PENNSTATE

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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

Annual Operating Report, FY 94-95
PSBR Technical Specifications 6.6.1
License R-2, Docket No. 50-5

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December 20, 1995

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Dear Sir:

Enclosed please find the Annual Operating Report of the Penn State Breazeale Reactor (PSBR). This report covers the period from July 1, 1994 through June 30, 1995, as required by technical specifications requirement 6.6.1. Also included are any changes applicable to 10 CFR 50.59.

A copy of the Fortieth Annual Progress Report of the Penn State Radiation Science and Engineering Center is included as supplementary information.

Sincerely yours,

M H Voth

Marcus H. Voth
Director, Radiation Science
and Engineering Center

Enclosures

cc: Region I Administrator
U. S. Nuclear Regulatory Commission
D. A. Shirley

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PENN STATE BREAZEALE REACTOR

Annual Operating Report, FY 94-95
PSBR Technical Specifications 6.6.1
License R-2, Docket No. 50-5

Reactor Utilization

The Penn State Breazeale Reactor (PSBR) is a TRIGA Mark III facility capable of 1 MW steady state operation, and 2000 MW peak power pulsing operation. Utilization of the reactor and its associated facilities falls into three major categories:

EDUCATION utilization is primarily in the form of laboratory classes conducted for graduate and undergraduate students and numerous high school science groups. These classes vary from neutron activation analysis of an unknown sample to the calibration of a reactor control rod. In addition, an average of 2000 visitors tour the PSBR facility each year.

RESEARCH accounts for a large portion of reactor time which involves Radionuclear Applications, Neutron Radiograpy, 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 are tailored to meet the needs of the participants. Individuals taking part in these programs fall into such categories as power plant operating personnel, PSBR staff, and foreign trainees.

The PSBR facility operates on an 8 AM - 5 PM shift, five days a week, with an occasional 8 AM - 8 PM or 8 AM - 12 Midnight shift to accommodate laboratory courses or research projects.

Summary of Reactor Operating Experience

<u>Technical Specifications requirement 6.6.1.a.</u>

Between July 1, 1994 and June 30, 1995, the PSBR was

critical for	561 hours	or 2.2 hrs/shift
subcritical for	401 hours	or 1.6 hrs/shift
used while shutdown for	474 hours	or 1.9 hrs/shift
not available	0 hours	or 0.0hrs/shift
Total usuage	1436 hours	or 5.6 hrs/shift

The reactor was pulsed a total of 131 times with the following reactivities:

less than \$2.00	43
\$2.00 to \$2.50	54
greater than \$2.50	34

The square wave mode of operation was used 89 times to power levels between 100 and 500 KW.

Total energy produced during this report period was 259 MWH with a consumption of 13 grams of U-235.

Unscheduled Shutdowns

Technical Specifications requirement 6.6.1.b.

The 9 unplanned shutdowns during the July 1, 1994 to June 30, 1995 period are described below.

July 7, 1994 - After the reactor operated at 800 kW for one hour, the N-16 pump stopped causing a west bridge monitor alarm, a building evacuation and a reactor scram. This was the first reactor operation since the bridge installation that required the newly installed N-16 pump to operate. Problem was a thermal overload of the heater coils in the pump relay box; coils were upgraded.

July 21, 1994 - After operating at 200 kW for about two minutes, the reactor operator noticed a drop in power and the auto control system driving three rods out to compensate. The operator scrammed the reactor. The transient rod drive air supply had not been returned to service following the cleaning and lubrication of the transient rod cylinder and the rod drifted into the core when the air supply in the accumulator tank on the reactor bridge was exhausted.

August 8, 1994 - With the reactor operating at 800 kW, the N-16 pump flow was adjusted to find an optimum flow to decrease the radiation levels as seen by the bridge monitors. First the valve was opened and at 16 psig no significant change in radiation levels was noted and then the valve was throttled to 20 psig. The pump shutoff and the operator scrammed the reactor but not in time to prevent an evacuation from the bridge east monitor at 40 mR/hr. An investigation found that because of thermal heating the pump would shutdown with a flow of about 20 psig (the pump had been operating at 18 psig). The flow was returned to 18 psig and operations resumed. The next day the valve was opened all the way for a pressure of 16 psig and power was increased in steps to check radiation levels; it was decided that this was the optimum pressure for operation.

August 25, 1994 - The operator scrammed the reactor as per SOP-9, Operation of the Rabbit System, upon the receipt of a Rabbit System I high radiation alarm from the monitor that looks at the radiation level in the system surge tank. The reactor had been operating at 900 kW for 31 minutes when the alarm was received. Health Physics and reactor staff investigation led to the decision to replace the reactor bay portion of the system poly tubing. The old tubing showed signs of deterioration and air leaks into the system were suspected to have caused elevated argon-41 production.

September 12, 1994 - Reactor power had just been increased to 1000 kW when a RSS Fuel Temperature 1 scram occurred. A historical trend revealed the scram temperature to be 588 degrees C. The fuel temperature had increased during the year and although operators knew the temperature was approaching the scram point, they thought the temperature scram was set at 600 degrees C.

February 10, 1995 - The reactor was approaching critical when a DCC-X Interlock Validation Failure Scram occurred ; the operator was not pushing the rod control buttons at the time of the scram. The interlock failure was generated for both the transient and regulating rods. The initial cause for the failure could not be determined from historical trends. A review of the logic did not indicate a condition that would be common for the transient and regulating rods and not common for all four rods. Verified that RSS relays were seated properly, verified up inhibits in DCC-X, verified control voltage for the safety system, and verified proper rod pushbutton up and down response.

March 31, 1995 - Safety rod was being raised to do a scram check during the morning checkout when a DCC-X Transient Rod Velocity Validation Failure occurred . The event was reproduced three times but could then not be repeated again. Using historical trends for troubleshooting, the spread between the feedback signal and the velocity out signal was greater than that allowable thus causing the validation failure. The I/O manufacturer was contacted and could suggest no maintenance once the connections were initially torqued down correctly . A torque screwdriver was ordered and all I/O connections were checked during a console calibration/maintenance check in June of 1995.

April 6, 1995 - A watchdog scram was initiated when DCC-X failed due to a matrox error while attempting a backup to floppy for DCC-X bin file group. The watchdog scram occurred as it should have. The reactor was shutdown at the time of this event.

