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College of Engineering
Radiation Science and Engineering Center

Breazeale Nuclear Reactor Building
The Pennsylvania State University
University Park, PA 16802-2301

December 3, 1996

Marvin Mendonca
United States Nuclear Regulatory Commission
Mail Stop 011-B20
Washington, DC 20555

Dear Mr. Mendonca:

It was a pleasure speaking with you today. I have enclosed a copy of the 1996 Radiation Science and Engineering Center's 41st Annual Progress Report. The NRC Report is being reviewed by Health Physics and should be available for you when you arrive on December 10.

Have a safe trip and I look forward to meeting with you.

Sincerely,

Warren F. Witzig

Warren F. Witzig
Interim Director, PSBR

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Enclosure

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Radiation Science and Engineering Center - 1996 Forty-First Annual Progress Report

August 1996 Forty-First

41st

Annual Progress Report

Radiation Science and Engineering Center

August 1996

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Contract DE-AC07-94ID-13223
Subcontract C88-101857
U.Ed.ENG 97-45

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FORTY-FIRST ANNUAL PROGRESS REPORT

PENN STATE RADIATION SCIENCE AND ENGINEERING CENTER

July 1, 1995 to June 30, 1996

Submitted to:

United States Department of Energy

and

The Pennsylvania State University

By:

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Terry L. Flinchbaugh (Editor)
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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 Graduate Education. 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 Forty-First Annual Progress Report (July 1995 through June 1996) of the operation of The Pennsylvania State University Radiation Science and Engineering Center is submitted in accordance with the requirements of Contract DE-AC07-94ID-13223 between the United States Department of Energy and Lockheed Idaho Technologies Company (LITCO), 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 commitment in this report, especially Terry Flinchbaugh who edited the report and Lisa Brazee 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 X.

INTRODUCTION

I. INTRODUCTION

This report details the accomplishments of the Radiation Science and Engineering Center (RSEC) over the past year. One of those accomplishments was to adopt a formal mission statement and vision statement. They are as follows:

MISSION

It is the mission of The Pennsylvania State University Radiation Science and Engineering Center in partnership with faculty, staff, students, alumni, government, and corporate leaders to safely use nuclear technology to benefit society through education, research, and service.

VISION

Our unique facility has a diverse & dedicated staff with a commitment to safety, excellence, quality, customer satisfaction, and education by example. It is the vision of the faculty and staff of the Radiation Science and Engineering Center to become a leading national resource and make significant contributions in the following areas:

Safety - To actively promote safety in everything we do.

Education - Further develop innovative programs to advance societal knowledge through resident instruction and continuing education for students of all ages and their educators throughout the nation.

Research - Expand leading edge research that increases fundamental knowledge and technology transfer through our diverse capabilities.

Service - Expand and build a diverse array of services and customers by maintaining excellence, quality, customer satisfaction, and efficient service to supplement income and enhance education and research.

In conducting this mission in pursuit of the stated vision, the following activities are highlighted among the numerous accomplishments reported in the pages that follow:

- The reporting period began in July as numerous high school groups participated in educational programs at the RSEC under the direction of Ms. Candace Davison. This continued into the spring when high school science classes on educational field trips visited and performed experiments. The student chapter of the American Nuclear Society, with Ms. Davison's support, also used the RSEC for educational events such as Boy Scout and Girl Scout merit badge programs. A complete list of groups hosted is presented in Appendix B.

- Reactor fuel performance studies showed that power is excessively concentrated in the central region of the core where fuel elements with a heavier uranium loading are placed. Until a technical specification change can be processed, power was reduced to 75% to reduce local peaking. More details are reported on page 50.

- A new cobalt-60 irradiator was installed, providing an eight-fold increase in the dose rate available to experimenters. This makes numerous experiments practical which previously would have taken excessive time.

- Hot cell use reached an all time high and is continuing into the future as Dr. Motta and his graduate students investigate the properties of irradiated reactor pressure vessel metals. Included in the research are analyses using positron annihilation techniques.

- A Reactor Review Committee was assembled to evaluate the safety culture of the RSEC. Eight primary action plans are in progress as a result of the committee report; return to full power, training, restructure Director's priorities, organizational development, issues beyond RSEC control, strategic planning, guidance to experimenters, and computational capabilities. One result was an organizational change made effective June 1, 1996.

- A thermal hydraulic loop is being constructed in the cobalt bay as a student design project. When completed, it will serve as both a teaching and research tool, simulating features of advanced reactor concepts.

- A redesign and optimization study of the heavy water thermal column used for neutron radiography was completed. Computer analyses predict a significant increase in the thermal neutron yield once the new tank is in place.

- Dr. Shirley Jackson, Chairman of the Nuclear Regulatory Commission, toured the RSEC and observed a demonstration of Dr. Edwards' advanced control theory research. Dr. Jackson was the featured speaker at the ANS International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies hosted by Penn State; this highly successful technical meeting drew over 300 attendees from 25 countries. Dr. Edwards conducted workshops where 23 of the participants observed advanced controls techniques on the TRIGA reactor. During the past year this project resulted in nine papers, three masters degrees, and one doctorate degree. Research summaries can be found on pages 40 to 44.

PERSONNEL

II. PERSONNEL

Alex McLellan resigned his reactor operator intern position effective November 10, 1995. T. Michael Engle, an ex-Navy nuclear reactor operator, was hired as an operator intern effective December 18, 1995. Michael J. Morlang, a graduate student in the Nuclear Engineering Department, was hired as an operator intern effective January 2, 1996.

Carol Houtz worked wage payroll from August 20, 1995 to December 12, 1995 while Pam Stauffer, Staff Assistant VII, participated in the College of Engineering Staff Fellowship Program. Lois Lunetta, Chris Davis and Tara Beam worked wage payroll in assisting in facility educational programs for high school students. Melissa Hunter provided secretarial wage payroll help and also helped on educational programs and tours.

On January 1, 1996, Gordon Robinson, Chairman (Professor, Nuclear Engineering, Penn State) and Paul Sokol (Associate Professor, Physics) left the Penn State Reactor Safeguards Committee after each served the maximum two terms allowed by the committee charter. Their replacements effective January 1, 1996 were Dhushy Sathianathan (Assistant Professor, Engineering Graphics) and Forrest Remick (Professor, Nuclear Engineering, Penn State - retired).

TABLE I

Personnel

	Faculty and Staff	Title
**	P. G. Boyle	Reactor Supervisor/Nuclear Education Specialist
	L. D. Brazee	Staff Assistant V
**	M. E. Bryan	Reactor Supervisor/Engineer
	G. L. Catchen	Professor
**	T. Daubenspeck	Reactor Supervisor/Reactor Utilization Specialist
**	C. C. Davison	Reactor Supervisor/Nuclear Education Specialist
**	T. M. Engle	Reactor Operator Intern
**	T. L. Flinchbaugh	Operations and Training Manager
*	M. P. Grieb	Engineering Aide
	R. Gould	Research Assistant
**	D. E. Hughes	Senior Research Assistant/Manager of Engineering Services
	W. A. Jester	Professor
	J. Lebiedzik	Research Support Technician III
**	A. J. McLellan (resigned)	Reactor Operator Intern
**	D. R. Miller	Reactor Operator Intern
	M. J. Morlang	Reactor Operator Intern
*	K. E. Rudy	Operational Support Services Supervisor
	P. J. Stauffer	Staff Assistant VII
**	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

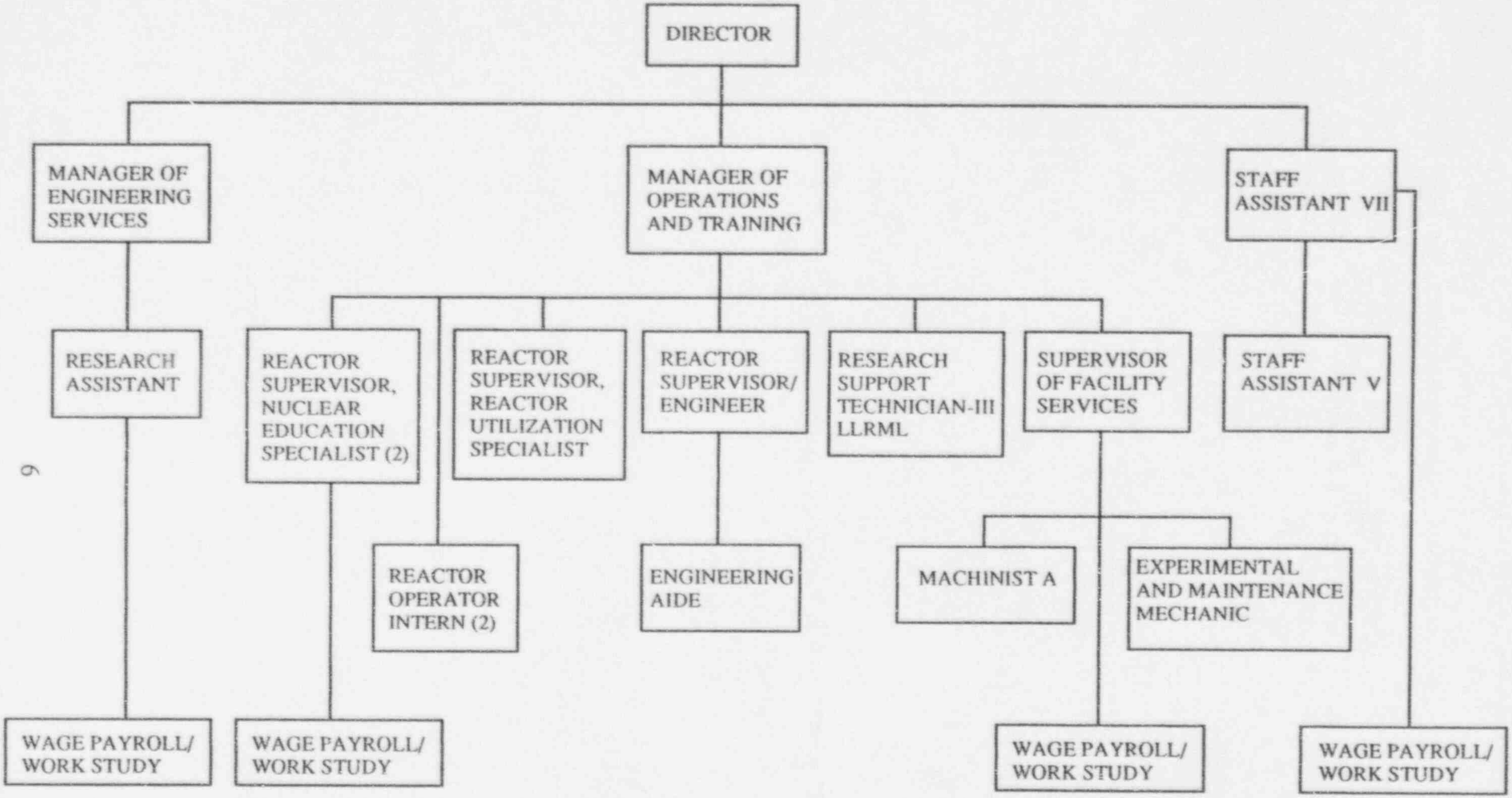
Wage Payroll

T. Beam
C. Houtz
M. Hunter
L. Lunetta
C. Davis

Penn State Reactor Safeguards Committee

	P. J. Donnachie, Jr.	Health Physicist, General Public Utilities
	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	Chairman, Assistant Professor, Nuclear Engineering, Penn State
**	F. J. Remick	Professor, Nuclear Engineering, Penn State (retired)
*	G. E. Robinson	Chairman, Professor, Nuclear Engineering, Penn State
**	D. Sathianathan	Assistant Professor, Engineering Graphics, Penn State
*	P. E. Sokol	Associate Professor, Physics, Penn State
	M. H. Voth	Ex officio, Director, Penn State Radiation Science and Engineering Center
	W. F. Witzig	Professor, Nuclear Engineering, Penn State (retired)

* Served through January 1, 1996
** Appointed January 1, 1996
*** Became Chairman effective January 1, 1996.



RSEC Organization Chart as of 6/1/96

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 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. Core rotational, east-west, and north-south movements provide flexibility in positioning the core against experimental apparatus.

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 the biennial fuel inspection took place 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 Unplanned Scrams Resulting from Personnel Action occurred when (1) the console sensed both bay exhaust fans were off because an Office of Physical Plant worker inadvertently turned off building power to the exhaust fans, (2) an Office of Physical Plant worker assembling scaffolding bumped the reactor scram button on the south wall of the neutron beam lab, and (3) a senior reactor operator caused a west air monitor alarm, evacuation horn and reactor scram while incorrectly checking the instrument's alarm set-point. The Unplanned Scram Resulting from Abnormal System Operation was because of an interlock validation failure when the software and hardware systems did not both verify within a specified time the control rod up push-button interlock that prevents simultaneous manual withdrawal of more than one control rod at a time.

Table 3, Part A, Reactor Usuage, 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. 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 1995, C. Frederick Sears, a former Northeast Utilities executive now a private nuclear engineering consultant, 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 December of 1995, a NRC routine inspection was conducted of activities authorized by the Cobalt-60 pool irradiation facility license (37-185-05). No items of non-compliance were identified.

