digital Simulation of TRIGA Reactor Dynamics
2. Control Rod Calibration
3. Large Reactivity Insertion (Pulsing)
4. Reactor Frequency Response
5. Neutron Noise
6. Reactor Control

This sequence was first used in 1991 and was again used in 1992. The reactor control experiment replaced a reactor gamma field measurement experiment and the digital simulation exercise was modified to point kinetics from its previous focus on Xenon dynamics. The mathworks SIMULDNK simulation software was used for the digital simulator exercise for the first time in 1992. Reactor control is offered as a graduate course in our department but until now our undergraduates have not received a complete introduction to feedback control.

In 1991, 5 MacIntosh Computers equipped with GW Electronics MacAdios and Superscope software became available for conducting TRIGA reactor experiment data collection and analysis. The goal for utilizing this computer equipment is to give students more hands-on experience in setting-up the data collection and conducting the TRIGA experiments. The MacIntosh computers were used to conduct the digital simulation, reactor pulsing, frequency response, and noise experiments. A Bailey NETWORK 90 microprocessor-based controller was used in the control experiment. They are also adaptable for the other experiments and work will continue to fully utilize them for this purpose.

Nuclear Engineering

NUCE 505 REACTOR CONTROL

Participants: R. M. Edwards
J. A. Turso
M. A. Power
M. E. Bryan
D. E. Hughes

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, Reactor Instrumentation and Support Staff

Two laboratories to demonstrate reactor frequency response and reactor control were conducted for the graduate Reactor Control course, NucE 505. The reactor frequency response used MacIntosh computers and superscope software. The control experiment used a Bailey Multifunction controller and included demonstration of optimal control.

Nuclear Engineering

ROBUST OPTIMAL CONTROL OF TRIGA REACTOR TEMPERATURE

Participants: R. M. Edwards
M. A. Power
D. E. Hughes
M. E. Bryan

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, Reactor Instrumentation and Support Staff

Based on a prototype TRIGA Reactor Optimal Control experiment conducted during the summer of 1991, this area was expanded into a full range of experiments to verify the robustness characteristics of this optimal control application. Initiated in 1992 as a FERMI project, this effect was continued into 1993 as a part of an NSF/EPRI funded project.

A Bailey NETWORK 90 Distributed Control System is used to implement the optimal control algorithm which is implemented in the Bailey controller using general purpose C language programming. The Bailey drives the Secondary Control Rod (SCR) drive which travels in the central thimble while the licensed control and safety system is in a manual mode of operation. The Bailey System at the reactor was augmented with a Computer Interface Unit which enables utilization of standard Bailey Software for generating displays of process information.

Advanced control algorithms, such as this optimal control algorithm, require some kind of dynamic model of the process in order to achieve improved performance characteristics. The concept of robustness is how far can the actual process deviate from the *assumed* process model and still maintain required stability and desired performance improvement. Through extensive simulation, this optimal controller which is based on a one-delayed neutron group model, has been shown to maintain desired performance for a factor of 10 variation in the power level and control rod worth for which it was designed. The current experimental program to verify these predictions will culminate in the Master's thesis of Mike Power during the summer of 1993. Further work will examine other robust control techniques, fuzzy logic, serial network, and intelligent control under NSF/EPRI support.

Master's Thesis:

Power, M. A., and R. M. Edwards, advisor. Optimum Control of Reactor Temperature Response. In progress.

Paper:

Power, M. A., R. M. Edwards and D. E. Hughes. Experimental Verification of Robust Optimal Nuclear Reactor Control. ANS Topical Meeting on Nuclear Power Plant Instrumentation, Control, and Man-Machine Interface Technologies, Oak Ridge, Tennessee. April 1993.

Publication:

Edwards, R. M., H. E. Garcia and K. Y. Lee. Experimental Development of Power Reactor Intelligent Control. *ANS Transactions*. November 1992.

Sponsors: FERMI $12,000 (1992) NSF/EPRI (1993-1995) $300,000

Nuclear Engineering

EXPERIMENTAL DEVELOPMENT OF POWER REACTOR INTELLIGENT CONTROL

Participants: R. M. Edwards
K. Y. Lee
D. E. Hughes
K. L. Shatto
P. Ramaswamy
M. A. Power
J. A. Turso

Services Provided: Laboratory Space, Machine Shop , Electronics Shop and Reactor Instrumentation and Support Staff

This is a major NSF and EPRI funded project which was initiated in 1993. A major task approaching completion is described under, "Robust Optimum Control of Triga Reactor Temperature." Other tasks to be conducted through 1995 include demonstration of other robust control techniques, fuzzy logic, neural network, and intelligent control. Some of these should be ready for initial implementation during the summer of 1993. A hybrid reactor/simulation capability and flow control apparatus are also to be developed to allow research in multivariable fault accommodating control for power reactors.

Master's Thesis:

Shatto, K. L., R. M. Edwards and A. Ray, advisors. Modeling and Controller Design for the Pennsylvania State University TRIGA Reactor. 1993.

Publications:

Edwards, R. M., H. E. Garica and K. Y. Lee. Experimental Development of Power Reactor Intelligent Control. *ANS Transactions*. November 1992.

Turso, J. A., R. M. Edwards and D. E. Hughes. Hybrid Reactor/Simulation Development for Commercial Power Plant Controller Testing. To appear in proceedings of The 16th Biennial ANS Topical Meeting on Reactor Operations Experience: Present and Future Technologies-Applying Lessons Learned, Long Island, New York. August 1993.