April 20, 1995 - The reactor operator wanted to turn on the second bay exhaust fan but indadvertently turned off the operating bay exhaust fan. As per design, the reactor console initiated a scram when it sensed both exhaust fans were off. The operator wanted to rid the bay of exhaust fumes coming from a roof repair project.

Major Maintenance With Safety Significance

Technical Specifications requirement 6.6.1.c.

No major preventative or corrective maintenance operations with safety significance have been performed during this report period.

Major Changes Reportable Under 10 CFR 50.59

Technical Specifications requirement 6.6.1.d.

Facility Changes - None reportable under 10 CFR 50.59

Procedures - All procedures are reviewed as a minimum biennially, and on an as needed basis. Changes during the year were numerous and no attempt will be made to list them. A current copy of all facility procedures will be made available on request.

New Tests and Experiments - None having safety significance.

Radioactive Effluents Released

Technical Specifications requirement 6.6.1.e.

Liquid

There were no liquid effluent releases under the reactor license for the report period. Liquid from the regeneration of the reactor demineralizer is evaporated and the distillate recycled for pool water makeup. The evaporator concentrate is dried and the solid salt residue is disposed of in the same way as other solid radioactive waste at the University.

Liquid radioactive waste from the radioisotope laboratories at the PSBR is under the University byproduct materials license and is transferred to the Health Physics Office for disposal with the waste from other campus laboratories. Liquid waste disposal techniques include storage for decay, release to the sanitary sewer as per 10 CFR 20, and solidification for shipment to licensed disposal sites.

Gaseous

Gaseous effluent Ar-41, is released from dissolved air in the reactor pool water, dry irradiation tubes, and air leakage from the pneumatic sample transfer systems.
The amount of Ar-41 released from the reactor pool is very dependent upon the operating power level and the length of time at power. The release per MWH is highest for extended high power runs and lowest for intermittent low power runs. The concentration of Ar-41 in the reactor bay and the bay exhaust was measured by the Health Physics staff during the summer of 1986. Measurements were made for conditions of low and high power runs simulating typical operating cycles. Based on these measurements, an annual release of between 196 mCi and 595 mCi of Ar-41 is calculated for July 1, 1994 to June 30, 1995, resulting in an average concentration at ground level outside the reactor building that is 0.3 % to 0.9 % of the effluent concentration limit in Appendix B to 10 CFR 20.1001 - 20.2401. The concentration at ground level is estimated using only dilution by a 1 m/s wind into the lee of the 200 m^2 smallest cross section of the reactor bay.

During the report period, several irradiation tubes were used at high enough power levels and for long enough runs to produce significant amounts of Ar-41. The calculated annual production was 66 mCi. Since this production occurred in a stagnant volume of air confined by close fitting shield plugs, most of the Ar-41 decayed in place before being released to the reactor bay. The reported releases from dissolved air in the reactor pool are based on measurements made, in part, when a dry irradiation tube was in use at high power levels; the Ar-41 releases from the tubes are part of rather than in addition to the release figures quoted in the previous paragraph. The use of the pneumatic transfer systems was minimal during this period and any Ar-41 releases would be insignificant since they operate with CO-2 and Nitrogen as fill gases.

Tritium release from the reactor pool is another gaseous release. The evaporation rate of the reactor pool was checked recently by measuring the loss of water from a flat plastic dish floating in the pool. The dish had a surface area of 0.38 ft^2 and showed a loss of 139.7 grams of water over a 71.9 hour period giving a loss rate of 5.11 g ft^{-2} hr^{-1}. Based on a pool area of about 395 ft^2 the annual evaporation rate would be 4680 gallons. This is of course dependent upon relative humidity, temperature of air and water, air movement, etc. For a pool ^3H concentration of 20,000 pCi/l (the average for July 1994 to June 1995) the tritium activity released from the ventilation system would be 354 μCi. A dilution factor of 2 x 10^8 ml s^{-1} was used to calculate the unrestricted area concentration. This is from 200 m2 (cross-section of the building) times 1 m s^{-1} (wind velocity). These are the values used in the safety analysis in the reactor license. A sample of air conditioner condensate showed no detectable ^3H. Thus, there is probably very little ^3H recycled into the pool by way of the air conditioner condensate and all evaporation can be assumed to be released.

^3H released	354 μCi
Average concentration, unrestricted area	2.6 x 10^{-14} μCi/ml
Permissible concentration, unrestricted area	1 x 10^{-7} μCi/ml
Percentage of permissible concentration	5.6 x 10^{-5} %
Calculated effective dose, unrestricted area	2.8 x 10^{-5} mrem

Environmental Surveys

Technical Specifications requirement 6.6.1.f.

The only environmental surveys performed were the routine TLD gamma-ray dose measurements at the facility fenceline and at control points in residential areas several miles away. This reporting year's measurements (in millirems) tabulated below represent the July 1, 1994 to June 30, 1995 period. A comparison of the North, West, East, and South fenceline measurements with the control measurements at Houserville (1 mile away) show the differences to be similar to those in the past.

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Total
Fence North	22.7	19.8	20.8	22.7	86.0
Fence West	20.0	19.1	17.9	21.7	78.7
Fence East	22.8	20.0	21.0	22.6	86.4
Fence South	19.9	19.1	20.8	21.4	81.2
Control-Houserville	17.5	15.3	16.5	18.6	67.9

Personnel Exposures

Technical Specifications requirement 6.6.1.g.

No reactor personnel or visitors received an effective dose equivalent in excess of 10% of the permissible limits under 10 CFR 20.

Fortieth Annual Progress Report

Radiation Science and Engineering Center

August 1995

Contract DE-AC07-94ID-13223
Subcontract C88-101857

FORTIETH ANNUAL PROGRESS REPORT

PENN STATE RADIATION SCIENCE AND ENGINEERING CENTER

July 1, 1994 to June 30, 1995

Submitted to:

United States Department of Energy

and

The Pennsylvania State University

By:

Marcus H. Voth (Director)
Terry L. Flinchbaugh (Editor)
Penn State Radiation Science and Engineering Center
Department of Nuclear Engineering
The Pennsylvania State University
University Park, PA 16802

August 1995

Contract DE-AC07-94ID-13223
Subcontract C88-101857
U.Ed.ENG 96-29

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This publication is available in alternative media on request.