TABLE 2

Reactor Operation Data
July 1, 1993 - June 30, 1996

	93-94	94-95	95-96
A. Hours of Reactor Operation			
1. Critical	601	561	591
2. Subcritical	362	401	423
3. Fuel Movement	31	27	84
B. Number of Pulses	48	131	96
C. Number of Square Waves	68	89	93
D. Energy Release (MWH)	391	259	245
E. Grams U-235 Consumed	20	13	13
F. Scrams			
1. Planned as Part of Experiments	27	15	36
2. Unplanned - Resulting From			
a) Personnel Action	2	1	3
b) Abnormal System Operation	1	5	1

TABLE 3

Reactor Utilization Data
Shift Averages
July 1, 1993 - June 30, 1996

		93-94	94-95	95-96
A.	Reactor Usage			
	1. Hours Critical	2.4	2.2	2.3
	2. Hours Subcritical	1.4	1.6	1.6
	3. Hours Shutdown	1.5	1.9	1.5
	4. Reactor Not Available	0.6	0	0.6
	TOTAL HOURS PER SHIFT	5.9	5.6	6.0
B.	Type of Usage - Hours			
	1. Industrial Research and Service	0.6	0.7	0.6
	2. University Research and Service	2.1	1.5	1.9
	3. Instruction and Training	1.4	1.3	1.3
	4. Calibration and Maintenance	1.8	2	1.9
	5. Fuel Handling	0.1	0.1	0.3
C.	Users/Experiments			
	1. Number of Users	2.3	2.4	2.3
	2. Pneumatic Transfer Samples	0.6	0.5	0.7
	3. Total Number of Samples	2.3	2.4	2.3
	4. Sample Hours	2.9	2.4	2.2
D.	Number of 8 Hour Shifts	254	255	262

GAMMA IRRADIATION FACILITY

IV. GAMMA IRRADIATION FACILITY

The University, in March of 1956, 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 the pool irradiation facility. 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 for the pool irradiator. These source rods have decayed through several half-lives, leaving a July 1, 1996 approximate total of 3,300 curies. In July of 1995, a GammaCell 220 dry irradiator was donated to Penn State by the David Sarnoff Research Center in Princeton, New Jersey. Total source content is 5,100 curies as of July 1, 1996.

In the pool irradiator, 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 sources 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. Four different irradiation configurations have been used depending on the size of the sample and dose rate required. The advantage of the pool irradiator is that the dose rate can be varied which is optimal for agricultural and life science research. Maximum exposure rates of 106 KR/Hr in a 3" ID tube and 62 KR/Hr in a 6" ID tube are available as of July 1, 1996.

The GammaCell 220 dry irradiator has a dose rate of 0.4 MegaRad/Hr in the center of its irradiation chamber, considerably higher than that indicated above for the RSEC pool irradiator. This is also a higher dose rate than available with other irradiators on campus. It will take approximately fifteen years for the dose rate of the GammaCell 220 to decay to the current Co-60 pool dose rates available, thus providing a fifteen year extension of usable irradiation capability. Other advantages of the GammaCell 220 include a large irradiation chamber (approximately 6 inches diameter and 7.5 inches high), an automatic timer to move the sample chamber away from the source and the ability to conduct in-situ testing of components during irradiation. The GammaCell has already received considerable use the first year. The sample hours for the GammaCell would be equivalent to 4,235 sample hours in the large pool irradiation tube.

The Gamma Irradiation facility is designed with a large amount of working space around the pool irradiator and the GammaCell 220 along with work benches and the usual utilities.

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, 1993 - June 30, 1996

	93-94	94-95	95-96	95-96
	Pool Irradiator	Pool Irradiator	Pool Irradiator	GammaCell
A. Time Involved (Hours)				
1. Set-Up Time	130	90	60	15
2. Total Sample Hours	6,547	2,694	2,042	605
B. Numbers Involved				
1. Samples Containers Run[1]	510	677	478	254
2. Different Experimenters[2]	36	39	25	20
3. Configurations Used	3	4	3	NA
C. Per Day Averages				
1. Experimenters	0.54	0.59	0.53	0.5
2. Samples	2.05	2.72	1.92	1.22

The sample hours for the GammaCell would be equivalent to 4,235 sample hours in the large pool irradiation tube.

Maximum Exposure Rate for the In-pool irradiation tubes as of July 1, 1996:

6" In-pool tube 62 KR/Hr
3" In-pool tube 106 KR/Hr

Maximum Dose rate at the center of the GammaCell 220 chamber as of July 1, 1996:

0.4 MegaRad/Hr

---

[1] Note that each sample container may contain multiple samples

[2] The number for Different Experimenters does not include the qualification exam for operators of the GammaCell

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.

The RSEC operating staff has maintained reactor operator competence and safe facility operation through training and requalification. In-house reactor operator requalification during November of 1995 consisted of an oral examination on abnormal and emergency procedures given by K. E. Rudy and an operating test given by C. C. Davison.

Operator interns Michael Engle and Michael Morlang participated in the reactor operator training program during 1995-96. Michael Engle was granted his senior reactor operator license by the NRC in June 1996.

The tenth session of the Pennsylvania Governor's School for Agricultural Sciences (PGSAS) was held at Penn State's University Park campus during the summer of 1995. 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 including core courses, elective courses and Independent Study Projects (ISP's). The core courses are fundamental instruction given to all participants. "Radiation Concepts for Research Applications" is one of the core courses in the program. The six-hour course consisted of four sections with sixteen students in each section.

The course was conducted at Penn State's RSEC by Candace Davison along with nuclear engineering student Christopher Norman. 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 simulation and calculation. 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.

In addition to the core course, a 14-hour elective course on "Nuclear Applications, Learning about the Past and Present" was conducted for twelve scholars. Jana Lebiedzik of the Low-Level Radiation Monitoring Laboratory provided a session on detection of radiation in the environment including radon gas. The students also learned about imaging using many types of radiation such as neutron radiography, x-ray and gamma-ray imaging including radiographs from the St. Mary's City Lead Coffin Project, a field trip to Radiology Associates and two sessions with the Scanning Electron Microscope.

Seven students conducted independent study projects related to radiation and nuclear science. Three students studied the effect of radiation on mushrooms and utilized the gamma irradiation facility along with the Scanning Electron Microscope. Two students focused on the disposal of Low-Level Radioactive Waste for their projects. One student chose the experiential route and gathered information about the Pennsylvania Siting Process. The other student conducted experiments to determine how well cesium and strontium are bound in a cement mixture by clay and other additives. Stable cesium and strontium were used in the cement mixture and then Neutron Activation Analysis was performed on the leachate to determine if there was a correlation between the binding of the cesium and strontium with the components of the cement mixture. The other projects focused on radiation and effects. The project on the effect of irradiation on Drosophila (fruit flies) was conducted by a student mentored by Dr. Diana Cox-Foster. The other project looked at Thermoluminescent dosimeters and shielding and/or backscattering materials to determine if these materials made a significant difference in measured dose. People from the Materials Research Laboratory, some Nuclear Engineering faculty and particularly the Health Physics personnel were very helpful in assisting with aspects of the PGSAS Independent Study Projects.

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.

A total of 671 students and teachers from 26 high school groups and 4 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 Thierry Daubenspeck, Jana Lebiedzik, Robert Gould and Alex McClellan.

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 for minority students, the High School Summer Internship, the Civil Engineering VEC-tour program, Women in Science and Engineering (WISE) and other programs associated with campus activities. Forty-one teachers from the Enter-2000 program received instruction and 12 toured the facility to learn more about nuclear energy and related careers. Two students from the SCIED498 course conducted at GPU Nuclear in Harrisburg came to the reactor to make-up the activities conducted during the June course.

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 122 formal or group tours for 2,708 persons. In addition approximately 30 informal tours were provided to 45 people.

The RSEC TRIGA reactor and Cobalt-60 irradiation facilities were used by several Nuclear Engineering and other courses during the year.

Semester		Course	Instructor	Students	Hours
Summer	1995	NucE 444-Nuclear Reactor Operations	D. E. Hughes	3	15
Fall	1995	NucE 451-Reactor Physics	R. M. Edwards W. A. Jester	19	51
Fall	1995	Food Science 413-Process Plant Production	R. B. Beelman	20	2
Fall	1995	Engineering Science 410 - Sr. Design Proj	P. Lenahan	1	5
Spring	1996	Engineering Science 411 - Sr. Design Proj	P. Lenahan	1	5
Spring	1996	Entomology 497C - Special Topics	A. Hower	1	4
Spring	1996	NucE 444-Nuclear Reactor Operations	D. E. Hughes	11	42
Spring	1996	NucE 450-Radiation Detection and Measurement	M. H. Voth W. A. Jester	17	20

In December of 1995 and January of 1996, a total of 32 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. University Health Physicist, Rodger Granlund, lectured to the groups on radiation safety at the reactor and other campus laboratories.

During the 1995-96 academic year, a visiting professor was hosted by the RSEC and Nuclear Engineering Department. Dr. Andrea Paesano is currently Assistant Professor of Physics at the State University of Maringá, Brazil. He received both his B.S. and Ph.D. in Physics from the Federal University of Rio Grande do Sul, Brazil. He was here for much of 1995-96 in the context of a collaboration between Penn State and the Federal University of Rio Grande do Sul to study defects in intermetallic compounds of the Zr-Fe system using nuclear spectroscopy, namely, perturbed-angular-correlation, Mössbauer-effect, and positron-lifetime spectrocopies. He is a specialist in multilayer thin films and Mössbauer-effect Spectroscopy, and worked with Dr. Arthur T. Motta and Dr. Gary L. Catchen.

TABLE 5

University Reactor Sharing Program
College and High School Groups
1995-1996 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	5	Altoona Homeschoolers Jennifer Calano	42
	20	Harmony HS Chad Weiwiora	23
	30	Bermudian Springs HS Jeanne Suehr	8
November	7	Eastern Lebanon HS Richard Schwalm	8
	10	Home-Schoolers Centre County Emily Welty	18
December	11	Carlisle HS Robert Barrick	46
	13	Carlisle HS Robert Barrick	47
January	10	State College HS Tod McPherson	41
	19	State College HS Delta Program Sara Bresler	10
February	21	Bald Eagle Area HS Andrew Snyder	13
	23	Penns Valley Area HS John Thompsen	23
March	11	Redland HS Robert Lighty	14
	15	Daniel Boone HS Larry Tobias	17
	18	Berwick HS Jeff Snyder	21
	20	Penns Valley Area HS John Thompsen	21
	22	Williamson HS Bob Burket, Jane Hultz	14
	25	Bald Eagle Area HS Andrew Snyder	13

TABLE 5

University Reactor Sharing Program
College and High School Groups
1995-1996 Academic Year
(Continued)

Month		School and Teacher	Number of Students & Teachers
April	3	Mount Union HS Janet Whitaker	30
	8	Bald Eagle Area HS Andrew Snyder	11
	12	State College HS Calvin Sleppy	18
	15	Juniata College Norm Siems	8
	16	Grove City College James Downey	12
	17	Harborcreek HS Dave Sidelinger	9
	19	Susquehanna Twp. HS Alan Ruch	13
	19	Jersey Shore HS Gary Heyd	8
	26	Ridgway HS Ernest Koos	10
	26	St. Mary's HS William Scilingo	30
	30	Indiana University of PA Frank Fazio	7
May	3	Camp Hill HS Philipp Schmelzle	10
	7	Allegany Community College Steve Heninger	25
	9	Somerset JHS Jon Critchfield	21
	13	Muncy HS Harold Shrimp, Debra Hepburn	22
	13	Perkiomen Valley HS Sandra Sweeney	8
	17	East Stroudsburg HS Heather Skeldon	16
	17	Danville HS Deb Slattery	12
	10	State College HS Delta Program Sara Bresler	7
June	18	Carnegie Science Academy Denise Turso	15

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 nondestructive 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. Equipment is available to digitize the real time radiography images for image processing. A photographic laboratory facilitates the development and analysis of static neutron radiographs.

The NBL was established partially with funds from the U.S. Department of Energy (DOE) 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. Bettis is to begin a second project which will require modifications to the Neutron Beam Laboratory. These modifications include removal of the ceiling in the Beam Area and the addition of a pit in the floor to allow radiography of an 8 foot long test section, the addition of new CCTV equipment for monitoring experiments, an improved Real Time Neutron Image Intensifier support assembly and the installation of a jib crane to support the long test section. The alterations are to be made as early as July, 1996, with the new project to begin immediately following.

A new D_20 thermal column to enhance the neutron beam in the NBL is to be installed in the Summer of 1996. This thermal column will take advantage of the extra degrees of freedom provided by the bridge upgrade completed in the Summer of 1994. The reactor core will be coupled to the thermal column in a position tangential to the beam line thereby improving the neutron to gamma ratio. It is expected that at least a factor of four increase in beam flux will result with a decrease in gamma ray intensity by a factor of six. Bettis has provided funding for computational support for the redesigned D_20 thermal column for graduate student John Wagner and Dr. Ali Haghighat both of the Nuclear Engineering Department.

Dr. Prescott and graduate student Byoung-Su Kim of the Penn State Mechanical Engineering Department are using this facility to examine a gallium - indium alloy with static neutron radiographs.

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 use a 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.

One hundred eighty-six semiconductor irradiations were performed last year at the RSEC. Laboratory personnel prepared each set of devices for irradiation, calculated the 1-MeV Silicon Equivalent fluence received, and determined the radioisotopes produced in the devices. Semiconductor chip pieces were analyzed to determine whether any trace contaminants were introduced during the production process.

The facility performed six isotope production runs of Na-24, Br-82 and Ar-41 for industrial use during the past fiscal year. In addition to production runs, several chemicals were analyzed using calculations and NAA to determine the feasibility of their use for production. As a result, our list of "approved" chemicals has expanded slightly.