Sponsors: NSF/EPRI $300,000 (1993-1995)

Nuclear Engineering

TRANSIENT RADIATION INDUCED ABSORPTION IN OPTICAL FIBERS

Participants: R. Gould
F. Boody

Service Provided: Neutron Irradiation

Experiments compared the transient radiation-induced absorption in optical fibers due to predominantly fast neutron irradiation with that produced by exposure at the core face. The experiments performed at RSEC will be compared with similar experiments performed at the Los Alamos LAMPF facility. The optical fibers were developed in the former Soviet Union for weapons programs. This technology will benefit the International Thermonuclear Experimental Reactor (ITER) optical and insulator materials group as well as other programs requiring radiation resistant optical and insulating materials.

Nuclear Engineering

QUALIFICATION OF UNDERVOLTAGE RELAYS FOR RADIATION HARDNESS FOR PP&L'S SUSQUEHANNA STEAM ELECTRIC STATION

Participants: R. Gould
M. Murmello
R. Conrad

Services Provided: Gamma Irradiation, Machine Shop and Electronics Shop

This project evaluated the radiation hardness of a set of ABB Model 27-N undervoltage relays. These relays are used in the switch gear at the Susquehanna Steam Electric Station and would be expected to withstand the radiation field due to the design basis accident at that station. The relays were irradiated in the Co^{60} facility in a special in-pool 10" irradiator assembly. During the tests the relays were monitored by a computer data acquisition system.

Sponsors: Pennsylvania Power and Light/Asea Brown Boveri (ABB) $7,500

Nuclear Engineering

GEMSTONE ENHANCEMENT BY IRRADIATION

Participants: R. Gould
M. Perlman

Services Provided: Neutron Irradiation and Radiation Counters

Gemstones can be enhanced by exposure to radiation including neutrons. Neutron exposure will alter the color of stones from less desirable colors to more desirable thereby increasing their value.

Nuclear Engineering

EVALUATING TWO PHASE FLOW USING NEUTRON RADIOGRAPHY

Participants: D. E. Hughes
R. Gould
S. S. Glickstein

Services Provided: Neutron Radiography, Machine Shop and Electronics Shop

This project is using neutron radiography to evaluate the production of voids in water flowing between two heated metal plates. The initial pilot studies are complete and a contract is being negotiated for a larger scale project.

Sponsor: Bettis Atomic Power Laboratory ~ $15,000

Nuclear Engineering

REACTOR BRIDGE CHANGE PROJECT

Participants: D. E. Hughes
R. Gould
D. Sathianathan
N. Bloser
K. Traver

Services Provided: Neutron Radiography, Machine Shop and Electronics Shop

The Bridge Change Project is intended to increase the versatility of the RSEC by increasing the degrees of motion of the reactor core from 1 to 3. The ultimate goal of the project is to allow a greater number of permanent experimental facilities and to enhance the neutron beam entering the Neutron Beam Laboratory. The initial concept has been approved by the PSRSC and the design drawings are presently being developed. The participants expect to complete the project in the next year.

Sponsor: U.S. DOE $73,000
Penn State matching in funds and other considerations $85,000

Nuclear Engineering

PENN STATE BREAZEALE REACTOR MODERNIZATION PROJECT-PHASE IV

Participants: D. E. Hughes
M. E. Bryan
M. H. Voth

Services Provided: Machine Shop and Electronics Shop

The main thrust of this project is a new facility monitoring and alarm system. Over the years, due to regulatory and self-imposed controls the reactor facility is now responsible for monitoring and maintaining a multitude of facility systems information. This monitoring and alarm system will give us the capability of monitoring these signals plus more importantly the flexibility to add additional alarm and system status messages to the system as the need arises. The new system will consist of a Programmable Logic Controller (PLC) located in the reactor control room and a distributed I/O system located in various laboratories throughout the facility. These remote I/O stations will be programmed individually to monitor and control equipment, sensors and associated reactor systems that are not presently monitored by the reactor control system. Each remote I/O station will be connected via a high speed network and remotely monitored by the PLC. The PLC will communicate with a local computer that will allow for overall facility monitoring and alarm logging. The logging computer will be located in the reactor control room and be utilized by the operations staff as a tool in determining facility equipment and alarm condition status.

The majority of the equipment has been purchased and the system is undergoing design. Facility installation and testing of the completed system is planned for the last quarter of 1993.

Sponsor: DOE $44,036
Penn State matching funds $23,712

Nuclear Engineering

NUCE 450 RADIATION DETECTION AND MEASUREMENT

Participants: W. A. Jester
M. H. Voth
M. Dechaine

Services Provided: Neutron Irradiation, Radiation Counters and Laboratory Space

NucE 450 introduces the student to many of the types of radiation measurement systems used in the nuclear industry as well as many of the mathematical techniques used to process and interpret the meaning of measured data.

Nuclear Engineering

FDA INTERLABORATORY COMPARISON TRIAL

Participants: W. A. Jester
T. Daubenspeck
J. A. Turso

Services Provided: Neutron Irradiation and Radiation Counters

A Food and Drug Administration (FDA) interlaboratory trial of using NAA as a method for determining the Na content in foods and related material was conducted. The irradiation has been completed and relative information was reported to the FDA. Graduate student Jim Turso is also using this data to write a user friendly user's guide for the new multichannel analyzers.

Nuclear Engineering

ENVIRONMENTAL BACKGROUND MONITORING USING ELECTRET PASSIVE ENVIRONMENTAL MONITORS

Participant: W. A. Jester

Services Provided: Radiation Counters, Laboratory Space and Low Level Monitoring Lab

Rad-Elect Electret passive environmental monitors are a new type of monitor for the detection of gamma environmental radiation. For the past three years, quarterly measurements have been taken at ten positions in and near the Radiation Science Center. At the same time and locations, the university Health Physics staff has been making TLD measurements of the gamma background. Results obtained from these two different methods of background measurements are then compared.