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PREFACE

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 Fortieth Annual Progress Report (July 1994 through June 1995) 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 committment 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

August 15, 1995, marked the fortieth anniversary of the initial criticality of the Penn State Breazeale Reactor (PSBR), making it the longest operating university research reactor in the nation. Despite its early beginnings, efforts are made to continually upgrade the entire Radiation Science and Engineering Center (RSEC) to a state-of-the-art facility capable of cutting edge research. This report tabulates the number of users, experiments performed, and hours of operation along with summaries of the nature of work performed, and its significance. Highlights among the year's accomplishments are discussed below:

- Three visiting scientists performed work at the RSEC. Ms. Faridah Idris, an IAEA Fellow, studied ways to increase the power level of the Malaysian TRIGA reactor. Dr. Evgueni Shabalin, a SABIT Intern, collaborated in cold neutron research techniques while investigating new applications for research reactors, specifically for his facility in Russia. Dr. Andrea Paesano of Brazil is performing research on materials in collaboration with Drs. Catchen and Motta.

- Dr. Edwards and his students continue to make major contributions in the field of advanced controls. They hosted a successful seminar to disseminate their research findings and prepare to host the 1996 American Nuclear Society topical meeting on Nuclear Plant Instrumentation, Control and Human Interface Technology at Penn State.

- Neutron radiography is being used for a new application by Dr. Prescott and his students as they investigate transport phenomena during the solidification of alloys.

- A staff program has commenced in the hot cell facility to monitor the long term performance of irradiated high nickel steels under strain, integrating the measurements with Dr. Motta's research in the performance of irradiated metals.

- The spatial transient behavior of the TRIGA reactor is being used by Dr. Feltus and her students to evaluate the fidelity of state-of-the-art power reactor computer models. Similar data was also provided to the Nuclear Regulatory Commission to simulate a classic rod drop accident or rod ejection accident as a benchmark for deliberations in their license review process.

- Preliminary experiments on cold neutron studies commenced with the assistance of Dr. Shabalin. Work continues on Dr. Sokol's cold neutron irradiation facility in support of improved performance of the Intense Pulsed Neutron Source at Argonne National Laboratory.

- A number of facility enhancements were made to improve the performance and capabilities of the RSEC. A work station provided as part of a DOE grant was installed and made operational for improved capability of analytical computations. A procedure was developed and demonstrated to implement the movable core feature of the bridge modification. A new Cobalt-60 dry irradiator was installed, increasing the effective age of our gamma irradiation capability by 15 years.

- Operations in support of these accomplishments proceeded with no violations cited in NRC inspection reports. One Reactor Operator and two Senior Reactor Operator license exams were administered by the NRC with all three candidates passing.

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II. PERSONNEL

Maurice Peagler was promoted from Environmental Analyst to Research Support Technician III effective July 1, 1994 in the LLRML. Maurice resigned his position effective August 1, 1994 to accept a health physics assistant position with the university. In anticipation of Maurice's departure, Jana Lebiedzik was hired as a wage payroll employee effective July 1, 1994 and assumed Maurice's position on August 1, 1994.

Mac Bryan was promoted from Assistant Research Engineer to Reactor Supervisor/Engineer effective March 1, 1995.

Lisa Brazee, Staff Assistant V, took a personal leave of absence from June 1, 1995 to June 30, 1995. Carol Houtz was hired as a wage payroll secretary during that time.

Several wage payroll personnel provided support during the year. Scott Anderson, Mary Lou Gougar, Joy Moncil, Chris Norman, Lois Lunetta and Danielle Page provided support in the educational programs area. Scott Anderson and Jeff Simons provided clerical support. Brian Marazi provided support to the supervisor of facility services.

Dhushy Sathianathan (Assistant Professor, Engineering Graphics) was appointed to serve on the Penn State Reactor Safeguards Committee (PSRSC) from August 1, 1994 to September 30, 1995 while committee member Paul Sokol was on sabbatical leave. On January 1, 1995, Mike Slobodien (Radiological Controls Director, General Public Utilities) left the committee after serving the maximum two terms allowed by the committee charter. His replacement was Patrick J. Donnachie, Jr. (Health Physicist, General Public Utilites).

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	Associate Professor
**	T. Daubenspeck	Reactor Supervisor/Reactor Utilization Specialist
**	C. C. Davison	Reactor Supervisor/Nuclear Education Specialist
**	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
	C. J. Kowalske	Administrative Assistant
	J. Lebiedzik	Research Support Technician III
**	A. J. McLellan	Reactor Operator Intern
**	D. R. Miller	Reactor Operator Intern
	M. Q. Peagler (resigned)	Research Support Technician III
*	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

S. Anderson
M. Gougar
C. Houtz
D. Page
L. Lunetta
B. Marazi
J. Moncil
C. Norman
J. Simons

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

* Served through January 1, 1995
** Appointed January 1, 1995
*** Temporary appointment from August 1, 1994 to September 30, 1995 during P. E. Sokol's sabbatical