Penn State students and faculty members continue to use the services offered by the radionuclear applications laboratory. Analysis work was performed for graduate and undergraduate students in the Nuclear Engineering, Materials Science, Anthropology and Horticulture departments. Preliminary work performed last year has resulted in this facility being used by various departments within the university.

The Penn State Radionuclear Applications Laboratory has continued to be involved with the Armed Forces Radiobiology Research Institute in activation analysis work of bomb blast dispersions. Preliminary studies conducted last year to determine the feasibility of using Dysprosium as a tracer material for bomb blasts was successful, and the RSEC is currently being used for verification of results.

A draft report regarding the bench marking of the reactor neutron energy spectrum following ASTM procedures was completed and reviewed by Penn State personnel. A final report was written and submitted to Raytheon.

The National Institute of Standards and Technology (NIST) performed two irradiations at our facility during September 1995. The items irradiated included flux monitors, Buffalo river sediment, methyl mercury, and sodium citrate.

The Nuclear Research Corporation used our pneumatic transfer system to calibrate a 2" × 2" BGO detector with respect to a known NaI detector. The calibration process involved the production of N-16 sources using deionized water and S-37 sources using sulfur pellets. An attenuation study was also performed using the above mentioned sources and 3" × 3" sheets of lead.

LOW LEVEL RADIATION MONITORING LABORATORY

VIII. LOW LEVEL RADIATION MONITORING LABORATORY (LLRML)

The laboratory continues to participate in the Environmental Protection Agency's (EPA) Environmental Radioactivity Laboratory Intercomparison Studies Program for gross alpha, gross beta, radium-226, radium-228, strontium-89, strontium-90, and other gamma emitters as part of the laboratory quality assurance program and to maintain staff proficiency. These analyses are carried out for clients not requiring the PA DER certification. These include the bottled water analyses and analyses for municipal water suppliers and the general public. Tritium analysis of ground water for laboratories involved in water testing is also provided. Radon in water analysis is also offered; certification for this analysis has been proposed but is not yet required by the EPA.

The laboratory provides analyses for gross alpha and gross beta activity in reactor pool water, cobalt-60 pool water, and the reactor's secondary heat exchanger water and tritium content analysis of reactor pool water. A gamma spectroscopy analysis is performed on these samples when the gross alpha or gross beta action limit is exceeded. Tritium concentration in the deuterium oxide tank is sampled each month. Gamma spectroscopy analyses are performed on a quarterly basis on the reactor pool water. The 6,000 gallon holding tank for the pool make-up water is analyzed according to Health Physic's requirements once a year.

The LLRML is maintaining its DER certification via the EPA National Radon Measurement Proficiency Program to test for radon in air using activated charcoal canisters and both short and long-term electret ionization chamber detectors. Dr. William Jester, the laboratory's technical supervisor is certified via the ongoing RPM program for radon test operators and the laboratory is listed in the EPA posting of certified radon testing firms/individuals. The calibration of new diffusion barrier charcoal radon monitoring canisters purchased to replace the existing open-face canisters presently used is under way to achieve the certification.

A major focus of the laboratory is on the gross alpha, gross beta and gamma spectroscopy analyses of zirconia materials used in producing femoral heads in hip-joint replacement pieces. This service work is required by Howmedica Inc. of New Jersey with its zirconia supplier, Morgan Matroc Limited, Warwickshire, England.

Cesium-134 and cesium-137 concentrations in soil samples determined by gamma spectroscopy for the Forest Resource Laboratory at PSU is an ongoing project to be continued within the next fiscal year.

Analyses to certify the % Lithium enrichment for enriched LiOH samples continue for Isotec Incorporated of Ohio. The higher lithium enrichments are important in the nuclear industry to minimize tritium production in pressurized water reactors.

Dr. William Jester's involvement with Dr. Art Rose, Professor of Geochemistry, in utilizing alpha spectroscopy analyses of uranium, thorium, and radium alpha emitters via ions plated on nickel disks should result in expanding the laboratory's capability to analyze soil, silt and clay samples for these elements.

THE ANGULAR CORRELATIONS

LABORATORY

IX. THE ANGULAR CORRELATIONS LABORATORY

The Angular Correlations Laboratory has been in operation for approximately 10 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 three spectrometers for making Perturbed Angular Correlation (PAC) measurements. One apparatus, which has been in operation for nine years, measures four coincidences concurrently using cesium fluoride detectors. A second spectrometer was acquired five years ago, and it measures four coincidences concurrently using barium fluoride detectors. A third spectrometer was set up two years ago to accommodate the increased demand for measurement capability. 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. The National Science Foundation is sponsoring the program, and the Office of Naval Research sponsored this program in the past.

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.

RADIATION SCIENCE & ENGINEERING

CENTER RESEARCH

X. 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, 14 papers, 14 publications, 1 patent, 9 masters' theses, and 13 doctoral theses. 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, 49 faculty and staff members, 49 graduate students and 14 undergraduate students have used the facility for research. This represents a usage by 16 departments or sections in 5 colleges of the University. In addition, 38 individuals from 31 industries, research organizations or other universities used the RSEC facilities.

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

Agronomy

MICROBIAL DEGRADATION OF CHLORDANE USING COMPOST AS A CULTURE MEDIUM

Participants: J. Bollag
C. Brunner

Service Provided: Gamma Irradiation

The purpose of the project is to determine the actual and potential biotransformation of a selected group of commonly used pesticides under aerobic and anaerobic conditions when using compost as a treatment process or for amending pesticide-contaminated soils as a means of bioremediation. Specifically, the study concentrates on the pesticide chlordane, a complex mixture of persistent chlorinated organic compounds. Composting involves a complex set of interactions between organic matter and a consortium of microorganisms including bacteria, actinomycetes, and fungi. The wide variety of microorganisms and organic constituents in composting environments suggests the possibility of using compost as the basis of a process to treat waste pesticide formulations and solutions, and to enhance the rate of biodegradation of pesticides in contaminated soils. To distinguish between biological and abiotical processes involved in the pesticide transformation during composting, it was necessary to prepare suitable control assays. Gamma irradiation was chosen among other sterilization methods, because of its known efficiency when sterilizing soils and other materials.

Sponsor: EPA Project CR 823892-01

Anthropology

OBSIDIAN SOURCE ANALYSIS OF ARCHAEOLOGICAL SPECIMENS FROM XOCHICALCO, MEXICO

Participants: K. Hirth
G. Bondar

Services Provided: Neutron Irradiation, Radiation Counters and Laboratory Space

The study is attempting to reconstruct prehistoric trade routes by matching the chemical composition of obsidian to natural geological outcrops of the same material. This will allow us to reconstruct the movement of material in the past along ancient trade routes.

One limitation of past studies was the small sample size used to reconstruct trade routes. This project will use a sample of about 300 specimens to identify prehistoric economic activity. Instead of using all obsidian as the sample, artifacts will be stratified by tool class and examined to determine if there were economic differences (and sources) in the obsidian used to manufacture different tools.

Research is just beginning. The 1995-96 school year has been used to establish the methodology used to carry out the analysis. Work will continue through the 1996-97 school year.

Sponsor: National Science Foundation $1,500

Anthropology

PREHISTORIC METARHYOLITE USE AND MIGRATION IN THE MID-ATLANTIC

Participants: K. Hirth
G. Bondar

Services Provided: Neutron Irradiation, Radiation Counters and Laboratory Space

4000 years ago, significant changes occurred in the Native American cultures of the Mid-Atlantic and Northeastern regions of what is now the United States. These have been attributed to either a migration of southern people into the region or, alternatively, a transfer of traits from southern cultures. This study will attempt to clarify this issue.

One of the major cultural changes that occurred was the dramatically increased use of a lithic material called metarhyolite. Metarhyolite in the regions of study is limited to several widely-separated formations, one of which runs, roughly, along a north/south line through the Blue Ridge mountains. I hypothesize that I should be able to differentiate between group migration and cultural diffusion in this setting.

Using the NAA capabilities of the Breazeale Nuclear Reactor facility, I intend to chemically characterize artifacts and geologic sources so as to match archaeological artifacts from dated sites to their sources of raw material. I expect to see a progression of source exploitation from south to north through time if a migration had occurred.

Currently, no quantitative examination of data has related to this issue. However, the significance of this research extends beyond the borders of this study area. One reason why I selected this topic was because it has the potential to discern an actual population migration based purely on the material culture of a prehistoric society. If successful, this method of analysis should prove useful to examine prehistoric migrations throughout the world.

At present, this research is at the stage of determining methodology and collecting data. Work on this project will continue throughout the next several years.

Doctoral Thesis:

Bondar, G. H., and K. G. Hirth, advisor. Prehistoric Metarhyolite Use and Migration in the Mid-Atlantic Region. In progress.

Publication:

Intend to present progress report at the 1997 Workshops in Archaeometry conference at SUNY/Buffalo, February 1997.

Biology

MECHANISMS OF THE YAN PROTEIN-MEDIATED INHIBITION OF CELL FATE DETERMINATION

Participants: Z.-C. Lai
E. Donaher
S. Schmidt
A. Uuni

Service Provided: Gamma Irradiation

How different cell types are generated from a group of equipotent cells is a central question in developmental biology. Inductive signal transduction that utilizes receptor tyrosine kinouse and small GtPase Ras protein is important in this process. However, increasing evidence shows that negative control is equally critical. Using the Drosophila eye system, a negative regulator at photoreceptor cell specification, the product of the yan gene has been previously characterized. Yan normally acts to maintain photoreceptor precursor cells in an undifferentiated state and such inhibition can be overcome by proneural signaling.

Our goal is to understand how Yan acts to maintain precursor cells undetermined, and to reveal the functional significance of negative control in nuclear signal transduction, by using a combination of genetic, molecular, and cellular approaches.

Publication:

Lai, Z.-C., S. D. Harrison, F. Karim, Y. Li and G. M. Rubin. The Traintrack Gene Represses a Sina-Independent Program of R7 Cell Determination in the Drosophila Eye. Proc. Natl. Acad. Sci. USA, in press, 1996.

Sponsor: National Science Foundation $285,000 /3 years

Biochemistry and Molecular Biology

GENETIC AND MOLECULAR CHARACTERIZATION OF MUSCLE DEVELOPMENT

Participants: S. M. Abmayr
D. Heyser
B. A. Bour

Service Provided: Gamma Irradiation

Gamma irradiation of Drosophila is routinely used to generate deletions in particular regions of the fly's genome that are of interest. Our research involves the identification and examination of genes that are involved in muscle development in the fruitfly. One of these genes, nautilus, is a Drosophila homolog of a gene known to be involved in vertebrate muscle development, MyoD. We have cloned this gene, and are in the process of elucidating its role in muscle development in the fly embryo. To this end, we are generating mutations that disrupt nautilus. As an initial step, deletions that remove this and nearby genes have been generated. In brief, the progeny of irradiated flies are examined for the loss of genetic markers in this region to identify the desired deletions. These deletions occur with a frequency of approximately 1 in 10,000 progeny.

Doctoral Thesis:

Bour, B. A., and S. M. Abmayr, advisor. Genetic and Molecular Characterization of Muscle Development. In progress.

Sponsor: American Cancer Society $90,500 /3 years

Biochemistry and Molecular Biology

GENETIC AND MOLECULAR ANALYSIS OF A DROSOPHILA HOMOLOG OF MYOD

Participants: S. M. Abmayr
D. G. Heyser
C. Keller

Service Provided: Gamma Irradiation

Gamma irradiation of Drosophila is routinely used to generate deletions in particular regions of the fly's genome that are of interest. Our research involves the identification and examination of genes that are involved in muscle development in the fruitfly. One of these genes, sns, was originally found on the basis of its mutant phenotype, in genetic screens designed to identify new genes involved in myogenesis. This genetic lesion has been genetically mapped on the chromosome, and our efforts now focus on cloning the gene responsible for the sns defect. As an initial step deletions that remove this gene, as well as nearby genes, have been generated. In brief, the progeny of irradiated flies are examined for the loss of genetic markers in this region to identify the desired deletions. These deletions occur with a frequency of approximately 1 in 10,000 progeny. These will provide us with DNA breakpoints that refine the location of the desired gene, and are detectable by standard molecular methods.

Doctoral Thesis:

Keller, C. A., and S. M. Abmayr, advisor. Genetic and Molecular Analysis of a Drosophila Homolog of Myod. In progress.

Sponsor: National Science Foundation $300,000 /3 years

Chemistry Department

SYNTHESIS AND CHARACTERIZATION OF PH-SENSITIVE POLY(ORGANOPHOSPHAZENE) HYDROGELS

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

Service Provided: Gamma Irradiation

A new class of pH-sensitive hydrogels has been designed and synthesized. These are novel polyphosphazenes that bear various ratios of sodium oxybenzoate and methoxyethoxyethoxy side groups. These water-soluble macromolecules were crosslinked by ^{60}Co gamma irradiation and the products were allowed to absorb water to form hydrogels. The hydrogels had higher equilibrium degrees of swelling in basic than in acidic buffer solutions, and polymers with a higher loading of the ionic side group showed higher swellability than those with a lower loading of this side group. The effects of ionic strength, cation charge, and radiation dose on the degree of swelling were also studied. A study of the diffusion of the dye, Biebrich Scarlet, from the hydrogels showed complete release of the dye in 4-12 hours in pH 7.4 buffer solution but significantly lower release at pH 2 even after 48 hours. The release rate also varied as the side group ratios were changed. The prehydrogel polymers were synthesized via the macromolecular substitution reactions of poly(dichlorophosphazene) with sodium methoxyethoxyethoxide and the sodium salt of propyl 4-hydroxybenzoate, followed by ester hydrolysis to yield the sodium carboxylate. The hydrogels are of interest for possible use as pH-sensitive membranes and for a number of potential biomedical applications.