Publication:

Kotrappa, P., and W. A. Jester. Electret Ion Chamber Radon Monitors Measured Dissolved 22Rn in Water. *Health Physics* 64 (4):397-405. April 1993

Sponsor: Equipment donated by Rad-Elec $3,500

Nuclear Engineering

FLUX AND FLUENCE DETERMINATION USING THE MATERIAL SCRAPINGS APPROACH

Participants: W. A. Jester
H. S. Basha

Services Provided: Neutron Irradiation, Hot Cell Lab, Radiation Counters, Laboratory Space, Machine Shop and Flux Monitoring

The purpose of this research is to develop a new and accurate methodology to determine the fast neutron exposure of critical components in light water reactors. The basic concept of this research is to take scrapings samples from critical components in the reactor and use the dosimetry data of the scrapings samples to determine their neutron exposure. In order to perfect this new technique, several ferritic and stainless steel samples have been irradiated in the TRIGA reactor to a fluence of about 10^{19} n/cm^2. The dosimetry data of the irradiated samples is currently being used to determine an integrated energy-wise neutron exposure of the samples. We believe that this research will lead to a new and accurate technique for determining the fast neutron exposure of many critical and aged components in light water reactors such as the reactor pressure vessel wall and core support structures. When this technique is completely developed, it will help many nuclear utilities in determining the service life of many of their important reactor components because it will provide accurate neutron exposure data.

Doctoral Thesis:

Basha, H. S., and W. A. Jester, advisor. Flux and Fluence Determination for Reactor Pressure Vessel Wall Components Using the Material Scrapings Approach. In progress.

Publication:

Basha, H. S., and W. A. Jester. Fast Neutron Exposure Calculations for the Surveillance Capsules of a Boiling Water Reactor. *Trans. of American Nuclear Society.* June 1993.

Report:

Basha, H. S., and W. A. Jester. Presentation on Plant-Life Extension Technology, Damage Parameters Determination Using Scrapings Technology. Progress report to project FERMI. April 1993.

Sponsor: Project FERMI $23,607

Nuclear Engineering

CHROMATOGRAPHIC SYSTEM FOR RADIONUCLIDE ANALYSIS OF REACTOR WATERS

Participants: W. A. Jester
A. R. Dulloo

Services Provided: Neutron Irradiation, Radiation Counters, Laboratory Space, Machine Shop, Isotope Production, Electronics Shop, Ion Chromatographic System and Low Level Radiation Monitoring Laboratory

The analysis of aqueous emissions from nuclear power plants prior to release to the environment is an area of importance to the nuclear industry. It is difficult to detect and quantify the activities of certain radionuclides present in the emissions due to interference from the activities of other radionuclides. Chemical separation methods are necessary to isolate these nuclides before detection. Unfortunately, these chemical methods are expensive, time-consuming, and are often performed offsite by commercial laboratories.

The purpose of this study is to develop a system which would allow for the automated separation of the radionuclides in an aqueous mixture using high performance liquid chromatography, followed by the detection and measurement of separated nuclides of interest with a radiation detector. Such a system would permit the onsite analysis of aqueous effluents from nuclear power plants without the need for costly and time-intensive chemical separation methods. Most plants already have high performance chromatography equipment used to perform chemical analysis of water samples.

Reports:

Bliestein, C. D., and W. A. Jester. Chromatographic System for Radioisotope Analysis. Interim and Final reports submitted to Ben Franklin Partnership Program. September 1, 1991 to November 30, 1991 and December 1, 1991 to August 31, 1992.

Dulloo, A. R., and W. A. Jester. Chromatographic System For Radionuclide Analysis. Second year project report to CB-Tech. June 1993.

Sponsors: Ben Franklin Partnership Program with matching funds from CB-Tech and Penn State $141,733 (1991-1992)
CB-Tech $8,100 (1992-1993)

Nuclear Engineering

VERIFICATION OF LITHIUM-7 ENRICHMENT IN LITHIUM HYDROXIDE BY THERMAL NEUTRON IRRADIATION

Participants: W. A. Jester
A. R. Dulloo
H. Boyle

Services Provided: Neutron Irradiation, Radiation Counters, Laboratory Space, Isotope Production and Low Level Radiation Monitoring Laboratory

Lithium hydroxide (LiOH) is used to control the pH of coolant water in the primary loop of pressurized water reactors. Natural lithium consists of 93.45 w/o ^{7}Li and 6.55 w/o ^{6}Li. Because of the high thermal neutron cross section of the ^{6}Li(n,α)^{3}H reaction, it is desirable to use a lithium compound enriched in the ^{7}Li isotope to minimize the production of radioactive tritium (^{3}H). ^{7}Li has a zero thermal neutron reaction cross section for ^{3}H formation, and lithium hydroxide compounds used in PWRs are typically enriched to 99.9 w/o ^{7}Li.

A simple method to measure the ^{7}Li content of an enriched LiOH compound has been developed. Enriched LiOH is irradiated in a thermal neutron flux, and its resulting ^{3}H activity is radioassayed and compared to that of natural LiOH which has been subjected to an identical irradiation. Since the ^{3}H activity is a linear function of the ^{7}Li amount in the compound, the percentage of ^{7}Li in the enriched compound can be calculated based on the well-known concentration of ^{7}Li in natural lithium. This method has been used to compare the ^{7}Li contents of several enriched LiOH powders sold by different vendors, and will be available to commercial customers by the facilities of the Low Level Radiation Monitoring Laboratory.