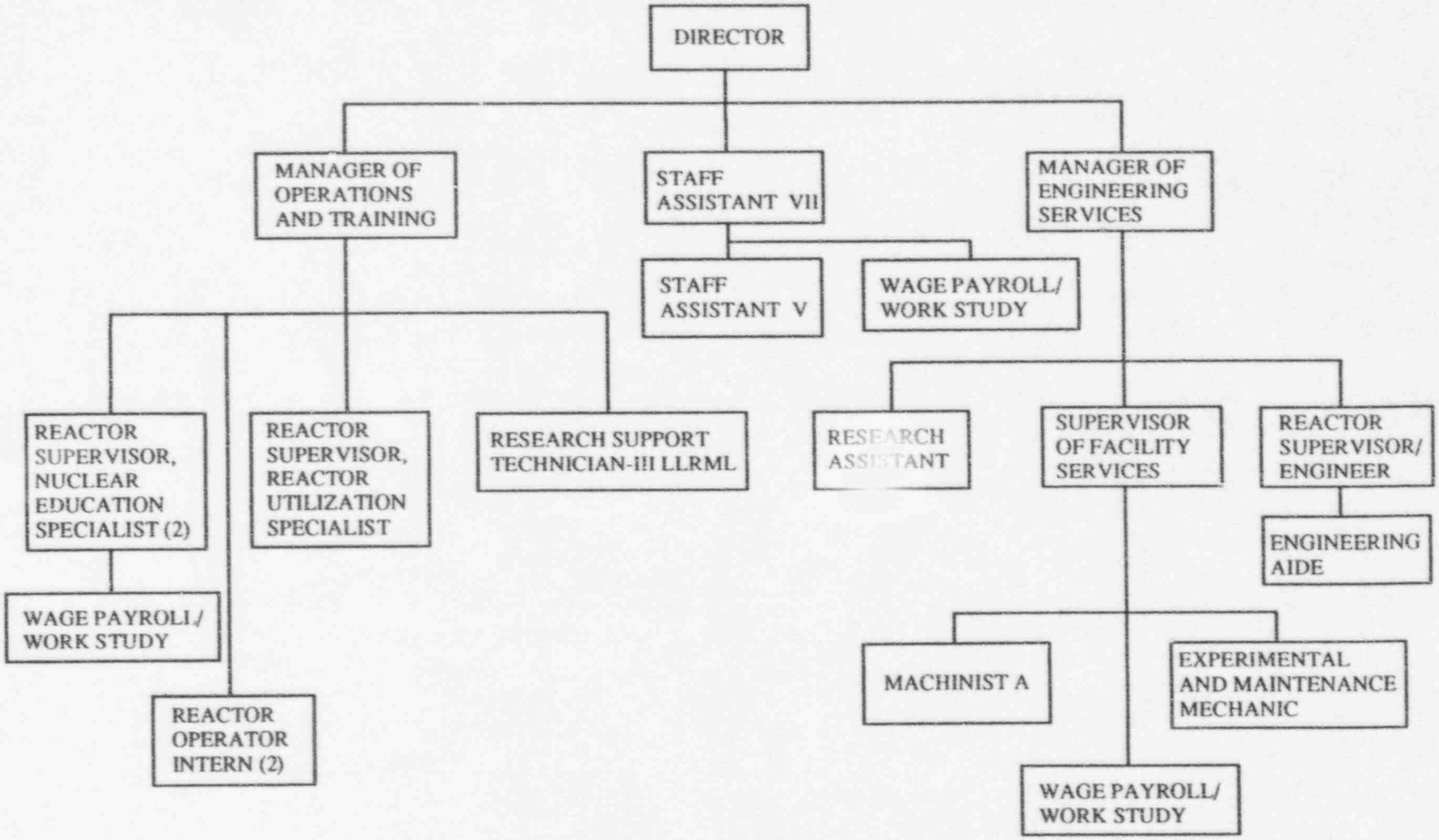

FIGURE 1 RSEC Organization Chart as of 6/30/95

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 there were minimal fuel movements made this year.

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

The number of Scrams Planned as Part of Experiments reflects experimenter needs. One Unplanned Scram Resulting from Personnel Action occurred when the console sensed both bay exhaust fans were off because of an operator switching error. The Unplanned Scrams Resulting from Abnormal System Operation were because of: 1) two N-16 pump failures from thermal overloads, 2) loss of transient rod air supply because of a maintenance error, 3) elevated Argon-41 in pneumatic transfer system because of air leaks and, 4) normal operating fuel temperature was too close to fuel temperature scram set point.

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

Part B gives a breakdown of the Type of Usage in Hours. The Nuclear Engineering Department and/or the Reactor Facility receives compensation for Industrial Research and Service. 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 1994, Stephen Miller, Deputy Director, AFRRI Triga Reactor Facility, 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 November of 1994, a NRC routine inspection was conducted of activities authorized by the broad byproduct material license (37-185-04), the Cobalt-60 facility license (37-185-05), the self-shielded irradiator license (37-185-06) and the SNM-95 license. No items of non-compliance were identified for reactor activities.

During April of 1995, a NRC routine inspection was conducted of activities authorized by the special nuclear materials license SNM-95 and the R-2 reactor license. No items of non-compliance were identified.

TABLE 2

Reactor Operation Data
July 1, 1992 - June 30, 1995

		92-93	93-94	94-95
A.	Hours of Reactor Operation			
	1. Critical	635	601	561
	2. Subcritical	404	362	401
	3. Fuel Movement	8	31	27
B.	Number of Pulses	77	48	131
C.	Number of Square Waves	60	68	89
D.	Energy Release (MWH)	391	391	259
E.	Grams U-235 Consumed	20	20	13
F.	Scrams			
	1. Planned as Part of Experiments	20	27	15
	2. Unplanned - Resulting From			
	a) Personnel Action	2	2	1
	b) Abnormal System Operation	1	1	5

TABLE 3

Reactor Utilization Data
Shift Averages
July 1, 1992 - June 30, 1995

		92-93	93-94	94-95
A.	Reactor Usage			
	1. Hours Critical	2.5	2.4	2.2
	2. Hours Subcritical	1.6	1.4	1.6
	3. Hours Shutdown	1.6	1.5	1.9
	4. Reactor Not Available	0.1	0.6	0
	TOTAL HOURS PER SHIFT	5.8	5.9	5.6
B.	Type of Usage - Hours			
	1. Industrial Research and Service	0.9	0.6	0.7
	2. University Research and Service	2.3	2.1	1.5
	3. Instruction and Training	1.1	1.4	1.3
	4. Calibration and Maintenance	1.4	1.8	2
	5. Fuel Handling	0.1	0.1	0.1
C.	Users/Experiments			
	1. Number of Users	2.7	2.3	2.4
	2. Pneumatic Transfer Samples	0.7	0.6	0.5
	3. Total Number of Samples	3.1	2.3	2.4
	4. Sample Hours	2.7	2.9	2.4
D.	Number of 8 Hour Shifts	250	254	255

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 November of 1971, the University obtained from the Natick Laboratories, 63,537 curies of Cobalt-60 in the form of aluminum clad source rods. These source rods have decayed through several half-lives, leaving a July 1, 1995 approximate total of 3300 curies.

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

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

Maximum exposure rates of 121 KR/Hr in a 3" ID tube and 70 KR/Hr in a 6" ID tube are available as of July 1, 1995.

A GammaCell 220 irradiator is being donated to Penn State by the David Sarnoff Research Center in Princeton, New Jersey. The transfer of the device is scheduled for July 1995. This device has a dose rate considerably higher than that currently available in the RSEC pool facility or with another irradiator on campus. It will take approximately fifteen years for the dose rate on the GammaCell 220 to decay to the current RSEC dose rates available, thus providing a fifteen year extension of usable irradiation capability.

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, 1992 - June 30, 1995

	92-93	93-94	94-95
A. Time Involved (Hours)			
1. Set-Up Time	171	130	90
2. Total Sample Hours	10,975	6,547	2694
B. Numbers Involved			
1. Samples Run	684	510	677
2. Different Experimenters	35	36	39
3. Configurations Used	4	3	4
C. Per Day Averages			
1. Experimenters	0.8	0.54	0.59
2. Samples	2.75	2.05	2.72

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 1994 consisted of an oral examination on abnormal and emergency procedures given by P. G. Boyle and an operating test given by T. L. Flinchbaugh. A written exam was administered by K. E. Rudy.