Doctoral Thesis:

Ambrosio, A. A., and H. R. Allcock, advisor. Synthesis and Study of Polyphosphazenes for Potential Biomedical Applications, 1996.

Publication:

Allcock, H. R., and A. A. Ambrosio. Synthesis and Characterization of pH-Sensitive Poly(organophosphazene) Hydrogels. Accepted for publication in Biomaterials.

Chemistry Department

BLOCK CO-POLYMER SYNTHESIS WITHIN THE ADDUCTS OF TRIS(OPHENYLENEDIOXY)CYCLOTRIPHOSPHAZENE

Participants: H. R. Allcock
P. Primrose

Service Provided: Gamma Irradiation

The goal of this project is to synthesis block co-polymers which normally do not form using standard solution techniques. This may be achieved first by inclusion of an initial monomer within the adducts of tris(o-phenylenedioxy)cyclotriphosphazene. Second, this solid is evacuated to remove excess monomer and then exposed to gamma irradiation for a specific period of time. Once irradiated, this solid will be exposed to a second monomer and will be left to sit for approximately one week. Through this simple procedure, it is hoped that block co-polymer formation will be achieved.

Engineering Science and Mechanics

STRUCTURE OF TRAPPING CENTERS IN AMORPHOUS INSULATING FILMS

Participants: P. M. Lenahan
J. F. Conley
J. T. Yount
C. J. Frye
C. Billmen

Service Provided: Gamma Irradiation

We are engaged in a long-term project to identify the structure of trapping centers in SiO_2, Si_3N_4, silicon oxynitrides and variously "doped" SiO_2 thin films. These films play very important roles in metal oxide silicon field effect transistor (MOSFET) technology. Under certain circumstances, the trapping centers may be generated or activated by exposing the oxides to gamma irradiation.

Doctoral Theses:

Yount, J. T., and P. M. Lenahan, advisor. The Structure and Behavior of Point Defects in Silicon Oxynitride Gate Dielectrics, 1995.

Conley, J. F. and P. M. Lenahan, advisor. An Electron Spin Resonance Investigation of the Many Roles of E'Variants in Amorphous Silicon Dioxide Thin Films on Silicon, 1996.

Master's Thesis:

Frye, C. J., and P. M. Lenahan, advisor. Trapping Centers in Borophosposilicate and Phosphosilicate Glass Films.

Publication:

Conley, J. F., and P. M. Lenahan, advisor. A Review of Electron Spin Resonance Spectroscopy of Defects in Thin Film SiO_2 on Silicon, The Physics and Chemistry of SiO_2 and the Si/SiO_2 Interface III, H. Z. Massoud, E. H. Poindexter, and C. R. Helms editors, Electrochemical Society, Inc., 1996.

Sponsors:	NASA/Prairie View	$30,000 /yr for 3 years
	ONR	$60,000
	Harris Semiconductor	$28,000
	Dynamics Research Corporation	$24,000

Entomology

RADIATION OF HOUSE FLY PUPAE

Participants: A. Hower
G. Godwin

Service Provided: Gamma Irradiation

Use of radiation as mortality factor and as a sterilant for house fly.

Food Science

IRRADIATION OF MUSHROOMS - EFFECTS ON QUALITY AND SHELF LIFE

Participant: R. Beelman

Service Provided: Gamma Irradiation

Food Science

EVALUATION OF KINETICS OF *ESCHERICHIA COLI* O157:H7 IN ACTIVATION IN COLICIN-TREATED BEEF PATTIES/HAMBURGERS

Participants: R. Roberts
S. Murinda
R. Wilson

Service Provided: Gamma Irradiation

Gamma irradiation was used to kill all background microflora on freshly manufactured beef hamburger patties. The hamburgers were inoculated with pathogenic *Escherichia coli* of serotype O157:H7 and then treated with colicins. Colicins are inhibitory proteins that kill susceptible

Escherichia coli . We intended to study this specific killing effect on hamburgers that were infected with *Escherichia coli* only after killing other contaminants using gamma rays (400 Kilorads). Project was suspended approximately August 1995 and will probably be continued in Summer of 1996.

Sponsor: Department of Food Science ~ $150

Mechanical Engineering

NEUTRON RADIOGRAPHIC ANALYSIS OF MACROSEGREGATION IN BINARY METAL ALLOYS

Participants: P. J. Prescott
B. Kim

Service Provided: Neutron Radiography

Convective transport phenomena are important during solidification of metal alloys. Fluid flows in the two-phase (mushy) and the fully melted regions are caused by thermally and solutally induced buoyancy forces during solidification of alloys. Fluid flows in the mushy and the melt regions have a profound influence on the metallurgical structure and chemical homogeneity of the final casting. Moreover, convection in the solidifying alloy is responsible for macrosegregation, a maldistribution of solute in castings.

A combined numerical and experimental study of convective transport phenomena during solidification of Ga-In (gallium-indium) alloy has been performed, and the effects of varying thermal boundary condition have been considered. Experiments have been performed in a vertical square cavity, which is cooled from a side wall while keeping the other wall insulated. Experiments are underway to analyze the solidified ingot for any macrosegregation using neutron radiography and comparisons will be made with numerical predictions.

Neutron radiography uses a collimated beam of neutrons to penetrate a specimen. The intensity of the neutron beam exiting the specimen depends on thickness and neutron absorption characteristics of the specimen. There is a large difference in neutron absorption coefficients for gallium (Ga) and indium (In). In other words, gallium is relatively transparent to the neutron beam while Indium is strongly absorbing. The neutron radiograph of the solidified ingot will show the distribution of Ga and In constituents, which is related to convection patterns during solidification.

To relate the neutron beam intensity with Ga-In concentrations, a calibration device has been fabricated. Using the calibration device, a few experiments at the Nuclear Reactor have been performed. The films obtained using Neutron Radiography are being analyzed to develop a correlation between the film density and Ga-In concentrations. In the future, films of the solidified ingot will be taken and the distribution of Ga-In constituents will be determined analyzing the film.

Doctoral Thesis:

Kim, B., and P. J. Prescott, advisor. An Experimental and Theoretical Investigation of Convection Heat and Mass Transfer During Solidification of Binary Metal Alloys. In progress.

Publication:

Kim, B., and P. . Prescott. Neutron Radiographic Measurement of Macrosegregation in an Experimentally Solidified Binary Metal Alloy, 1996 National Heat Transfer Conference, ASME, August 3-6, 1996, Houston, Texas, in press.

Nuclear Engineering

STRUCTURAL PHASE TRANSITION AND T_C DISTRIBUTION IN HF-DOPED $LaMnO_3$ INVESTIGATED USING PERTURBED-ANGULAR-CORRELATION SPECTROSCOPY

Participants: G. L. Catchen
W. E. Evenson
D. Allred

Service Provided: Neutron Irradiation and Angular Correlations Lab

Using perturbed-angular-correlation (PAC) spectroscopy, via the $^{181}Hf \rightarrow ^{181}Ta$ probe, we have measured Mn-site electric-field gradients (EFGs) at Ta nuclei in ceramic samples of $LaMnO_3$. Two crystallographic phases coexist over a temperature interval of ≈ 16 K near the orthorhombic-to-rhombohedral transition at ≈ 724 K, which shows a thermal hysteresis of ≈ 1.7 ± 0.2 K. Concurrently, in the two phases, we determined the temperature dependence of the EFG parameters, V_{zz}, η, and δ, and the ratio of the probe concentrations A_1/A_2. To explain the apparent coexistence of two phases in this weakly first-order transition, we present a model that assumes a spatial distribution of T_c - values. This distribution could arise from a spatially non-uniform distribution of Mn^{4+} ions. We show the PAC technique to be a uniquely powerful probe of local symmetries that reflect the effects of a local distribution of valences, which drive the phase transition.

Publication:

Catchen, G. L., W. E. Evenson and D. Allred. Structural Phase Transition and T_c Distribution in Hf-Doped $LaMnO_3$ Investigated Using Perturbed-Angular-Correlation Spectroscopy, *Physical Review B*, 53: R3679-R3682, August 1996.

Nuclear Engineering

CHARACTERIZING PHASE TRANSITIONS IN THE PEROVSKITES $PbTiO_3$ AND $BaTiO_3$ USING PERTURBED-ANGULAR-CORRELATION SPECTROSCOPY

Participants: G. L. Catchen
E. F. Hollinger
T. M. Rearick

Services Provided: Neutron Irradiation and Angular Correlations Lab

Perturbed-angular-correlation (PAC) spectroscopy was used to measure in ceramic samples of $PbTiO_3$ and $BaTiO_3$ the temperature dependence of the Ti-site electric-field gradients (EFGs) at temperatures very close to the ferroelectric-to-paraelectric transition temperatures T_c. The samples were doped with small amounts of Hf that carried the $^{181}Hf \rightarrow ^{181}Ta$ probe radioactivity. A high-frequency nuclear quadrupole interaction that decreases very little as the temperature approaches T_c characterizes the $PbTiO_3$ transition. The tetragonal and cubic phases for $PbTiO_3$ appear to coexist over a temperature interval of 8 ± 1 K, and the transition shows a thermal hysteresis of about 4 K. In contrast, a lower-frequency interaction that decreases rapidly as temperature approaches T_c, characterizes the $BaTiO_3$ transition. Both phases of $BaTiO_3$ appear to coexist over an interval of about 2 K, and the thermal hysteresis is about 1 K. At temperatures above T_c, both $PbTiO_3$ and $BaTiO_3$ show weak, non-vanishing Ti-site EFGs. Although, for $BaTiO_3$, this effect limits that accuracy with which critical effects can be measured, we estimate a power-law exponent $\beta \approx 0.21 \pm 0.05$, which most likely is somewhat lower in magnitude than the actual critical exponent. For the explanation of our observations we assume the existence of a distribution of T_c-values. The distribution would arise because the crystals could have spatially non-uniform distributions of nucleation sites, which for $PbTiO_3$ and $BaTiO_3$ could be point defects.

Master's Thesis:

Hollinger, E. F., and G. L. Catchen, advisor. Characterization of the Ferroelectric-to-Paraelectric Phase Transition in Barium Titanate by Perturbed Angular Correlation Spectroscopy, 1995.

Publication:

Catchen, G. L., E. F. Hollinger and T. M. Rearick. Characterizing Phase Transitions in the Perovskites $PbTiO_3$ and $BaTiO_3$ Using Perturbed-Angular-Correlation Spectroscopy. Zeitschrift der Naturforschung, 51a, 411-421, July 1996.

Nuclear Engineering

ELECTRIC-FIELD GRADIENTS AND SUPERTRANSFERRED MAGNETIC HYPERFINE FIELDS AT ^{181}Ta PROBE IONS IN THE PEROVSKITES $LaMnO_3$ AND $NdMnO_3$

Participants: G. L. Catchen
R. L. Rasera
T. M. Rearick

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

Perturbed γ-ray angular correlation measurements have been carried out on the antiferromagnetic perovskites $NdMnO_3$ and $LaMnO_3$ with the dilute tracer ^{181}Hf substituted into the manganese site. Above the Néel temperature T_N, both compounds show a very large ($\omega_Q[LaMnO_3] = 158(1)$ Mrad/s; ($\omega_Q[NdMnO_3] = 191(1)$ Mrad/s and highly anisotropic electric-quadrupole interaction (EQI) at the ^{181}Ta probe ($\eta \approx 0.8$ in both cases). Below T_N a supertransferred magnetic hyperfine field appears, of a strength comparable to that of the EQI. Analysis of the resulting combined interaction suggests that the angle β between the principal axis of the EQI tensor and the direction of the magnetic field is near 65°.

Publication:

Rasera, R. L., G. L. Catchen and T. M. Rearick. Electric-Field Gradients and Supertransferred Magnetic Hyperfine Fields at ^{181}Ta Probe Ions in the Perovskites $LaMnO_3$ and $NdMnO_3$. 10th International Conference on Hyperfine Interactions, Leuven Belgium, August 28 - September 1, 1995, Baltzer Science Publishers, Basel, Switzerland, 1996.