Publication:

Dulloo, A. R., and W. A. Jester. Verification of ^{7}Li Enrichment in Lithium Hydroxide by Thermal Neutron Irradiation. *Trans. of American Nuclear Society*. TANSAO 661-626, 66: 171, (1992)

Nuclear Engineering

RADIOLOGICAL ANALYSIS OF THE MATERIALS USED IN THE PRODUCTION OF FEMORAL HEADS

Participants: W. A. Jester
R. W. Granlund
H. Boyle

Services Provided: Radiation Counters, Laboratory Space and Low Level Radiation Monitoring Laboratory

The objective of this work is to determine the relative patient dose from three types of femoral balls used in hip joint replacement. The samples are composed of either zirconia, alumina, or cobalt/chromium alloy. The alpha, beta, and gamma activities emitted by these samples were measured using long counting times and where possible low background radiation detection equipment.

Report:

Jester, W. A., R. Granlund and H. Boyle. Radiological Analysis of Materials Used in the Production of Femoral Heads. Progress reports submitted to Howmedica. January and June 1993.

Sponsor: Howmedica, Inc. $10,000

Nuclear Engineering

STUDY OF THE DEPOSITION LOSSES OF AIRBORNE RADIOIODINE SPECIES IN SAMPLE LINES UNDER NORMAL AND ACCIDENT CONDITIONS OF NUCLEAR POWER PLANTS

Participants: W. A. Jester
B. S. Lee

Services Provided: Neutron Irradiation, Radiation Counters, Laboratory Space, Machine Shop, Isotope Production and Electronics Shop

Airborne radioiodine species either in gaseous or particulate forms can be lost inside sample lines used in nuclear power plants. The deposition losses of these radioiodine species can make a bias in the measured iodine activity collected in monitor filters installed at the end of the long sample lines. Currently available experimental data do not agree with each other and no models exist to explain the experimental results. Most of the experimental work is black-box approach, knowing only input and output amounts of radioiodine. To better understand mechanisms involved in the radioiodine deposition in the sample lines, experiments using short half-lived ^{128}I radioisotope (either I_2 or Ch_3I or particulate iodines) have been conducted on the two types of stainless steel sample lines, one aluminum line, and one plastic line. The deposition profiles of these radioiodine species were obtained using a thin Geiger tube along the length of the line for various test conditions. Radioiodine particles are also produced by reacting I_2 with cigarette smoke. The deposition of these particles in the various lines was studied.

Doctoral Thesis:

Lee, B. S., and W. A. Jester, advisor. Airborne Radioiodine Deposition Losses in Nuclear Reactor Sample Lines. 1993.

Publication:

Jester, W. A., T. T. Tseng and B. S. Lee. Radioiodine Monitoring of Nuclear Power Plant Airborne Emissions Under Accident Conditions. Proceedings of the seventh ASTM-EURATOM Symposium on Reactor Dosimetry. ISBNO-7923-1792-0, 915-922. 1992.

Reports:

Lee, B. S., and W. A. Jester. Airborne Radioiodine Losses in Nuclear Reactor Sample Lines. Final report to Project FERMI. April 1993.

Lee, B. S., and W. A. Jester. Study of Airborne Radioiodine Deposition Losses in Reactor Sample Lines. Progress report to FERMI. November 1991.

Sponsor: FERMI $17,068

Nuclear Engineering

DEVELOPMENT OF A SOURCE HOLDER AND CONVERSION TABLES FOR USE WITH EBERLINE RO-2'S TO ALLOW THE MEASUREMENT OF THE SKIN DOSE RATES FROM BETA-GAMMA SOURCES

Participants: W. A. Jester
S. H. Levine
T. J. Lin

Services Provided: Radiation Counters, Laboratory Space, Machine Shop, Isotope Production, Low Level Monitoring Lab and Electronics Shop

In this project, techniques are being developed to determine skin dose rates from beta-gamma sources using an Eberline RO-2 ion chamber. A program called E13RO2 has been modified from the ZEBRA code (a Monte Carlo program developed by Martin J. Berger) for use in computing the beta dose from an RO-2 measurement. The E13RO2 program is a two dimensional program written in Turbo Basic and can be run on an IBM compatible microcomputer. It calculates the energy deposited in the detector air volume and computes beta skin dose rates as a function of source type, source strength, source diameter, source-detector distances and shield between source and chamber. To fit the RO-2, the geometrical factors of that detector have been taken into consideration.

A table is being developed to evaluate the skin dose from RO-2 outputs as a function of the measured dose ratio, which is the ratio of outputs obtained without and with a gradient shield of 7 mg/cm^2 mass thickness, various source radii and source-detector distances.

A source holder for the RO-2 chamber has been designed and finished to hold any kind of beta-gamma source at a fixed source-detector distance. The holder has been used to measure many different sources to generate the conversion tables in cooperation with the E13RO2 program. Measurements using ^{60}Co, ^{204}Tl, ^{147}Pm, and $^{90}Sr/^{90}Y$ sources under different conditions show good agreement with E13RO2 calculations.

Master's Thesis:

Lin, T. J., and W. A. Jester, advisor. Development of a Beta Skin Dose Monitor Utilizing an Eberline RO-2 Portable Ion Chamber. 1992.

Report:

Jester, W. A., S. H. Levine and T. J. Lin. Development of a Beta Skin Dose Monitor Utilizing an Eberline RO-2 Portable Ion Chamber. Final report submitted to PP&L. December 1992.