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The Nuclear Concepts and Technological Issues Institute (NCTII) was conducted from July 11-22, 1994 at the University Park campus. The Nuclear Concepts program was designed to prepare secondary science educators to teach the basics of nuclear science, radiation, and applications and is offered as a special topics course in nuclear engineering. Twenty-three secondary science teachers participated in the program. The program was developed in 1970 and has been conducted every summer since that time. The 1994 program differed in that it was a two-week applications course. This change provided an intense course in a short period of time.

Support for the program included funding through a grant from the National Science Foundation for ten teachers. Sponsorship of the other thirteen participants was provided by Baltimore Gas and Electric Company, Chem-Nuclear Systems Inc., Edison Electric Institute, General Electric Company, Gilbert Associates, GPU Nuclear Corporation, Oxford Instruments Inc. and various school districts. Materials were obtained from the U.S. Department of Energy, USCEA, ANS and other sources. General Electric Company donated many educational materials to the course including a full-size Chart of the Nuclides and booklet to each participant.

The institute was coordinated by Candace Davison and was conducted through Penn State's Continuing Education Office. Joseph Bonner presented the fundamental nuclear science lectures. Other instruction was provided by Nuclear Engineering department personnel and Rodger Granlund, University Health Physicist. Guest speakers from government, research, and industry provided expertise for the technical and issues sessions. Guest speakers included Mr. Alan Brinser from Chem-Nuclear Systems Inc., Mr. John Redding from General Electric Company, Mr. Chris Davis from Westinghouse Electric Corporation, and Dr. Frank Olney from Radiology

Associates. Several Alumni from the course discussed implementation of nuclear science into their curriculum.

Laboratory experiments are an important aspect of the institute as the teachers are able to have hands-on experience with radioactive materials. The laboratories were conducted at the RSEC under the direction of the RSEC and Health Physics personnel. Guy Anderson, a chemistry teacher from the Bald Eagle Area School District was in charge of the laboratories. The laboratory experiments and demonstrations included: characteristics of ionizing radiation, neutron activation of Indium, complex decay of Silver-110 and Silver-108, neutron radiography, and the approach to critical experiment. Discussion and problem solving sessions along with a field trip to either Three Mile Island Unit 1 (a PWR) or Susquehanna Steam Electric Station (a BWR) were included in the schedule.

Evaluations from the participants were very positive concerning the course. As in previous institutes, the participants in NCTII were encouraged to return with their students for a day of experiments at the RSEC. Two follow-up programs were conducted during October in the Harrisburg area. The first program on the Medical Applications of Radiation and Radiosotopes was conducted at the Hershey Medical Center on Friday, October 14, 1994. The program included a variety of speakers who discussed their research and how radioisotopes are used. An overview of medical imaging and a tour of the Low-level waste storage facility was also included for the participants. A program on Fundamental Particles and Interactions was conducted on Saturday, October 15, 1994 at the Penn State Harrisburg Campus. Dr. Ted Zalesckiewizc of the University of Pittsburgh at Greensburg conducted the program and utilized a hypercard computer program and slides to introduce the topic.

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 842 students and teachers from 35 high schools and 2 colleges came to the RSEC for experiments and instruction. (see Table 5). Candace Davison and Lois Lunetta were the main instructors for the program. Other instruction and technical assistance for experiments were provided by 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, the High School Summer Internship, the Civil Engineering VEC-tour program and the Upward Bound program for minority and "at risk" students. Twenty-four teachers from the Harrisburg area participated in a full day of experiments as part of the course "Exploring the Nuclear Option". Thirty-six teachers from the Enter-2000 program received instruction and toured the facility to learn more about nuclear energy and related careers.

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 tours for 2,518 persons.

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

Semester		Course	Instructor	Students	Hours
Summer	1994	NucE 497B-Nuclear Concepts	C. C. Davison	23	4
Summer	1994	NucE 444-Nuclear Reactor Operations	D. E. Hughes	3	12
Fall	1994	NucE 451-Reactor Physics	R. M. Edwards W. A. Jester	23	67
Fall	1994	Food Science 313-Process Plant Production	R. B. Beelman	21	2
Spring	1995	NucE 444-Nuclear Reactor Operations	D. E. Hughes	8	32
Spring	1995	NucE 450-Radiation Detection and Measurement	M. H. Voth W. A. Jester	23	66
Spring	1995	NucE 401-Introduction to Nuclear Engineering	E. S. Klevans	8	4
Summer	1995	SciEd 497-Exploring the Nuclear Option	C. C. Davison	24	4

In January and February of 1995, a total of 42 University Police Services personnel were given training and retraining sessions by C. C. Davison at the RSEC to ensure familiarity with the facilities and to meet Nuclear Regulatory Commission requirements.

During the 1994-95 academic year, one IAEA fellow and two other visiting professors were hosted by the RSEC and Nuclear Engineering Department.

Ms. Faridah Idris, Research Officer for the reactor at the Malaysian Institute for Nuclear Technology Research in Kajank, Malaysia, arrived in January 1995 for a four month visit. She was sponsored as an International Atomic Energy Agency Fellow. Her mission was to study safety analysis technique in preparation for upgrading their one megawatt TRIGA to two megawatts. In addition to working with the RSEC staff, she worked closely with Dr. Haghighat in applying Monte Carlo techniques and using the MCNP code for power distribution and shielding calculation.

Dr. Evgueni Shabalin of the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research in Dubna, Russia, arrived in May 1995 for a five-month visit. He is an intern in the Special American Business Internship Training Program (SABIT) with Penn State, funded by the U.S. Department of Commerce. The purpose of Dr. Shabalin's visit is to receive training in commercial aspects of operation of a research reactor. He has also furnished technical expertise to the reactor staff and the physics department as they design a Cold Neutron Irradiation Facility.

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 will be here for at least one year 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 he is working with Dr. Arthur T. Motta and Dr. Gary L. Catchen.