Nuclear Engineering

VARIOUS ANALYSES OF SAMPLES USING THE SERVICES OF THE RADIONUCLEAR APPLICATIONS LABORATORY

Participant: T. Daubenspeck

Services Provided: Neutron Irradiation, Radiation Counters and Flux Monitoring

Penn State was used to verify Armed Forces Radiobiological Research Institute (AFRRI) calculations on a project to determine the dispersion pattern of bomb blasts. Soil, concrete, and other residual samples were irradiated and the ppm of Dysprosium-165 (used as a monitor) was determined. This was a continuation of a study performed during the previous year. (Mark Moore - AFRRI)

NAA of two PolyEtherEtherKeystone (PEEK) samples to determine trace element concentrations. (Westinghouse)

Six isotope production runs were performed for Tru-Tec during the past year. These runs included one Sodium-24 run, four Bromine-82 runs, and one Argon-41 run. A total of approximately 200 mCi of Sodium-24, 1300 mCi of Bromine-82 and 100 mCi of Argon-41 were produced during the year. With the assistance of the Penn State Health Physics office, we were able to give Tru-Tec information to "correct" deficiencies in their license and update their license to more accurately reflect quantities of radioactive isotopes produced during radioisotope production. (M. Flenniken - Tru-Tec)

Two different catalysts were investigated through the use of spreadsheet calculations and NAA to determine the practicality of using those chemicals for radioisotope production. (M. Flenniken - Tru-Tec)

Irradiation of Yttrium Nitrate ($Y(NO_3)_3$) solutions were performed for thesis work. (U. Senaratne, and W. A. Jester - Nuclear Engineering)

Aluminum samples (types 4043, 1100, 6061, 6063) were irradiated and analyzed to determine activation products created to help select materials for a new D_2O tank. (D. E. Hughes - Nuclear Engineering)

Activated and analyzed steel foils. (S. Cumblidge - Nuclear Engineering)

Irradiation of magnesium oxide powder. (W. A. Jester - Nuclear Engineering)

Irradiation of thyroxine powder in CT for thesis work (measure ratio of Iodine-129 and Iodine-127. (J. Kwon - Nuclear Engineering)

Flux measurements using gold-aluminum, nickel, iron and zirconium activation foils. (H. Basha - Nuclear Engineering)

NAA demos for high school/college/miscellaneous tours. (C. C. Davison - Nuclear Engineering)

Activation and analysis of concrete leach sample for Governor's School student's project. (C. C. Davison - Nuclear Engineering)

Irradiation of plant membrane on nitrocellulose filters to determine the amount of Silicon taken up by the plant. (D. Halperin - Horticulture)

Production of 0.5 mCi of Na-24 for additional plant studies. (D. Halperin - Horticulture)

Continuation of feasibility study to determine if NAA using the rabbit system would be useful in determining sources of various obsidian artifacts. Preliminary investigation of rhyolite (another form of obsidian) was performed. (K. Hirth and G. Bondar - Anthropology)

Irradiated samples and flux monitors in the central thimble. (E. Mackey - NIST)

Semiconductor irradiations, 186 total. (Harris-179, Raytheon-2, E-Systems-3, Honeywell-2)

NE 451, UNDERGRADUATE LABORATORY OF REACTOR EXPERIMENTS

Participants: R. M. Edwards
W. A. Jester
J. A. Turso
M. E. Bryan

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, 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. 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 Introduction to Nuclear Engineering text 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 1995, 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 introduced in 1991 when 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 laboratory utilizes Macintosh computers with GW Electronics MacAdios Jr data acquisition hardware and Superscope II software. The Superscope II software was a major software upgrade for 1993 and with its new point-by-point seamless mode enabled effective reactivity calculations and control experiments. The Mathworks SIMULINK simulation software was used for the digital simulation exercise for the first time in 1992. Reactor control is offered as a graduate course in our department but until 1991 our undergraduates did not receive a complete introduction to feedback control. In the Fall of 1994, a new UNIX network compatible control system was utilized for the reactor control experiment. The new system was also acquired to enhance the NSF/EPRI sponsored research and is described in more detail in subsequent sections. The UNIX Network compatible controller programming is performed using the Mathworks SIMULINK block programming language in a SUN SPARC workstation. An automatic C code generation process produces and downloads the necessary real-time program for execution in a microprocessor-based controller with an ETHERNET network interface to the host workstation.

The 1994 version of the control experiment thus unified all of the MATLAB/SIMULINK instruction earlier in the course into a demonstration of state-of-the-art CASE-based control system design and implementation.

Nuclear Engineering

NSF/EPRI: EXPERIMENTAL DEVELOPMENT OF POWER REACTOR INTELLIGENT CONTROL

Participants: R. M. Edwards
K. Y. Lee
D. E. Hughes

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, Reactor Instrumentation and Support Staff

This is a major three year project supported by the National Science Foundation and Electric Power Research Institute. Initiated in January 1993, the project is composed of five major tasks: 1) Advanced Direct Control Experiments, 2) Intelligent Control Research, 3) Multivariable Control Capability, 4) Hybrid Reactor/Simulation, and 5) Dissemination of results. Specific activities during the 1994-95 academic year are summarized in the following descriptions.

For the summer of 1995, an NSF supplemental grant for Research Experiences for Undergraduates (REU) was obtained and two undergraduate students participated.

Paper:

Edwards, R. M., K. Y. Lee and D. E. Hughes. Testbed For Nuclear Plant Instrumentation And Control Validation. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 287-294, University Park, Pennsylvania, May 6-9, 1996.

Sponsors:	FERMI	$12,000 (1992)	NSF/EPRI	(1993-1996) $300,000 for the
	FERMI	$18,000 (1994)		following NSF/EPRI projects:

Nuclear Engineering

NSF/EPRI ADVANCED REACTOR TEMPERATURE CONTROL ALGORITHMS

Participants: R. M. Edwards
H. D. Gougar
K. Y. Lee
P. Ramaswamy
R. M. Johns
S. Shyu
D. E. Hughes
M. E. Bryan

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, Reactor Instrumentation and Support Staff

Advanced reactor temperature control algorithms were developed in the first component of the NSF/EPRI project. Based on a prototype TRIGA Reactor Optimal Control experiment conducted during the summer of 1991 and subsequent work by Mike Power in the previous 93-94 academic year, this area was expanded into design of optimized feedforward control during the 94-95 academic year and continued into the 95-96 academic year. An additional component in 95-96 was the estimation of TRIGA reactor thermal-hydraulic parameters via extended Kalman Filter.

Master's Theses:

Johns, Richard M., and R. M. Edwards, adviser. Optimal Setpoint Generation for Improved Fuel Temperature Response, 1995.

Deceñas-Falcón, M., and R. M. Edwards, adviser. Parameter Estimation for the Pennsylvania State University TRIGA Reactor, 1996.

Papers:

Johns, R. M., S. Shyu, and R. M. Edwards. Experimental Validation of Optimized Feedforward Control for Improving Reactor Temperature Response. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 295-302, University Park, Pennsylvania, May 6-9, 1996.

Ceceñas-Falcón, M., and R. M. Edwards. On-Line Parameter Estimation for a Nuclear Reactor Using an Extended Kalman Filter. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 1099-1106 University Park, Pennsylvania, May 6-9, 1996.

Johns, R. M., and R. M. Edwards. Optimal Set-Point Generation for Improved Fuel Temperature Performance. Trans. Amer. Nucl. Soc. 73:300-301, November 1995.

Nuclear Engineering

NSF RESEARCH EXPERIENCES FOR UNDERGRADUATES PROJECT

Participants: R. M. Edwards
G. L. Meyers
R. F. Sanchez
D. E. Hughes
M. E. Bryan

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, Reactor Instrumentation and Support Staff

Gary L. Meyers and Roberto F. Sanchez conducted research under an NSF Research Experiences for Undergraduates project during the Summer of 1995. Mr. Meyers worked on PID control for enhanced reactor temperature response. This analysis and experiments provided benchmark data for comparison with optimal and robust control experiments describe in NSF/EPRI Advanced Reactor Temperature Control Algorithms. Mr. Sanchez developed a reactivity computer on the experimental reactor control hardware/software platform and used it to help improve the Macintosh reactivity computer used in the NucE 451 laboratory.

Papers:

Sanchez, R. F., and R. M. Edwards. Development of a UNIX Network Compatible Reactivity Computer. To appear in Trans. Amer. Nucl. Soc. 74:, Reno Nevada, June 16-20, 1996.

Meyers, G. L., R. M. Johns and R.M. Edwards. Reactor Temperature Control Experiments Using Modern Control Design Tools with Automated Program Generation. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant

Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 859-866, University Park, Pennsylvania, May 6-9, 1996.

Sanchez, R.F., and R. M. Edwards. Development of a UNIX Network Compatible Reactivity Computer. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 851-858, University Park, Pennsylvania, May 6-9, 1996.

Meyers, G. L., R. M. Johns and R.M. Edwards. PID Control for Enhanced Fuel Temperature Response. Trans. Amer. Nucl. Soc. 73:298-300, November 1995.

Publications:

Meyers, G. L. Reactor Temperature Control Experiments Using Modern Control Design Tools with Automated Program Generation. Report to the National Science Foundation on A Research Experiences for Undergraduates Supplemental Grant to ECS-9216504, November 21, 1995.

Sanchez, R. F. Development of a UNIX Network Compatible Reactivity Computer. Report to the National Science Foundation on A Research Experiences for Undergraduates Supplemental Grant to ECS-9216504, November 9, 1995.

Sponsor: NSF/REU (1995) $9,000

Nuclear Engineering

NSF/EPRI INTELLIGENT CONTROL OF TRIGA REACTOR TEMPERATURE

Participants: R. M. Edwards
S. J. Kenney
D. E. Hughes

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, Reactor Instrumentation and Support Staff

An intelligent reconfigurable reactor power controller was developed and implemented in the second component of the NSF/EPRI project. The intelligent controller automates a monitoring and decision-making process that chooses the best controller to achieve improved reactor temperature performance over a wide range of operating conditions. The available controllers are those developed in the previously described advanced reactor temperature control algorithm research. On-line performance of an enforced controller is determined by measures of integrated quadratic temperature error, power demand, rod reactivity rate demand, and rod reactivity demand. The decision making process uses a learning systems based automaton at the present time.

Master's Thesis:

Kenney, S. J., and R. M. Edwards, adviser. An Intelligent Reconfigurable Reactor Power Controller, 1995.

Papers:

Kenney S. J., and R. M. Edwards. Enhancing An Intelligent Reconfigurable Reactor Power Controller. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 835-842, University Park, Pennsylvania, May 6-9, 1996.

Kenney, S. J., and R. M. Edwards. Enhanced Situation Awareness and Decision Making for An Intelligent Reconfigurable Reactor Power Controller. ICONE-IV, International Conference on Nuclear Engineering Systems, pp. 255-264, New Orleans, Louisiana, March 10-14, 1996.

Nuclear Engineering

NSF/EPRI MULTIVARIABLE CONTROL DEVELOPMENT

Participants: R. M. Edwards
D. E. Hughes
H. D. Gougar

Services Provided. Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, Reactor Instrumentation and Support Staff

Experimental multivariable control capability is being developed as the third component of the NSF/EPRI funded project. The benefits of advanced algorithms and intelligent control can be more clearly demonstrated in a multiple input-multiple output system where failure in the ability to manipulate one of the inputs can be accommodated by appropriate action in remaining operational control loops. In 1995-96 a core shroud was designed that allows the adjustment of coolant flow entering from the sides of the reactor. The shroud design and supporting analyses were considered by the Penn State Reactor Safeguards committee, approved, and construction initiated. Supporting analyses include evaluation of past and recent coolant temperature profile measurements and detailed thermal-hydraulic analyses using the COBRA and VIPRE codes.

Masters Thesis:

Gougar, H. D., and R. M. Edwards, adviser. Multivariable Control for the Penn State TRIGA Reactor. In progress.

Paper:

Gougar H. D., D. E. Hughes and R. M. Edwards. Design Considerations in Experimental Multivariable Control of the Penn State TRIGA Reactor Using Passive Manipulation of Coolant Flow. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 303-310, University Park, Pennsylvania, May 6-9, 1996.

Nuclear Engineering

NSF/EPRI HYBRID SIMULATION OF BWR USING THE TRIGA REACTOR

Participants: R. M. Edwards
J. A. Turso
G.L. Meyers
D. E. Hughes

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, Reactor Instrumentation and Support Staff

Hybrid reactor simulation is the fourth component of the NSF/EPRI project and is achieved by interfacing a computer simulation of an alternate reactor's reactivity feedback mechanism, such as a BWR, to appropriately position a control rod in the reactor. The result is that the observed TRIGA reactor power begins to mimic the characteristics of the alternate reactor. Results obtained from the HRS were utilized to validate a new method of BWR stability monitoring in the dissertation of James A. Turso.

Doctoral Thesis:

Turso, J. A., and R. M. Edwards, adviser. Reduced-Order Modeling, Analysis and Monitoring of Boiling Water Reactor Dynamic Behavior, 1995.

Paper:

Turso, J. A., R. M. Edwards and T. Highlands. Boiling Water Reactor Stability Analysis Via Kalman Filter-Based State Estimation And Maximum A Posteriori Detection. Proceedings of The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96, pp. 1107-1116, University Park, Pennsylvania, May 6-9, 1996.

Nuclear Engineering

NSF/EPRI ADVANCED MONITORING AND CONTROL FOR NUCLEAR REACTORS WORKSHOPS

Participants: R. M. Edwards
K. Y. Lee
D. E. Hughes
M. Ceceñas-Falcón
H. D. Gougar
S. J. Kenney
G. Meyers
S. Shyu
P. Walter

Services Provided: Classroom and Laboratory Space, SUN SPARC Server Computer System, Reactor Instrumentation and Support Staff

In addition to publications and conference presentations, the fifth component of the NSF/EPRI project also disseminates research results through periodic workshops. One day workshops were held on May 5, 1996 and May 10, 1996 in conjunction with "The 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, NPIC&HMIT'96". Twenty-three people from 8 countries participated in the workshops. NPIC&HMIT'96 was held at the Penn State Nittany Lion Inn from May 6-9, 1996 and attracted over 300 attendees from 25 countries.

Publication:

Workshop Overheads and Reference Papers.