Sponsor: Pennsylvania Power and Light Company $52,766

Nuclear Engineering

DEVELOPMENT OF A BETA SKIN DOSE MONITOR USING SILICON DETECTORS

Participants: W. A. Jester
S. H. Levine
M. Chung
T. Y. Lin

Services Provided: Radiation Counters, Laboratory Space, Machine Shop, Isotope Production, Low Level Monitoring Lab and Electronics Shop

The purpose of the research is to develop improved ways to compute and measure the beta skin dose. The one-dimensional Monte Carlo electron transport code, ZEBRA, was converted to Eltran2 and Eltran3 for use on the Macintosh or any IBM compatible microcomputer. Of the various types of detectors, the semiconductor detector was chosen, because it has small size and high sensitivity. Especially, a low leakage current ion-implanted silicon detector was selected for this research. To cover a wide range of dose rate, both the pulse and current mode operations of the silicon detector were used, with an overlap of one order of magnitude in the measurable dose rate ranges in the two modes. By using a shield of 7 mg/cm^2 on the silicon detector, dose gradient measurements were performed. Based on this research, a prototype beta skin dose monitor has been constructed, including an A/D converter and a microprocessor with a machine coded program to calculate the skin dose. It covers more than five orders of magnitude in the measurable beta dose rate ranges. The prototype device has been field tested at the TMI nuclear plant site with hot particles and various other radioactive sources. Nuclear Research Corporation is building a commercial monitor based on this work and the system is being calibrated at Penn State.

Nuclear Engineering

DEVELOPMENT OF A COMMERCIAL BETA SKIN DOSE MONITOR

Participants: W. A. Jester
S. H. Levine
T. J. Lin
M. Chung

Services Provided: Laboratory Space, Machine Shop, Low Level Monitoring Lab and Electronics Shop

This project is an extension of our previous work on the development of a beta skin dose monitor. Nuclear Research Corporation in cooperation with Dr. Jester and Dr. Levine are developing a commercial version of one of the concepts proposed and evaluated by Manho Chung during his Ph.D. thesis work. In this concept the beta dose response of a silicon detector as a function of applied voltage is used to determine the beta skin dose. The magnitude of the reverse bias voltage determines the thickness of the dead layer between the beta source and the sensitive volume of the silicon detector. This layer can be used to approximate the dead layer thickness of the skin.

Publications:

Voth, M. H., and W. A. Jester. Power Reactor Services Provided by Penn State Radiation Science and Engineering Center. *Trans. American Nuclear Society*. June 1993.

Alam, K. M., and W. A. Jester. The Development of a Carbon-14 and Tritium Gaseous Effluent Monitor. *Trans. of American Nuclear Society*. TANSAO 651-580, 65:38 (1992).

Report:

Jester, W. A., and S. Pandy. Development of a Commercial Beta Dose Monitor. Interim reports and final report submitted to Ben Franklin Partnership Program. September 1, 1991-August 21, 1992.

Sponsors: Nuclear Research Corporation and Ben Franklin Partnership Program $74,027

Nuclear Engineering

GENERATION AND MOBILITY OF RADON IN SOILS

Participants: W. A. Jester
A. W. Rose
Y. J. Chang

Services Provided: Radiation Counters, Laboratory Space, Machine Shop and Electronics Shop

The behavior of Rn precursors Th-230 and U-234 in soils is being investigated. Samples from previously studied soil profiles are being analyzed for these two nuclides to investigate the possible separation of Rn precursors in soil formation. Samples are electroplated onto a metal disk which is then counted in an alpha spectroscopy system using a surface barrier detector.

Master's Thesis:

Chang, Y. J., A. W. Rose and W. A. Jester, advisors. Separation of Th and U in Soil Utilizing α Spectroscopy. In progress.

Report:

Rose, A. W., E. J. Ciolkosz and W. A. Jester. Generation and Mobility of Radon in Soil, Annual Research Report Submitted to U.S. Department of Energy, Indoor Radon Program. August 1992.

Sponsor: U.S. Department of Energy $110,000 March 1992-March 1993

Nuclear Engineering

PIPE WALL THINNING USING SCATTERED GAMMA RAYS

Participants: E. S. Kenney
X. Xu
R. Gould
S. Kahn
A. Snauffer

Services Provided: Hot Cell Lab, Radiation Counters, Laboratory Space, Machine Shop, Isotope Production and Electronics Shop

Pipe wall thinning continues to be a serious problem in the nuclear industry. The problem first appeared in PWRs, but is now recognized throughout the industry. This project has demonstrated that pipe wall thinning can be detected using scattered gamma rays. A combination of Monte Carlo studies and pilot experiments have confirmed the potential of such a technique. We have designed a laboratory prototype gauge using up to 0.5 curies of Ir-192. A field usable device is now being developed to use up to 1.0 curie of Hg-203.

Doctoral Thesis:

Xu, X., and E. S. Kenney, advisor. A High Speed Wide-Aperture Compton Scatter NDT Gauge Using a Multi-Energy Source. In progress.

Report:

Xu, X., E. S. Kenney, E. Klevans and R. Gould. Study of a High Speed Wide-Aperture Compton Scattering NDT Gauge. Report to Project FERMI. April 1993.

Sponsor: FERMI $30,000

Nuclear Engineering

NEUTRON ATTENUATION MEASUREMENTS OF BORAFLEX

Participants: D. Kline
D. Vonada
K. Lindquist

Services Provided: Neutron Irradiation, Neutron Instrumentation and Neutron Beam Lab

The purpose of this project is to measure the neutron attenuation of boraflex coupons that have been taken from fuel storage racks. It is a part of a larger project to monitor the performance of the boraflex which is used to control the reactivity of spent nuclear fuel. The attenuation measurements are made by using a fission chamber instrument to compare the incident beam with the transmitted beam.

Nuclear Engineering

PROPERTIES OF THE NEUTRON ABSORBER MATERIAL BORAFLEX

Participants: D. Kline
D. Vonada
K. Lindquist

Services Provided: Neutron Irradiation and Laboratory Space

Boraflex is a composite polymer of polysiloxanes with a B_4C-filler used in maximum-density storage of fuel elements to control the reactivity. The performance of Boraflex over its expected service life has not, as yet, been determined.