TABLE 5

University Reactor Sharing Program
College and High School Groups
1994-1995 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	4	Harrisburg Academy Barbara Thrush	29
	7	Harmony HS Chad Weiwiora	23
	7	IU-9 Karen Kelly	50
November	9	Glendale HS Paul Conway	53
	14	State College HS Jan Hildenbrandt	8
	16	IU-9 JoAnn Castle	7
	18	Williamson HS Bob Burket	31
	21	Greensburg-Salem HS Cheryl Harper	39
December	1	Lock Haven University	4
	15	Dubois HS Physics	3
	16	Carlisle HS Robert Barrick	70
March	1	Germantown Friends Gary Garber	10
	6	Redland HS Robert Lighty	19
	13	Berwick HS Jeff Snyder, Dave Dobler	14
	15	Bermudian Springs HS Jeanne Suehr	16
	20	Daniel Boone HS Larry Tobias	13
	22	Eastern Lebanon HS Richard Schwalm	8
	22	Peters Township HS Walter Jennings	18
	28	State College HS Tod McPherson	42

FORTIETH ANNUAL PROGRESS REPORT

PENN STATE RADIATION SCIENCE AND ENGINEERING CENTER

July 1, 1994 to June 30, 1995

Submitted to:

United States Department of Energy

and

The Pennsylvania State University

By:

Marcus H. Voth (Director)
Terry L. Flinchbaugh (Editor)
Penn State Radiation Science and Engineering Center
Department of Nuclear Engineering
The Pennsylvania State University
University Park, PA 16802

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PENNSTATE

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STATEMENT OF NONDISCRIMINATION

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PREFACE

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 Fortieth Annual Progress Report (July 1994 through June 1995) 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 committment 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

August 15, 1995, marked the fortieth anniversary of the initial criticality of the Penn State Breazeale Reactor (PSBR), making it the longest operating university research reactor in the nation. Despite its early beginnings, efforts are made to continually upgrade the entire Radiation Science and Engineering Center (RSEC) to a state-of-the-art facility capable of cutting edge research. This report tabulates the number of users, experiments performed, and hours of operation along with summaries of the nature of work performed, and its significance. Highlights among the year's accomplishments are discussed below:

- Three visiting scientists performed work at the RSEC. Ms. Faridah Idris, an IAEA Fellow, studied ways to increase the power level of the Malaysian TRIGA reactor. Dr. Evgueni Shabalin, a SABIT Intern, collaborated in cold neutron research techniques while investigating new applications for research reactors, specifically for his facility in Russia. Dr. Andrea Paesano of Brazil is performing research on materials in collaboration with Drs. Catchen and Motta.

- Dr. Edwards and his students continue to make major contributions in the field of advanced controls. They hosted a successful seminar to disseminate their research findings and prepare to host the 1996 American Nuclear Society topical meeting on Nuclear Plant Instrumentation, Control and Human Interface Technology at Penn State.

- Neutron radiography is being used for a new application by Dr. Prescott and his students as they investigate transport phenomena during the solidification of alloys.

- A staff program has commenced in the hot cell facility to monitor the long term performance of irradiated high nickel steels under strain, integrating the measurements with Dr. Motta's research in the performance of irradiated metals.

- The spatial transient behavior of the TRIGA reactor is being used by Dr. Feltus and her students to evaluate the fidelity of state-of-the-art power reactor computer models. Similar data was also provided to the Nuclear Regulatory Commission to simulate a classic rod drop accident or rod ejection accident as a benchmark for deliberations in their license review process.

- Preliminary experiments on cold neutron studies commenced with the assistance of Dr. Shabalin. Work continues on Dr. Sokol's cold neutron irradiation facility in support of improved performance of the Intense Pulsed Neutron Source at Argonne National Laboratory.

- A number of facility enhancements were made to improve the performance and capabilities of the RSEC. A work station provided as part of a DOE grant was installed and made operational for improved capability of analytical computations. A procedure was developed and demonstrated to implement the movable core feature of the bridge modification. A new Cobalt-60 dry irradiator was installed, increasing the effective age of our gamma irradiation capability by 15 years.

- Operations in support of these accomplishments proceeded with no violations cited in NRC inspection reports. One Reactor Operator and two Senior Reactor Operator license exams were administered by the NRC with all three candidates passing.

PERSONNEL

II. PERSONNEL

Maurice Peagler was promoted from Environmental Analyst to Research Support Technician III effective July 1, 1994 in the LLRML. Maurice resigned his position effective August 1, 1994 to accept a health physics assistant position with the university. In anticipation of Maurice's departure, Jana Lebiedzik was hired as a wage payroll employee effective July 1, 1994 and assumed Maurice's position on August 1, 1994.

Mac Bryan was promoted from Assistant Research Engineer to Reactor Supervisor/Engineer effective March 1, 1995.

Lisa Brazee, Staff Assistant V, took a personal leave of absence from June 1, 1995 to June 30, 1995. Carol Houtz was hired as a wage payroll secretary during that time.

Several wage payroll personnel provided support during the year. Scott Anderson, Mary Lou Gougar, Joy Moncil, Chris Norman, Lois Lunetta and Danielle Page provided support in the educational programs area. Scott Anderson and Jeff Simons provided clerical support. Brian Marazi provided support to the supervisor of facility services.

Dhushy Sathianathan (Assistant Professor, Engineering Graphics) was appointed to serve on the Penn State Reactor Safeguards Committee (PSRSC) from August 1, 1994 to September 30, 1995 while committee member Paul Sokol was on sabbatical leave. On January 1, 1995, Mike Slobodien (Radiological Controls Director, General Public Utilities) left the committee after serving the maximum two terms allowed by the committee charter. His replacement was Patrick J. Donnachie, Jr. (Health Physicist, General Public Utilites).

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	Associate Professor
**	T. Daubenspeck	Reactor Supervisor/Reactor Utilization Specialist
**	C. C. Davison	Reactor Supervisor/Nuclear Education Specialist
**	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
	C. J. Kowalske	Administrative Assistant
	J. Lebiedzik	Research Support Technician III
**	A. J. McLellan	Reactor Operator Intern
**	D. R. Miller	Reactor Operator Intern
	M. Q. Peagler (resigned)	Research Support Technician III
*	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

S. Anderson
M. Gougar
C. Houtz
D. Page
L. Lunetta
B. Marazi
J. Moncil
C. Norman
J. Simons

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

* Served through January 1, 1995
** Appointed January 1, 1995
*** Temporary appointment from August 1, 1994 to September 30, 1995 during P. E. Sokol's sabbatical