THREE DIMENSIONAL COUPLED KINETICS THERMAL-HYDRAULIC BENCHMARK EXPERIMENTS USING THE BREAZEALE TRIGA REACTOR

Participants: M. Feltus
F. A. Alpan

Service Provided: TRIGA Reactor

The major goal of this experimental research project is to provide separate effects tests in order to benchmark neutron kinetics models coupled with thermal-hydraulics models used in the NRC's best-estimate codes, RELAP and TRAC. Using simple reactor core configurations, it is possible to determine the level of neutronics modeling required to describe kinetics and thermal-hydraulic feedback interactions. With fuel element thermocouple instrumentation, it is also possible to benchmark the fuel temperature, flux distribution, and thermal-hydraulics models in these codes.

This research effort seeks to provide experimental results to quantify the 1- and 3-dimensional kinetics models in the NRC's RELAP and TRAC codes and the RETRAN code series. The first series of experiments will have steady-state power levels to provide flux and fuel temperature distributions on a core wide basis. Then tests using transient power levels, square waves, neutron pulses, and rapid and slow control rod movements will be performed that simulate time-dependent transients with kinetic and thermal-hydraulic feedback. Various symmetric and asymmetric core configurations will be used to develop spatially dependent kinetics and thermal-hydraulic conditions for quasi-static benchmarks. Finally, time-dependent core configurations (e.g., asymmetric control rod and fuel rod movements) will be simulated first with the computer codes. Then experimental data will be used to demonstrate code fidelity and what corrections are needed.

The NRC's TRAC and RELAP, and EPRI's RETRAN thermal-hydraulics codes have neutron kinetics models, either in point or 1-dimensional cases in their official released versions. Generally, it is assumed that thermal-hydraulically induced transients do not provide sufficient perturbation in the kinetics to warrant three-dimensional kinetics treatment within the systems codes. However, Feltus has shown that even thermal-hydraulically induced PWR transients, such as Loss of Reactor Coolant Flow, Main Steam Line Break, and Anticipated Transients without Scram (Station Blackout and Loss of Main Feedwater), require three-dimensional kinetics analysis coupled with thermal-hydraulic feedback, in terms of core and system-wide best-estimate response. Although there have been some numerical test cases of 1- and 3-dimensional kinetics, and benchmarks of kinetics models with actual plant tests, i.e., Peach Bottom Turbine Trip Tests, where core-wide parameters, such as pressure, have been matched, benchmarks of these codes against simpler test results have not been done extensively.

One reason is that there is a limited amount of actual in-core kinetics experiments, with thermal-hydraulic feedback coupling available. Recent startup experiments for the Ljubljana TRIGA reactor have been well-documented and have been proposed as suitable for benchmark calculations for physics codes. Such research reactor tests could provide better understanding of the reactor kinetics with thermal-hydraulic feedback.

Another reason is that there is a general perception that small research reactors are essentially point or zero-dimensional in their reactor physics. However, TRIGA reactors can be configured to simulate complex physics conditions. Recently, Mele et. al. performed experimental steady-state, pulse, and control rod worth measurements at the Ljubljana TRIGA Mark II reactor, which was reconstructed in 1991. All the benchmark experiments were performed with fresh, compact, and uniform fuel at 12 wt%, at well-known operating conditions. The Ljubljana TRIGA benchmark results would be used in this project to qualify the neutronics models in the thermal-hydraulic (i.e., TRAC, RELAP, and RETRAN) codes.

This project also seeks to provide relatively simple benchmark experiments on the Penn State Breazeale TRIGA reactor, where the flux and temperature distributions are obtained. Using steady-state power distributions for static neutronics feedback, it is possible to evaluate the neutronic/thermal-hydraulic coupling for transient power conditions, including TRIGA pulsing, square waves, power ramps, control rod movements, and rapid scram conditions. One special experiment being evaluated is simulation of the University of Michigan plate-fueled reactor incident where a fuel element was moved while critical. Such a test would be considered only after pretest calculations are performed, and then, only after the other code-to-experiment benchmarks are completed.

Master's Thesis:

Alpan, F. A., and M. A. Feltus, advisor. Three Dimensional Coupled Kinetics Thermal-Hydraulic Benchmark Experiments Using the Penn State TRIGA Reactor. In progress.

Paper:

Alpan, F. A., M. DeChaine and M. A. Feltus, advisor. STAR 3D Nodal Kinetics and T/H Model for the Penn State TRIGA Reactor. To be presented at the Canadian Nuclear Society Fifth International Conference on Simulation Methods in Nuclear Engineering, Montreal, Canada, September 1996.

Sponsor: US Nuclear Regulatory Commission $109,839 (1/95 - 12/31/96)

Nuclear Engineering

NEUTRON RADIOGRAPHY EXPERIMENTS FOR VERIFICATION OF SOLUBLE BORON MIXING AND TRANSPORT MODELING UNDER NATURAL CIRCULATION CONDITIONS

Participants: M. A. Feltus
G. M. Morlang

Service Provided: Neutron Radiography

The major goal of this experimental research project is to provide separate effects tests in order to benchmark boron transport models used in best-estimate thermal-hydraulic codes, such as RELAP and TRAC. Using simple and complicated fluid flow geometries, boron mixing effects can be determined under natural circulation and low flow conditions using non-intrusive, non-destructive neutron radiography techniques.

This research effort seeks to provide experimental results to quantify boron transport and mixing effects, and assess the boron mixing models used in the NRC RELAP and TRAC thermal-hydraulics code series. The first series of experiments will model simple flow configurations to create boron transport separate effects tests to benchmark code results. Later, tests will simulate natural circulation and low flow conditions in the reactor vessel during boron injection during Anticipated Transients Without Scram (ATWS) events and severe accident scenarios. The neutron radiography visualization films and test results and analyses will provide sufficient information to qualify thermal-hydraulic boron tracking models, turbulent mixing assumptions, etc., to upgrade NRC code models to really yield best-estimate results.

Neutron radiography techniques provide a non-intrusive, non-destructive method to "see" turbulent effects in fluid flow streams. The neutron imaging is able to distinguish an image based on hydrogen content and other elements, rather than simple mass attenuation, as in the case of x-ray or gamma-ray imaging techniques. This means that the turbulent effects and small scale phenomena can be differentiated, without perturbing the fluid flow stream with instrumentation or flow blockages. More conventional fluid flow measurements yield bulk mixing effects; however, the small concentration of boron and solute phenomena can not be readily visualized. Resolution can be achieved by real-time or steady-state video camera visualization. This implies that geometric effects, turbulent and laminar flow, and boron mixing effects can be determined under natural circulation and low flow conditions using neutron radiography.

The proposed neutron radiography technique provides significant advantages over more conventional fluid flow methods:

1. There is no perturbation in the flow stream by instrumentation.
2. Various densities, solution concentrations, flow rates, etc., can be used to demonstrate turbulent mixing effects.
3. The fine fluid flow structure can be resolved in apparatus that is not transparent, and resolved in three dimensions.

This research effort will provide experimental benchmark information for boron transport and mixing, for real-time transient effects, and static imaging. The results from the tests can be used to qualify the boron tracking models in NRC and industry thermal-hydraulics codes, such as RELAP, TRAC, and RETRAN. By using a neutron-transparent fluid at different flow rates, densities, and temperatures, it is possible to simulate boron injection effects in ATWS conditions for BWR and PWR cores. Effects of turbulence and mixing can be simulated and measured to assess thermal-hydraulic code predictions.

Doctoral Thesis:

Morlang, G. M., and M. A. Feltus, advisor. Neutron Radiography Experiments for Verification of Soluble Boron Mixing and Transport Modeling Under Natural Circulation Conditions. In progress.

Paper:

Morlang, G. M., and M. A. Feltus, advisor. Neutron Radiography Experiments for Verification of Soluble Boron Mixing and Transport Modeling Under Natural Circulation Conditions. Proceedings of the ASME 4th International Conference on Nuclear Engineering 1996 (ICONE-4), Vol. 1 Part A, pp. 9-23, New Orleans, Louisiana, March 1996.

Sponsor:	Nuclear Regulatory Commission	$56,406	Phase I (11/93-11/94)
		$69,878	Phase II (11/94 - 7/96)

Nuclear Engineering

PIPE WALL THICKNESS MEASUREMENT USING SCATTERED GAMMA RAYS

Participants: R. Gould
E. S. Kenney
E. H. Klevans
S. Kahn
D. Wulsch

Services Provided: Hot Cell Lab, Laboratory Space, Machine Shop 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. A field usable device has been developed to use up to 0.5 curie of Hg-203. Field tests are planned for late summer 1996. Pending the outcome of these field tests, commercialization of the system is expected to be completed by early 1997.

Doctoral Thesis:

Xu, X., and E. H. Klevans, advisor. A High Speed Compton Scatter Imaging System, 1996.

Master's Theses:

Khan, S., and E. H. Klevans, advisor. A Monte Carlo Analysis for a Compton Back-Scatter Pipe Wall Thickness Gauge. In progress.

Wulsch, D., and E. H. Klevans, advisor. Field Testing And Practical Application Of A Compton Backscatter Pipe-Wall Thickness Gauging System. In progress.

Presentations:

Gould, R. , E. S. Kenney, E. H. Klevans, S. Khan and D. L. Wulsch. A Compton Backscatter Pipewall Thickness Gauge. Presented at The Utility/Manufacturers Robot Users Group Conference, Groton, CT, May, 1996.

Patents:

Gould, R., E. S. Kenney, S. Khan and X. Xu. A Compton Back-Scatter Pipe Wall Thickness Gauge Employing Focusing Collimator and Annular Detector, Provisional Patent filed March, 1996.

Sponsor: FERMI $30,000

Nuclear Engineering

EVALUATING TWO PHASE FLOW USING NEUTRON RADIOGRAPHY

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

Services Provided: Neutron Radiography, Machine Shop and Electronics Shop

This project is using neutron radiography to perform 2-phase fluid flow experiments. An upgrade of the flow loop from atmospheric pressure to 2000 psi is being performed, with measurements to follow.

Sponsor: Bettis Atomic Power Laboratory $70,436

Nuclear Engineering

IDENTIFICATION OF TRACE ELEMENTS IN POLYETHERETHERKETONE (PEEK) SPECIMENS BY NEUTRON ACTIVATION

Participants: R. Gould
T. Daubenspeck

Services Provided: Neutron Irradiation, Neutron Activation Analysis and Flux Monitoring

The level of trace elements was determined for 2 specimens of this material using neutron activation analysis.

Sponsor: Bettis Atomic Power Laboratory $2,000

Nuclear Engineering

STRESS CORROSION CRACKING IN NICKEL-BASED STAINLESS STEELS

Participants: R. Gould
A. Motta
R. Daum

Service Provided: Hot Cell Laboratory

This project will use Hot Cell #2 to house 3 autoclaves in which irradiated stainless steel fracture specimens will be loaded to observe stress corrosion cracking in a PWR environment over a two year period. 71 fracture specimens with a total activity of 36 Curies are presently stored in a cave in Hot Cell #1. The autoclaves are to be installed along with a Scanning Electron Microscope and a Fein-Focus X-ray inspection system in July 1996, after which the specimens will be transferred out of Cell #1.

Sponsor: Materials Engineering Associates $60,000

Nuclear Engineering

DETERMINATION OF NEUTRON ATTENUATION FACTOR OF IRRADIATED BORAFLEX COUPONS

Participants: R. Gould
T. Daubenspeck

Services Provided: Neutron Beam Laboratory, Neutron Activation Analysis and Machine Shop

The neutron attenuation factor was determined via gold foil activation for irradiated Boraflex coupons.

Sponsor: Westinghouse Electric Corporation $4,100

Nuclear Engineering

FUEL MANAGEMENT STUDY OF PSU TRIGA REACTOR CORE

Participants: D. E. Hughes
S. H. Levine
P. G. Boyle

Services Provided: Reactor Operations, Access to PSU Main Frame Computer

During the recent operating history of Penn State's TRIGA reactor, the fuel temperature, at full power of one Megawatt as indicated by the in-core thermocouple, had risen close to the scram point of 600°C. Review of the Safety Analysis Report (SAR) also revealed that the maximum temperature analyzed for a source term release was 466°C. To reduce the indicated fuel element temperature the maximum power was de-rated to 75 % (750kw). Additional constraints on operating hours per week as well as wait times before permitting fuel movement were applied to stay below the consequence of the current SAR maximum hypothetical accident.

A study of the core loading was performed, utilizing standard fuel management tools (LEOPARD, EXTERMINATOR-2 and MCRAC), to determine the ratio of the maximim elemental power density as compared to the average core power density or normalized power (NP). Experiments were run to determine the ability to predict the NP, and consequently indicated fuel element temperature, of a specific core location (loading). Finally, a core was designed to reduce the maximum fuel temperature below 550°C (possibly even below 500°C) while operating at one Megawatt (full power).

To use the new core design, the technical specifications must be altered to allow placing the 12wt% instrumented element in a core position other than the B-ring. Additionally, the SAR and technical specifications will be revised to increase the number of permitted operating hours in a week. The results of this study will be published in a technical journal and presented at the ANS conference in November 1996.

Publications:

Hughes, D. E., P. G. Boyle, and S. H. Levine. A New Fuel Management Plan for the Penn State TRIGA Reactor with Supporting Experiments and Calculations. Publication date and journal to be determined.

Hughes, D. E., P. G. Boyle, and S. H. Levine. Analysis of Higher Than Normal Fuel Temperatures in the Hexagonal Geometry TRIGA Reactor. ANS/ENS 1996 International Conference and Embedded Topicals, Washington, D.C., November 10-15, 1996.

Hughes, D. E., P. G. Boyle, and S. H. Levine. A New Fuel Management Plan for the Penn State TRIGA Reactor with Supporting Experiments and Calculations. ANS/ENS 1996 International Conference and Embedded Topicals, Washington, D.C., November 10-15, 1996.