Data from the literature concerning polydimethylsiloxane were evaluated a few years ago, and Boraflex coupon monitoring is currently being carried out at storage pool sites. It is also of academic interest to study some of the properties of the polymer using the nuclear reactor (PSBR), and other facilities.

It is hoped that results can be obtained to explain certain aspects of the changes in properties, and that they can be used by utilities throughout Pennsylvania and the United States in estimating and/or extending the service life of the B_4C-filled polymer system.

An additional phase involves ascertaining property changes of in-service Boraflex. About once per year a surveillance coupon from a storage pool is sent to PSU and evaluated for radiation-induced changes. Fractions of deteriorated Boraflex with a substantial irradiation history are also monitored for possible post-irradiation deterioration in water baths held at controlled conditions which simulated the in-service environment of this material.

Nuclear Engineering

PROOF OF PRINCIPLE TESTS TO EVALUATE NEUTRON ABSORBERS IN SITU

Participants: D. Kline
D. Vonada
K. Lindquist

Services Provided: Neutron Irradiation, Laboratory Space and Beam Hole Lab

This research is applied to the use of neutron detector systems for evaluation of material performance in spent fuel racks of storage pools. With time, the properties of neutron absorbers can change and this can potentially cause concern with respect to the K_{eff} of the fuel assemblies in the storage racks. Preliminary experiments using the neutron beam are part of proof-of-principle tests for delineating the effectiveness of the neutron absorbers.

Reports:

Lindquist, K., and D. Kline of Northeast Technology Corporation, Kingston, New York. Boraflex Test Results and Evaluation. EPRI TR-101986, Electric Power Research Institute, Palo Alto, California.

Lindquist, K., and D. Kline of Northeast Technology Corporation, Kingston, New York. EPRI Workshop #6-Boraflex Update. July 29, 1992. Washington, DC.

Sponsor: Electric Power Research Institute

Plant Pathology

NOVEL DELAYED-RELEASE NUTRIENT SUPPLEMENTS FOR THE CULTIVATION OF MUSHROOMS

Participant: C. P. Romaine

Service Provided: Gamma Irradiation

Seeds were gamma irradiated to destroy their ability to sprout. Irradiated seed, specifically rape (= canola), was added to mushroom-growing medium. Nutrients in the seed were slowly released from the seed and increased the yield of mushrooms.

Patent Pending:

Romaine, C. P., and A. Marlowe. An Intact Seed-Based Delayed-Release Nutrient Supplement for Mushroom Cultivation. 1992.

School of Engineering Technology and Commonwealth Campus Engineering

LEAD-BISMUTH LIQUID METAL FLOW

Participants: D. Sathianathan
J. Cimbala

Service Provided: Neutron Radiography

In August 1992, Professor Dhushy Sathinathan and John Cimbala continued the joint experiments, started in May 1992, with Professor Takenaka and his co-workers from Kobe University, Japan. Neutron radiography techniques were used to visualize natural and forced convection flow patterns in molten lead-bismuth. The flow patterns were observed using neutrally buoyant particles in a 1-D stainless steel test-section. The particles were clearly visible and could be easily tracked using the real-time (30 frames/sec.) imaging system. Using these results, Professor Takenaka is hoping to secure funding for further research from the Japanese agencies.

Sponsor: Kobe University, Japan

School of Engineering Technology and Commonwealth Campus Engineering

VISUALIZATION OF COMPRESSIBLE EFFECTS IN GASES

Participants: D. Sathianathan
N. Bloser
B. Donato
K. Traver

Service Provided: Neutron Radiography

This is a long term research project, conducted by Professor Dhushy Sathianathan, to image shock waves in gases through metal enclosures. As part of the initial phase of the project, Room 130A was converted to a new darkroom for developing x-ray films. The funds for the equipment were provided by the Research Initiation Grant, the Penn State Fund for Research, and the Nuclear Engineering Department. Currently, the darkroom equipment is being calibrated to accurately measure the film density, which is necessary to measure the compressible effects in gases. The construction of the test rig for the project is expected to begin in the Fall of 1993. Students working on the project are Brian Donato (ME-Senior), Nathan Bloser (ME-Junior), and Keith Traver (ME-Senior).

Sponsors:	Research Initiation Grant	$9,990
	Penn State Fund for Research	$1,500

B. OTHER UNIVERSITIES' AND INDUSTRIAL RESEARCH UTILIZING THE FACILITIES OF THE RADIATION SCIENCE AND ENGINEERING CENTER

University or Industry	Type of Use
Asea Brown Boveri	Gamma Irradiation
ALCOA	Neutron Radiography
	Neutron Activation Analyses
American Inspection Agency	Environmental Analyses
Armed Forces Radiobiology Research Institute	Neutron Radiography
	Neutron Activation Analyses
Army Pulsed Reactor Facility, Aberdeen	Neutron Energy Spectrum Analyses
Bettis Labs, Westinghouse	Neutron Radiography
Carpenter Technology	Neutron Irradiation
CB-Tech	Neutron Activation Analyses
Diamond Processing Laboratory	Gamma Irradiation
E-Systems, ECI Division	Semiconductor Irradiation
Fairway Laboratories	Environmental Analyses
GEC-Marconi	Semiconductor Irradiation
Geochemical Testing	Environmental Analyses
Harris Semiconductor	Semiconductor Irradiation
Honeywell	Semiconductor Irradiation
Howmedica	Radiological Analyses
Hrebeniuk, Alex - Horticulturist	Gamma Irradiation
Ion Light Corporation	Neutron Irradiation
Isotec Incorporated	Neutron Activation Analyses
Kearfott, Inc.	Semiconductor Irradiation
Kobe University, Japan	Neutron Radiography
National Sanitation Foundation	Environmental Analyses
Northeast Technology Corporation	Neutron Radiography
Nuclear Research Corporation	Gamma Irradiation
P. R. Hoffman Materials Processing Corp.	Cobalt Irradiation
Pennsylvania Power and Light	Gamma Irradiation
Q. C. Inc.	Environmental Analyses
Rad-Elec	Environmental Analyses
Raytheon	Semiconductor Irradiation
Sandia National Laboratory	Neutron Energy Spectrum Analyses
Seewald Laboratories	Environmental Analyses
St. Mary's City Museum	Neutron Radiography
	Neutron Activation Analyses
Tru-Tec	Isotopes for Tracer Studies
University of Connecticut	Gamma Irradiation
University of Maryland	Perturbed Angular Correlation
Villanova University	Neutron Activation Analyses
Wright Lab Services	Environmental Analyses