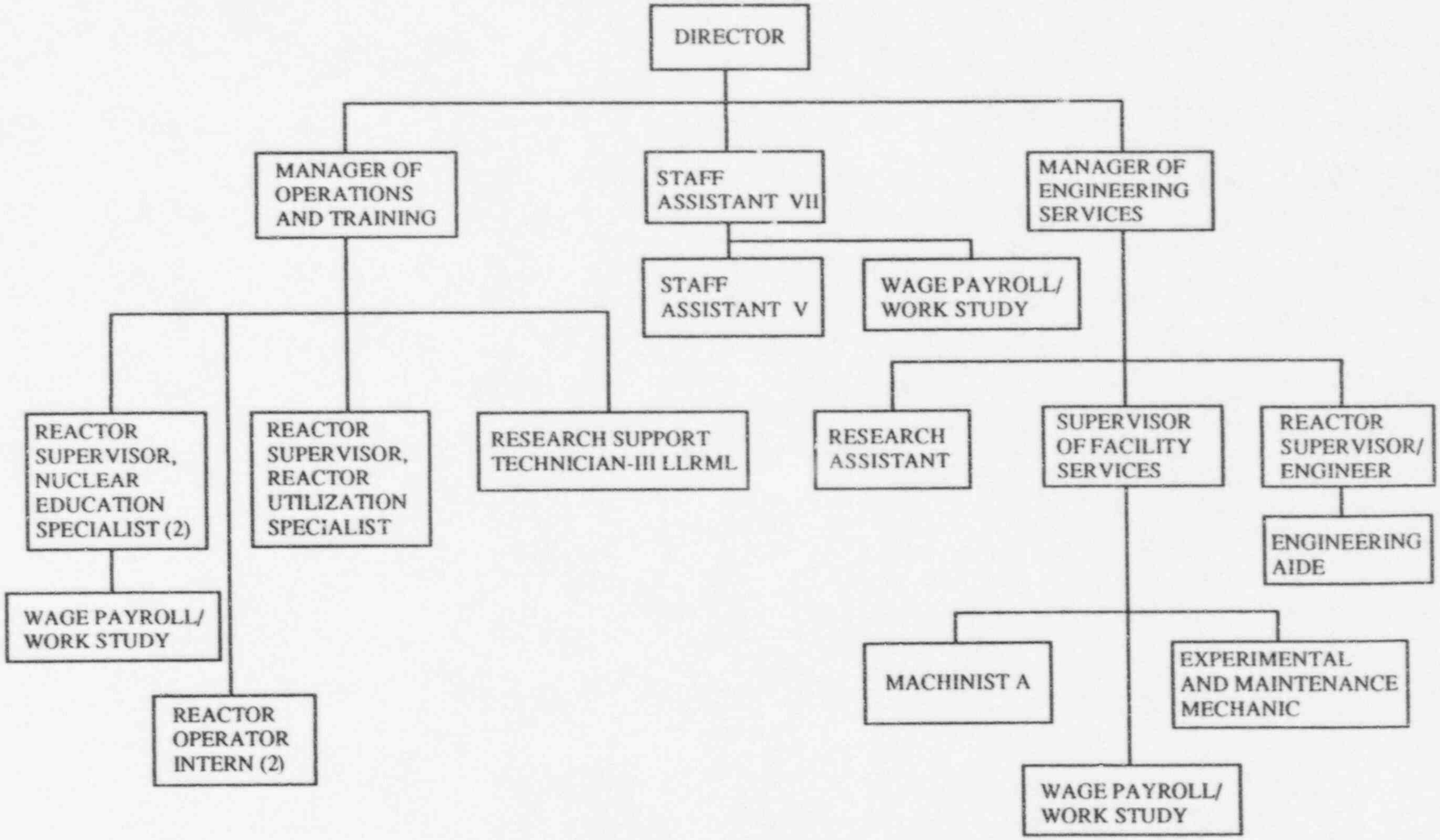

FIGURE 1 RSEC Organization Chart as of 6/30/95

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 there were minimal fuel movements made this year.

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

The number of Scrams Planned as Part of Experiments reflects experimenter needs. One Unplanned Scram Resulting from Personnel Action occurred when the console sensed both bay exhaust fans were off because of an operator switching error. The Unplanned Scrams Resulting from Abnormal System Operation were because of: 1) two N-16 pump failures from thermal overloads, 2) loss of transient rod air supply because of a maintenance error, 3) elevated Argon-41 in pneumatic transfer system because of air leaks and, 4) normal operating fuel temperature was too close to fuel temperature scram set point.

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

Part B gives a breakdown of the Type of Usage in Hours. The Nuclear Engineering Department and/or the Reactor Facility receives compensation for Industrial Research and Service. 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 1994, Stephen Miller, Deputy Director, AFRRI Triga Reactor Facility, 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 November of 1994, a NRC routine inspection was conducted of activities authorized by the broad byproduct material license (37-185-04), the Cobalt-60 facility license (37-185-05), the self-shielded irradiator license (37-185-06) and the SNM-95 license. No items of non-compliance were identified for reactor activities.

During April of 1995, a NRC routine inspection was conducted of activities authorized by the special nuclear materials license SNM-95 and the R-2 reactor license. No items of non-compliance were identified.

TABLE 2

Reactor Operation Data
July 1, 1992 - June 30, 1995

		92-93	93-94	94-95
A.	Hours of Reactor Operation			
	1. Critical	635	601	561
	2. Subcritical	404	362	401
	3. Fuel Movement	8	31	27
B.	Number of Pulses	77	48	131
C.	Number of Square Waves	60	68	89
D.	Energy Release (MWH)	391	391	259
E.	Grams U-235 Consumed	20	20	13
F.	Scrams			
	1. Planned as Part of Experiments	20	27	15
	2. Unplanned - Resulting From			
	a) Personnel Action	2	2	1
	b) Abnormal System Operation	1	1	5

TABLE 3

Reactor Utilization Data
Shift Averages
July 1, 1992 - June 30, 1995

		92-93	93-94	94-95
A.	Reactor Usage			
	1. Hours Critical	2.5	2.4	2.2
	2. Hours Subcritical	1.6	1.4	1.6
	3. Hours Shutdown	1.6	1.5	1.9
	4. Reactor Not Available	0.1	0.6	0
	TOTAL HOURS PER SHIFT	5.8	5.9	5.6
B.	Type of Usage - Hours			
	1. Industrial Research and Service	0.9	0.6	0.7
	2. University Research and Service	2.3	2.1	1.5
	3. Instruction and Training	1.1	1.4	1.3
	4. Calibration and Maintenance	1.4	1.8	2
	5. Fuel Handling	0.1	0.1	0.1
C.	Users/Experiments			
	1. Number of Users	2.7	2.3	2.4
	2. Pneumatic Transfer Samples	0.7	0.6	0.5
	3. Total Number of Samples	3.1	2.3	2.4
	4. Sample Hours	2.7	2.9	2.4
D.	Number of 8 Hour Shifts	250	254	255

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 November of 1971, the University obtained from the Natick Laboratories, 63,537 curies of Cobalt-60 in the form of aluminum clad source rods. These source rods have decayed through several half-lives, leaving a July 1, 1995 approximate total of 3300 curies.