Nuclear Engineering

INEL BURIED WASTE INTEGRATION PROGRAM

Participant: W. A. Jester

Service Provided: Office Space

In 1994, Dr. Jester was chosen to be a member of the Technical Academic Review Group (TARG) that reviews the technologies being developed by the Idaho National Engineering Laboratory under the Buried Waste Integrated Demonstration (BWID) program. Dr. Jester was chosen for this prestigious committee because of his expertise in radiation monitors. This program continued through August 1995.

Nuclear Engineering

FLUX AND FLUENCE DETERMINATION USING SCRAPINGS FROM VESSEL COMPONENTS

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

Services Provided: Neutron Irradiation, Radiation Counters and Laboratory Space

Experimental analyses were performed to develop a new method to obtain neutron dosimetry data from scrapings chips taken from various vessel components in light water reactors. The concept behind this new methodology is to take steel scrapings from an in-service vessel component such as the reactor pressure vessel wall, core internals, or support structures and use the measured specific activity of radionuclides in the material to predict its neutron exposure. To develop the scrapings technology, several well characterized cadmium covered and bare ferritic and stainless steel samples were irradiated at the PSBR facility to a fluence level of 10^{16}-10^{17} n/cm^2. Instrumental and radiochemical analyses were performed on the irradiated steel samples using a HPGe detector system. The final set of reactions for flux measurements included ^{54}Fe(n,p)^{54}Mn, ^{58}Fe(n,γ)^{59}Fe, ^{58}Ni,(n,p)^{58}Co, ^{59}Co(n,γ)^{60}Co, ^{123}Sb(n,γ)^{124}Sb, and ^{181}Ta(n,γ)^{182}Ta for ferritic steel and ^{54}Fe(n,p)^{54}Mn, ^{58}Fe(n,γ)^{59}Fe, ^{58}Ni(n,p)^{58}Co, and ^{59}Co(n,γ)^{60}Co for stainless steel. The maximum difference between the flux calculated using the scrapings methodology and that calculated using the conventional flux wire approach was about 12% for energies greater than 10 kev. The good agreement obtained between the two techniques demonstrated the potential accuracy and reliability of the scrapings technique for RPV wall flux measurements.

Doctoral Thesis:

Basha, H. S., and W. A. Jester, advisor. Flux and Fluence Determination Using Scrapings from Reactor Pressure Vessel Components, August 1995.

Sponsor: Project FERMI $15,000

Nuclear Engineering

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

Participants: W. A. Jester
R. W. Granlund
J. Lebiedzik

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 Vitallium® Alloy and zirconia femoral heads used in hip joint replacement. The Vitallium® Alloy samples are composed of a 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. Of special interest was the cobalt-60 activity detected in one of the heads.

A quality assurance procedure has been developed in conjunction with Howmedica to insure that the zirconia used to produce the femoral heads does not contain harmful amounts of alpha and beta emitters. Suppliers of this material send to the LLRML two thin disks produced from each of their batches, for low level alpha and beta activity measurements. Only if the activity of these two samples pass the various quality assurance criteria can the raw material be sent to Howmedica for the production of femoral heads.

Sponsor: Howmedica, Inc. $30,000

Nuclear Engineering

SEPARATION OF STRONTIUM AND CESIUM FROM REACTOR ION EXCHANGER RESINS, AND THEIR QUANTIFICATION, USING HIGH PERFORMANCE LIQUID CHROMATOGRAPHY AND BETA AND GAMMA SPECTROSCOPY

Participants: W. A. Jester
U. P. M. Senaratne

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

Nuclear reactor ion exchanger resins, once spent, contain a variety of cations and anions adhered to them. Among the host of cations are strontium (notably ^{89}Sr and ^{90}Sr) and cesium (notably ^{137}Cs).

The object of current research is to perfect a technique by which this strontium and cesium may be extracted from the resins, separated from the other cations present in the resulting extract, and quantified. The proposed methodology is briefly described in the following paragraphs.

Initially, all the cations adhering to the resin are extracted using a solvent such as potassium nitrate or hydrochloric acid, of suitable concentration. This results in an extract comprising all the cations in a solvent matrix. A sample of this extract is then injected into a High Performance Liquid Chromatograph (HPLC) unit, and with the use of an appropriate eluent, the strontium and cesium fractions are separated and collected. Since the concentrations of these cations in the extract are invariably low, the addition of a non radioactive carrier may be necessary to separate each cation by detecting them conductivity-wise using the HPLC unit. Finally, the fractions are counted using a suitable radiation detector, so that quantification may be accomplished.

Currently, the extraction of cations from the resins has been successfully accomplished. The eluent and the regenerant required for the separation of strontium from the other cations in the presence of the solvent matrix have been identified, together with the optimum concentration of the eluent and the regenerant. At present, the possibility of using a scintillation counter to quantify the ^{89}Sr and ^{90}Sr present is being investigated. This is to be followed by perfecting similar techniques for separating and quantifying cesium.

Master's Thesis:

Senaratne, U. P. M., and W. A. Jester, advisor. Individual Quantification of Strontium-89 and Strontium-90 in Nuclear Reactor Effluent, 1995.

Sponsor: CB Tech, Valley Forge, PA $1,018

Nuclear Engineering

A STUDY OF THE RADIATION LEVELS IN AND NEAR THE PENNSYLVANIA STATE UNIVERSITY BREAZEALE NUCLEAR REACTOR FACILITY

Participants: W. A. Jester
N. K. Umisedo
R. W. Granlund

Service Provided: Laboratory Space

Ms. Nancy Umisedo was a visiting scientist from the Institute de Fisca da Universidade Sao Paulo, Brazil. She worked at the Low Level Radiation Monitoring Laboratory on a project designed to determine the sources of radiation fields at certain locations near the Breazeale Nuclear Reactor Facility. Health Physics TLD Measurements indicate that certain locations have higher than expected activity and that this activity does not seem to be related to the operation of the Nuclear Reactor. This project was designed to determine the sources of these low intensity radiation fields.

Nuclear Engineering

NUCE 450, RADIATION DETECTION AND MEASUREMENT

Participants: W. A. Jester
M. H. Voth
H. Gougar
U. Shoop

Services Provided: Neutron Irradiation, Radiation Counters and Laboratory Space

NucE 450 introduces the student to many of the types of radiation measurement systems and associated electronics used in the nuclear industry as well as many of the mathematical techniques used to process and interpret the meaning of measured data. The major accomplishments of this year is the continued revising of five experiments in NucE 450 (and four experiments in NucE 451) to use five new model 486 personal computers and interfaces. The radiation instruments studies in this course include, GM detectors, gas flow proportional counters, NaI(Tl) detectors, BF_3 counters, ion chambers, wide range GM detectors, and surface barrier detectors. The data collection and analysis techniques studied include radiation counting statistics, gamma ray and charged particle spectroscopy, and the interfacing of computeres with nuclear instrumentation.

Nuclear Engineering

POST IRRADIATION INSPECTION AND TESTING OF NEUTRON ABSORBER MATERIALS

Participants: D. Kline
D. Vonada
K. Lindquist

Services Provided: Neutron Irradiation and Laboratory Space

The purpose of this work is to quantitatively characterize the in-service physical properties of neutron absorber materials used in spent fuel storage racks and shipping casks. Utilities use surveillance coupons of neutron absorber materials such as BORAFLEX, BORAL, borated graphite and NEUTRASORB borated stainless steel to track the performance of these materials in casks and racks. The coupons are tested with respect to dimensional changes, weight changes, hardness changes, density changes, changes in dynamic shear modules and neutron attenuation characteristics. The latter measurements are performed in the Neutron Beam Laboratory.

Sponsor: Various Electric Utilities

Nuclear Engineering

DISSOLUTION RATE OF THE NEUTRON ABSORBER MATERIAL BORAFLEX

Participants: D. Kline
D. Vonada
K. Lindquist

Services Provided: Laboratory Space and Technical Support

This project's objective is to quantify the dissolution rate of Boraflex, a polymer-based neutron absorber material, in simulated spent fuel pool environments. The test conditions include different temperature, irradiation exposure and the presence of solubility inhibitors. The data are used as the basis for a computer model of Boraflex in the spent fuel pool environment.

Sponsor: Electric Power Research Institute

Nuclear Engineering

DEVELOPMENT/TESTING OF A DEVICE TO MEASURE THE BORON-10 AREAL DENSITY IN SPENT FUEL RACK NEUTRON ABSORBER MATERIALS

Participants: D. Kline
D. Vonada
K. Lindquist
M. Harris

Services Provided: Neutron Irradiation and Cobalt-60 Facility

This project started with proof-of-principle testing in the Neutron Beam Laboratory. Based on the results of these tests, a proto-type measurement device was designed and fabricated. The proto-type equipment was tested in the Cobalt-60 pool. After this initial testing, the device was shipped to the Peach Bottom Atomic Power Station Unit 2 for demonstration in a spent fuel pool. The equipment is now being scheduled for use at BWR plants around the country. A device suitable for measurements in PWR racks is now being designed and fabricated. Initial testing of this equipment will be carried out in the Cobalt-60 pool.

Sponsor: Electric Power Research Institute

Nuclear Engineering

EXAMINATION OF NEUTRON IRRADIATED PRESSURE VESSEL STEEL USING POSITRON ANNIHILATION LIFETIME SPECTROSCOPY

Participants: A. T. Motta
G. L. Catchen
S. E. Cumblidge

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

This project is aimed at developing a method to evaluate the embrittlement suffered by reactor pressure vessels upon exposure to neutron irradiation. Positron annihilation lifetime spectroscopy is used to detect damage to pressure vessel steel at the nanometer scale. Currently, samples irradiated to fluences of 10^{18} - 10^{19} n/cm^2 are being examined. The goal is to be able to develop a technique that will allow us to non-destructively assess neutron and environmental damage to PV steels, and help utilities verify that their reactors can be granted a life extension.

Master's Thesis:

Cumblidge, S. E., G. L. Catchen and A. T. Motta, advisors. Positron Annihilation Lifetime Spectroscopy of Neutron Irradiated Pressure Vessel Steel. In progress.

Sponsor: FERMI $23,000 /yr

Nuclear Engineering

MEASURING PRESSURE VESSEL EMBRITTLEMENT USING POSITRON ANNIHILATION SPECTROSCOPY

Participants: A. T. Motta
G. L. Catchen
S. Cumblidge

Services Provided: Laboratory Space

One of the leading mechanisms of reactor degradation is pressure vessel embrittlement that could cause vessel failure in the case of a pressurized thermal shock during rewetting after a loss-of-coolant accident. The ductility of the pressure vessel, as measured by the Charpy V-notch test, decreases with increasing neutron fluence. To develop a non-destructive means to detect submicroscopic defect structures that evolve in pressure vessels during irradiation is thus highly desirable. The goal of this project is to evaluate positron annihilation lifetime spectroscopy (PALS) as an independent means to characterize neutron radiation damage to pressure vessels. Neutron irradiated pressure vessel materials furnished by Westinghouse were irradiated at room temperature to a neutron fluence of 10^{17} n.cm^{-2}. The positron lifetime distributions could be represented by a three lifetime constrained fit that correspond well to two different types of defects, one with a lifetime around 165 ps and one with a lifetime around 300 ps. The average positron lifetime ($\bar{\tau}$) increases with neutron fluence. By annealing at 450 C for different times, we determined that 30 minutes provides enough time to anneal all of the damage. At higher temperatures, we have examined end-of-life pressure vessel materials exposed to fast neutron fluences of 8×10^{18} n.cm^{-2} and 1.5×10^{19} n.cm^{-2}. In these samples, $\bar{\tau}$ was much smaller that in samples irradiated at room temperature, indicating that the damage is dynamically annealed at 300 C.

Master's Thesis:

Cumblidge, S. E., A. T. Motta and G. L. Catchen, advisors. Positron Annihilation Lifetime Spectroscopy: Measurement of Embrittlement of Pressure-Vessel Steel, 1996.

Paper:

Cumblidge, S. E., A. T. Motta and G. L. Catchen, advisors. Examination of Irradiated Pressure Vessel Steel Using Positron Annihilation Lifetime Spectroscopy. Fall meeting of the Materials Research Society, Boston, Massachusetts, December 2-6, 1996.

Sponsor: FERMI $25,000

Nuclear Engineering

POINT DEFECTS IN INTERMETALLIC COMPOUNDS OF THE Zr-M SYSTEM

Participants: A. T. Motta
G. L. Catchen
A. Paesano, Jr.

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

An international collaboration has been established between The Pennsylvania State University, The Federal University of Rio Grande do Sul, Brazil and Argonne National Laboratory, to study the defect energetics and configurations of point defects in the intermetallic compounds $ZrFe_2$, Zr_3Fe and other intermetallics of the Zr-Fe-M system (M = Cr, Ni, Al, Co).

The nuclear probe techniques of Perturbed Angular Correlation, Mössbauer Spectroscopy, and Positron Annihilation Lifetime Spectroscopy will be used to study defects on neutron irradiated intermetallic samples. These studies will be complemented by the study of the amorphization response of the compounds under charged particle irradiation. Computer simulations of these lattice structures will also be performed using the embedded atom method. The results from both experiments and from the computations can then inform each other, confirming experiments, suggesting new ones and verifying theoretical models.

Currently, samples of $ZrFe_2$ and Zr_3 containing radioactive Hf produced in the reactor are being examined by PAC. These samples were prepared by arc melting and heat treating in reactor Room 6 and the hot cell laboratory area.