APPENDIX A

APPENDIX A

Personnel Utilizing the Facilities of the Penn State RSEC.
Faculty (F), Staff (S), Graduate Student (G), Undergraduate (U)

COLLEGE OF AGRICULTURE

Entomology

Hower, Art (F)

Northeast Watershed Research Center

Schnabel, Ron (F)
Montgomery, Charles (S)

Plant Pathology

Juba, Jean (S)
Nelson, Paul (F)
Romaine, Peter (F)

COLLEGE OF EARTH & MINERAL SCIENCES

Geosciences

Dodin, Arnold (G)
Eggler, Dave (F)
Gold, David (F)
Rose, Arthur (F)
Teixeira, Jaoa (G)

Materials Science and Engineering

Brown, Paul (F)
Tenhuisen, Kevor (G)

Metals Science and Engineering

Cuddy, Lee (F)
Howell, Paul (F)
Irwin, Mark (G)
Poduri, Ram (G)
Ryba, Earle (F)

Mineral Engineering

Phelps, Barry (F)

COLLEGE OF ENGINEERING

Electrical Engineering

Lee, Kwang (F)
Ramaswamy, Pramath (G)

Industrial Engineering

Poeth, Dean (G)
Ruud, Clayton (F)

Mechanical Engineering

Bloser Nathan (U)
Cimbala, John (F)
Donato, Brian (U)
Prescott, Patrick (F)
Shatto, Kevin (G)
Traver, Keith (U)

Nuclear Engineering

Adams, James (G)
Basha, Hassan (G)
Baratta, Anthony (F)
Boyle, Hermina (S)
Boyle, Patrick (S)
Bryan, Mac (S)
Catchen, Gary (F)
Chang, Yi-Jui (G)
Chung, Manho (G)
Cumblidge, Steven (U)
Daubenspeck, Thierry (S)
Davison, Candace (S)
Dechaine, Michael (G)
Deithorn, Ward (F)
Dulloo, Abdul (G)
Edwards, Robert (F)
Esh, David (U)
Flinchbaugh, Terry (S)
Gould, Robert (F)
Hannold, Eric (S)
Hollinger, Ed (G)
Hughes, Dan (F)
He, Jianhui (G)

APPENDIX A
(Continued)

Personnel Utilizing the Facilities of the Penn State RSEC.
Faculty (F), Staff (S), Graduate Student (G), Undergraduate (U)

Nuclear Engineering

Jester, William (F)
Kahn, Saif (G)
Kenney, Edward (F)
Lee, Byung-Soo (G)
Levine, Samuel (F)
Lin, Tzyy-Jye (G)
Miller, David (S)
Power, Mike (G)
Raupach, Dale (S)
Rearick, Todd (G)
Rudy, Kenneth (S)
Sipos, Rick (S)
Snauffer, Andrew (U)
Turso, James (G)
Vergato, Bryan (S)
Voth, Marcus (F)
Xu, Xiangjun (G)
Yeh, Tsung-Kuang (G)

School of Engineering Technology and
Commonwealth Campus Engineering

Sathianathan, Dhushy (F)

COLLEGE OF SCIENCE

Chemistry

Allcock, Harry (F)
Ambrosio, Archel (G)
Coley, Suzanne (G)
Dudley, Gary (G)
Kim, Young Baek (F)
Pucher, Shawn, (G)
Reed, Carey (G)
Silverberg, Eric (G)
Smith, Dawn (F)
Visscher, Karyn (G)

COLLEGE OF SCIENCE

Physics

Enders, Todd (G)
Fu, Jainming (G)
Miller, David (F)
Pilione, Larry (F)
Sokol, Paul (F)

INTERCOLLEGIATE PROGRAMS

Health Physics

Boeldt, Eric (S)
Granlund, Rodger (S)
Hollenbach, Donald (S)

INDUSTRIES

Asea Brown Boveri	Conrad, Richard
ALCOA	Carkin, Gerry
	Dastolfo, Leroy
	VanLinden, JHL
American Inspection Agency	Harris, George
Armed Forces Radiobiology Research Institute	George, Robert
	Miller, Steven
	Moore, Mark
Army Pulsed Reactor Facility	Oliver, Mark
Bettis Labs, Westinghouse	Glickstein, Stan
	Murphy, Jack
Carpenter Technology	Balliett, Thomas
CB-Tech	Bleistein, Charles
Diamond Processing Laboratory	Perlman, Max
E Systems, ECI Division	Dobson, Robert
	Herbst, J.
	Uber, Craig
Fairway Laboratories	Markel, William L. Jr.
GEC Marconi	Murtaugh, Steve
	O'Neill, Jerre
Geochemical Testing	Bergstresser, Tim
Harris Semiconductor	Kalkbrenner, F.
Honeywell	Collins, Dennis
	Hildebrand, K.
	Lintz, John
	Willis, Dave
Howmedica	Hizer, Jennifer
Hrebeniuk, Alex-Horticulturist	Hrebeniuk, Alex
Ion Light Corporation	Fred Booty
Isotec Incorporated	Smith, Keith
Kearfott	Breen, Larry
	Casparro, Robert
	Walendenski, William
National Sanitation Foundation	Miller, Michael P.
Northeast Technology Corporation	Kline, Don
	Lindquist, Kenneth O.
	Vonada, Doug
Nuclear Research Corporation	Riggin, Fred
P. R. Hoffman Materials Processing Corporation	Casey, Ken
	Kingsborough, Lee
Pennsylvania Power and Light	Murmello, Michael
Q. C. Inc.	Dascoli, Jean
Rad-Elec	Kotrappa, P.
Raytheon	Diette, R.
	Enriquez, G. J.
	Kellicker, R.
	Mikulski, C. V.
	Mulford, S.
	O'Connor, T.
	Surro, J.
	Stransky, D. F.