Sponsor: NSF $80,000 /3 yrs

B. OTHER UNIVERSITIES, ORGANIZATIONS AND COMPANIES UTILIZING THE FACILITIES OF THE RADIATION SCIENCE AND ENGINEERING CENTER

University or Industry	Type of Use
American Inspection Agency	Environmental Analyses
Armed Forces Radiobiology Research Institute	Neutron Activation Analyses
	Reactivity Computer
Bettis Labs, Westinghouse	Neutron Radiography
BH Labs	Environmental Analyses
C & B Property Evaluation, Inc.	Environmental Analyses
CB-Tech	Neutron Activation Analyses
Centre Analytical	Environmental Analyses
Converse Consultants East	Radiological Analyses
E-Systems	Semiconductor Irradiation
Gannett Flemming	Environmental Analyses
Geochemical Testing	Environmental Analyses
Harris Semiconductor	Semiconductor Irradiation
Honeywell	Semiconductor Irradiation
Howmedica	Radiological Analyses
Microbac Bradford	Environmental Analyses
Morgan Matroc Limited	Radiological Analyses
National Institute of Standards and Technology	Neutron Irradiation
Northeast Technology Corporation	Neutron Radiography
NRC (Corporation)	Neutron Activation Analyses
Oglevee Ltd.	Gamma Irradiation
Pottsville Environmental Testing Lab	Environmental Analyses
PRC Environmental Lab	Environmental Analyses
Raytheon	Semiconductor Irradiation
TA & D	Gamma Irradiation
TOSOH SMD, Inc.	Neutron Activation Analyses
Tru-Tec	Isotopes for Tracer Studies
Ty-Flot	Gamma Irradiation
United Water of Pennsylvania	Environmental Analyses
Westinghouse	Neutron Activation Analyses

A P P E N D I X A

APPENDIX A

Personnel Utilizing the Facilities of the Penn State RSEC.
Faculty (F) Post-Doctoral (PD), Staff (S), Graduate Student (G), Undergraduate (U), Visiting Faculty (VF), Visiting Staff (VS), IAEA Fellow (IAEA)

COLLEGE OF AGRICULTURE

Agronomy

Bollag, Jean-Marc	(F)
Brunner, Christian	(G)
Halperin, Dave	(G)

Entomology

Godwin, Gregory	(G)
Hower, Art	(F)

Food Science

Beelman, Robert	(F)
Knabel, Stephen	(F)
Murinda, Shelton	(G)
Roberts, Robert	(F)
Wilson, Richard	(F)
Woody, Jon	(G)

Plant Pathology

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

COLLEGE OF EARTH AND MINERAL SCIENCES

Polymer Science

Gupta, Anunay	(G)
Harrison, Ian	(F)
Karoglanian, Serop	(G)
Thavarungkul, Nandh	(G)

Fuel Science

Li, John	(G)

COLLEGE OF ENGINEERING

Electrical Engineering

Garcia, Humberto	(G)
Lee, K. Y.	(F)
Miller, David	(F)
Ramaswamy, P.	(G)

Engineering Science and Mechanics

Billman, Curt	(U)
Conley, John	(G)
Frye, Christopher	(G)
Lenahan, Patrick	(F)
Yount, J. T.	(G)

Mechanical Engineering

Kim, Byoung-Su	(G)
Prescott, Patrick	(F)

Nuclear Engineering

Alpan, Arzu	(G)
Anin-Sampong	(IAEA)
Basha, Hassan	(G)
Blair, Steve	(G)
Boyle, Patrick	(S)
Bryan, Mac	(S)
Capper, Edward	(U)
Catchen, Gary	(F)
Cecenas-Falcon, Miguel	(G)
Costa, Joseph	(U)
Cumblidge, Steven	(G)
Daubenspeck, Thierry	(S)
Daum, Robert	(G)
Davis, Chris	(G)
Davison, Candace	(S)
DeChaine, Michael	(G)
Edwards, Robert	(F)
Feltus, Madeline	(F)
Flinchbaugh, Terry	(S)
Gougar, Hans	(G)
Gould, Robert	(F)
Grieb, Mark	(S)
Haws, Ken	(G)
Hazenburg, Mark	(U)
Hollinger, Ed	(G)
Hughes, Dan	(F)

APPENDIX A
(Continued)

Personnel Utilizing the Facilities of the Penn State RSEC.
Faculty (F) Post-Doctoral (PD), Staff (S), Graduate Student (G), Undergraduate (U), Visiting Faculty (VF), Visiting Staff (VS)

COLLEGE OF ENGINEERING

Nuclear Engineering

Jester, William	(F)
Johns, Richard	(G)
Kahn, Saif	(G)
Kenney, Edward	(F)
Kenney, Stephen	(G)
Kim, Byoung-Su	(G)
Klevans, Edward	(F)
Kwon, Junhyun	(G)
Labowski, Kris	(G)
Lebiedzik, Jana	(S)
Levine, Samuel	(F)
Lunetta, Lois	(S)
Maakuu, Mulmo	(IAEA)
McLellan, Alexander	(S)
Meyers, Gary	(U)
Miller, David	(S)
Morlang, Mike	(G)
Motta, Arthur	(F)
Paesano, Andrea	(VF)
Pagano, Luciano	(G)
Pantano, Davis	(U)
Ray, Thomas	(U)
Rearick, Todd	(G)
Robinaccio, Guiseppe	(U)
Rudy, Kenneth	(S)
Sanchez, Roberto	(G)
Schrass, Benjamin	(U)
Senaratne, Harsha	(VS)
Senaratne, Uditha	(G)
Shabalin, Evgeni	(VF)
Shoop, Undine	(G)
Shyu, Shian-Shing	(G)
Strohecker, Mark	(U)
Tompot, Randy	(U)
Turso, James	(G)
Umisedo, Nancy	(VS)
Voth, Marcus	(F)
Walter, Phil	(G)
Wulsch, Dan	(G)
Xu, Xiangjun	(G)

School of Engineering Technology and Commonwealth Campus Engineering

Sathianathan, Dhushy	(F)

COLLEGE OF LIBERAL ARTS

Anthropology

Bondar, Gregory	(G)
Hirth, Kenneth	(F)

COLLEGE OF SCIENCE

Biology

Donaher, Erin	(U)
Hayaran, Archana	(G)
Lai, Zhi-Chun	(F)
Schmidt, Stacy	(U)
Unni, Arun	(U)

Chemistry

Allcock, Harry	(F)
Ambrosio, Archel	(G)
Lai, Zhi-Chun	(F)
Primrose, Aaron	(G)

Biochemistry and Molecular Biology

Abmayr, Susan	(F)
Bour, Barbara	(G)
Heyser, Deidre	(S)
Keller, Cheryl	(G)

INTERCOLLEGIATE PROGRAMS

Health Physics

Augustine, Edward	(S)
Boeldt, Eric	(S)
Granlund, Rodger	(S)
Hollenbach, Donald	(S)
Wiggins, Jim	(S)

APPENDIX A
(Continued)

INDUSTRIES, ETC.

American Inspection Agency	Harris, George
Armed Forces Radiobiology Research Institute	Cohill, Brian Moore, Mark
Bettis Labs, Westinghouse	Glickstein, Stan Murphy, Jack
BH Labs	Brunk, Scott
Brigham Young University	Allred, D. Evenson, W. E.
CB-Tech	Bleistein, Charles
Centre Analytical	Robb, Shawn
Converse Consultants East	Brusse, Bill
E-Systems	Uber, Craig
Gannett Flemming	Abbe, Dough Lane, David
Geochemical Testing	Gearhard, Susan
Harris Semiconductor	Borza, Peter Kalkbrenner, F. Zarosky, Elaine
Honeywell	Nawrocki, Peter
Howmedica	Wang, Kathy
Microbac Bradford	Anderson, J. L.
Morgan Matroc Limited	Murray, Michael
National Institute of Science & Technology	Becker, Don Mackey, Elizabeth
Northeast Technology Corporation	Harris, Matt Kline, Don Lindquist, Kenneth O. Vonada, Doug
NRC (Corporation)	Xu, Xiangju;n
Oglevee Ltd.	Wiles, Linda S.
Pottsville Environmental Testing	Sobian, Michael
Raytheon	Stransky, D. F.
TA & D	Snipes, Wallace
Tru-Tec	Bothe, Mike Kolek, Jerome Flenniken, Mike
Ty-Flot	Mareau, Darrell
University of Maryland	Rasera, Robert L.

APPENDIX A
(Continued)

MISCELLANEOUS

LLRML - Radon in air and water analyses for various individuals

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

APPENDIX B

APPENDIX B
FORMAL TOUR GROUPS

JULY 1995 JUNE 1996	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
July	5	Governor's School	68
	6	Governor's School	68
	7	Governor's School	70
	12	Trac Tour	9
	13	Vectour Group	17
	14	Various High School Interns	10
	18	Individual Study Program-Governor's School	3
	19	BEST Program	24
	20	Vectour Group	23
	20	Water Treatment	26
	26	Penn State Student Tour	10
	27	Vectour Group	13
	28	Enter 2000	12
August	3	Vectour Group	13
	4	4-H Group	37
	8	GPU NCTII Group	2
	22	Prospective Nuclear Engineering Student	1
September	7	Food Science 413	37
	19	Our Lady of Victory School	39
	23	Parent's Weekend Open House	318
October	5	Altoona Home Schoolers	42
	14	Fall Alumni Weekend	50
	16	Trac Tour	20
	16	Test-Loop Tour	2
	19	American Nuclear Society Tour	4
	19	IPAC Tour	2
	20	Harmony High School	24
	21	Boy Scout Instructors	16
	21	ANS Workshop Tour	16
	21	Boy Scout Tour	21
	23	Combustion Lab Tour	7
	24	Scanticon Business Executives	3
	25	Science Writers	10
	30	Bermudian Springs High School	8
	31	Oak Ridge National Laboratory	1
November	6	IAEA Fellow	1
	7	Eastern Lebanon High School	8
	10	Home Schoolers-Centre County	18
	20	State College Elementary	25
	29	ARNL Tour	1
	29	Nuclear Engineering Staff Assistants Tour	2
December	4	State College Elementary (Fairmont)	50
	11	Carlisle High School	46
	13	Carlisle High School	47

APPENDIX B
FORMAL TOUR GROUPS
(Continued)

JULY 1995 JUNE 1996	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
December	14	Penn State DuBois Campus Tour	6
	14	Police Services	17
January	5	Police Services	15
	10	State College High School	41
	19	State College Delta Program	10
	19	Potential Student	3
February	7	Lewistown High School	2
	9	Jr. Girl Scout Troop #1184	9
	15	Graduate Student Tour	4
	19	PSU Student Tour	1
	21	Bald Eagle High School	13
	23	Penns Valley High School	23
	29	Graduate Tour	3
March	11	Redlands High School	14
	14	Communications 465 Class Tour	5
	15	Daniel Boone High School	17
	16	Boy Scout Troop #83	71
	18	Prospective PSU Students	5
	18	Berwick High School	22
	18	PA Junior Science & Humanities Symposium	8
	20	Penns Valley High School	21
	21	Human Factors and Ergonomics Society - Penn State Student Chapter	4
	22	Williamson High School	14
	22	Prospective Student	1
	23	Girl Scout Troop #90 and #1155	56
	25	Bald Eagle High School	13
	26	Prospective Students	3
	29	1996 Open House	17
	30	1996 Engineering Open House	330
April	3	Mt. Union High School	30
	8	Bald Eagle High School	11
	9	1996 Engineering and Student Open House	111
	12	State College High School	18
	13	Visiting Scientists from Czech Republic	8
	15	Juniata College	8
	16	Grove City College	12
	16	Westinghouse Representative Tour	1
	17	Harbor Creek High School	9
	19	Visiting Scientist	1
	19	Susquehanna High School	13
	19	Jersey Shore Area Senior High School	8
	22	Bettis and MEA Tour	5

APPENDIX B
FORMAL TOUR GROUPS
(Continued)

JULY 1995 JUNE 1996	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
	23	College of Agriculture	3
	25	"Take Our Daughters To Work" Tour	30
	26	St. Mary's High School	31
	26	Ridgway High School	10
	30	Indiana University of PA	7
May	3	Camp Hill High School	10
	5	ANS International Topical Mtg (NPIC & HMIT)	17
	7	Allegany Community College	25
	7	ANS International Topical Mtg (NPIC & HMIT)	2
	8	ANS International Topical Mtg (NPIC & HMIT)	11
	9	Somerset Junior Hjigh School	21
	10	ANS International Topical Mtg (NPIC & HMIT)	8
	10	IEEE Tour	3
	11	1996 Graduate Open House	99
	13	Muncy High School	22
	13	Science Fair High School Teachers	3
	13	Perkiomen High School	8
	16	Food Science	1
	16	State College Friends School	18
	17	East Stroudsburg High School	16
	17	Danville High School	12
	17	Career Day	1
	17	President Graham Spanier Tour	2
	24	Bald Eagle School/Wingate	19
	28	State College High School Delta Program	7
	31	Lakeland High School	3
June	5	Harris Semi-Conductor	5
	5	OSHA Tour	1
	14	Graduate Women in Science	7
	18	Carnegie Science Academy	15
	19	Brimrose Corporation Tour	2
	20	Vectour Group	17
	26	Engineering Education Workshop	9
	27	Vectour Group	18
	28	WISE Group	31
	28	Aerospace Tour	7