INDUSTRIES
(Continued)

Sandia National Laboratory	....	Kelly, John
Seewald Laboratories	....	Chianelli, Robert E.
St. Mary's City Museum	....	Harry, Silas D. Miller, Henry
Tru-Tec	....	Boothe, Mike Kolek, Jerome Flenniken, Mike
Wright Lab Services	....	Milnes, Jan

UNIVERSITIES

Kobe University, Japan	Takenaka	Professor
University of Connecticut	Cramer, Chris	Graduate Student, Plant Science
University of Maryland	Rasera, Robert L.	Professor of Physics
Villanova University	Vile, Melanie	Graduate Student, Biology
	Wieder, R. Kelman	Professor of Biology

MISCELLANEOUS

LLRML - 37 laboratories representing 257 public water systems (only 6 major laboratories are listed above)

Various Cobalt - 60 irradiations for high school classes' research projects.

APPENDIX B

APPENDIX B
FORMAL TOUR GROUPS

JULY 1992 JUNE 1993	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
July	2	Atoms Scholars Program	28
	2	Boy Scout Troop 339	14
	7	Nuclear Concepts	27
	10	Aerospace	9
	15	ACCURI	5
	15	RENEW	17
	16	See the Future	43
	16	BEST	23
	17	WPSX-TV	7
	21	Science and Technology	8
	22	Upward Bound	24
	23	Upward Bound	26
	24	Enter 2000	39
	30	Materials Science 101	18
August	7	Police Services - Student Auxiliary	10
	14	Stone Valley	52
	18	South Halls Residence Assistants	14
	24	NucE Transfer Students	2
September	3	Food Science 313	32
	8	Science and Technology 200	51
	9	Science and Technology 200	67
	17	IPAC	1
	25	Ceramic Society Spouses	13
October	3	1992 Open House	255
	6	Society of Physics Students	11
	6	Argonne National Labs	1
	12	University Scholars	7
	19	Clearfield County Teachers	7
	20	Science and Technology 400	3
	21	English Interest House	6
	21	Materials Science 101	54
	22	Materials Science 101	49
	22	Ferguson Elementary School 3rd Grade	30
	23	Ferguson Elementary School 4th Grade	56
	23	Office of Physical Plant	4
	27	ALCOA	4
November	2	Jr. Science Symposium	14
	4	Twin Valley High School	55
	5	Association for Computing Machine	6
	5	Freshman Seminar	13
	6	ASEE	7
	9	Berwick High School	12
	13	Park Forest Elementary	30
	13	Teacher Workshop	7

APPENDIX B
FORMAL TOUR GROUPS
(Continued)

JULY 1992 JUNE 1993	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
November	16	Reactor Sharing IU-9	17
	19	Earth and Mineral Science & Interest House	11
	24	NASA [illegible] Research	3
	24	IMPO	3
December	2	Wyomissing High School	4
	4	Oak Ridge	3
	7	Greensburg - Salem High School	18
	9	State College Jr. High School	2
	14	Carlisle High School	44
	15	Studsvik of America	1
January	15	Jersey Shore High School	16
	19	Argonne National Lab	2
	21	ETP	2
February	1	Nuclear Regulatory Commission	1
	2	American Society of Military Engineering	6
	8	Brownie Troop 1167	21
	9	Police Services Training	23
	16	Police Services Training	20
	18	State College High School	26
	20	Engineering Open House	270
	26	Appalachian States LLRW	1
	26	Entomology Class	10
March	1	State College High School	12
	17	Daniel Boone High School	15
	29	Prospective Students	4
	29	Redland High School	15
April	5	Mt. Union	20
	6	Health Physics Review	5
	12	Northern Bedford High School	31
	14	Spring Week	5
	14	Carmichael High School	23
	14	Puricons, Inc.	3
	16	St. Mary's/Ridgeway	43
	19	Loyalsock High School	23
	21	Juniata College	6
	28	EG 50	18
	28	Harbor Creek High School	12
May	3	Muncy High School	35
	10	Dallastown High School	8
	15	1993 Graduation Reception	73
	17	Gilbert Commonwealth	3
	18	Danville High School	27
	19	Somerset High School	27

APPENDIX B
FORMAL TOUR GROUPS
(Continued)

JULY 1992 JUNE 1993	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
May	19	Open House	6
	19	Pennsylvania Power and Light	3
	21	Prospective Reactor Operators	2
	24	Warren High School	11
	24	State College High School	11
June	2	Lock Haven PS 101	2
	9	Warriors Mark Elementary	29
	16	Mechanical Engineering	3
	16	Walk in Tour	4
	16	Williamson High School	24
	21	Pre-Freshman Engineering	23
	23	GPU Nuclear Concepts	25
	24	Women in Engineering	24
	28	Prospective Graduate Students	2