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

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

Maximum exposure rates of 121 KR/Hr in a 3" ID tube and 70 KR/Hr in a 6" ID tube are available as of July 1, 1995.

A GammaCell 220 irradiator is being donated to Penn State by the David Sarnoff Research Center in Princeton, New Jersey. The transfer of the device is scheduled for July 1995. This device has a dose rate considerably higher than that currently available in the RSEC pool facility or with another irradiator on campus. It will take approximately fifteen years for the dose rate on the GammaCell 220 to decay to the current RSEC dose rates available, thus providing a fifteen year extension of usable irradiation capability.

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, 1992 - June 30, 1995

	92-93	93-94	94-95
A. Time Involved (Hours)			
1. Set-Up Time	171	130	90
2. Total Sample Hours	10,975	6,547	2694
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Staff member Thierry Daubenspeck and operator intern Alexander McLellan participated in the reactor operator training program during 1994 and were granted their senior reactor operator licenses by the NRC in September 1994. Staff member Mark Grieb participated in the reactor operator training program during 1994 and 1995 and was granted a reactor operator's license by the NRC in June 1995.

The ninth session of the Pennsylvania Governor's School for Agricultural Sciences was held at Penn State's University Park campus during the summer of 1994. Sixty-four high school scholars participated in the five week program at Penn State. The Governor's School for Agricultural Sciences includes introduction and experience in many different agricultural disciplines. There are several parts of the program which are considered "core courses". The core courses are fundamental instruction given to all participants. "Radioisotope Applications in Agricultural Research" is one of the core courses in the program. The program was conducted at Penn State's RSEC by Candace Davison along with Mary Lou Gougar and nuclear engineering student Scott Anderson. Maurice Peagler, Supervisor of the Low-Level Radiation Monitoring Laboratory provided a session on detection of radiation in the environment including radon gas. The students performed a series of experiments focusing on the fundamentals of radiation interaction and principles of radioisotope applications. These experiments included a demonstration of a cloud chamber; penetrating ability of alpha, beta and gamma radiation; half-life calculation and gamma ray spectroscopy. The importance of statistics in taking data and other applications of radioactive materials in research were discussed. The students were also given a tour of the reactor facility.

The Nuclear Concepts and Technological Issues Institute (NCTII) was conducted from July 11-22, 1994 at the University Park campus. The Nuclear Concepts program was designed to prepare secondary science educators to teach the basics of nuclear science, radiation, and applications and is offered as a special topics course in nuclear engineering. Twenty-three secondary science teachers participated in the program. The program was developed in 1970 and has been conducted every summer since that time. The 1994 program differed in that it was a two-week applications course. This change provided an intense course in a short period of time.

Support for the program included funding through a grant from the National Science Foundation for ten teachers. Sponsorship of the other thirteen participants was provided by Baltimore Gas and Electric Company, Chem-Nuclear Systems Inc., Edison Electric Institute, General Electric Company, Gilbert Associates, GPU Nuclear Corporation, Oxford Instruments Inc. and various school districts. Materials were obtained from the U.S. Department of Energy, USCEA, ANS and other sources. General Electric Company donated many educational materials to the course including a full-size Chart of the Nuclides and booklet to each participant.

The institute was coordinated by Candace Davison and was conducted through Penn State's Continuing Education Office. Joseph Bonner presented the fundamental nuclear science lectures. Other instruction was provided by Nuclear Engineering department personnel and Rodger Granlund, University Health Physicist. Guest speakers from government, research, and industry provided expertise for the technical and issues sessions. Guest speakers included Mr. Alan Brinser from Chem-Nuclear Systems Inc., Mr. John Redding from General Electric Company, Mr. Chris Davis from Westinghouse Electric Corporation, and Dr. Frank Olney from Radiology

Associates. Several Alumni from the course discussed implementation of nuclear science into their curriculum.

Laboratory experiments are an important aspect of the institute as the teachers are able to have hands-on experience with radioactive materials. The laboratories were conducted at the RSEC under the direction of the RSEC and Health Physics personnel. Guy Anderson, a chemistry teacher from the Bald Eagle Area School District was in charge of the laboratories. The laboratory experiments and demonstrations included: characteristics of ionizing radiation, neutron activation of Indium, complex decay of Silver-110 and Silver-108, neutron radiography, and the approach to critical experiment. Discussion and problem solving sessions along with a field trip to either Three Mile Island Unit 1 (a PWR) or Susquehanna Steam Electric Station (a BWR) were included in the schedule.

Evaluations from the participants were very positive concerning the course. As in previous institutes, the participants in NCTII were encouraged to return with their students for a day of experiments at the RSEC. Two follow-up programs were conducted during October in the Harrisburg area. The first program on the Medical Applications of Radiation and Radiosotopes was conducted at the Hershey Medical Center on Friday, October 14, 1994. The program included a variety of speakers who discussed their research and how radioisotopes are used. An overview of medical imaging and a tour of the Low-level waste storage facility was also included for the participants. A program on Fundamental Particles and Interactions was conducted on Saturday, October 15, 1994 at the Penn State Harrisburg Campus. Dr. Ted Zalesckiewizc of the University of Pittsburgh at Greensburg conducted the program and utilized a hypercard computer program and slides to introduce the topic.

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 842 students and teachers from 35 high schools and 2 colleges came to the RSEC for experiments and instruction. (see Table 5). Candace Davison and Lois Lunetta were the main instructors for the program. Other instruction and technical assistance for experiments were provided by 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, the High School Summer Internship, the Civil Engineering VEC-tour program and the Upward Bound program for minority and "at risk" students. Twenty-four teachers from the Harrisburg area participated in a full day of experiments as part of the course "Exploring the Nuclear Option". Thirty-six teachers from the Enter-2000 program received instruction and toured the facility to learn more about nuclear energy and related careers.

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 tours for 2,518 persons.

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

Semester		Course	Instructor	Students	Hours
Summer	1994	NucE 497B-Nuclear Concepts	C. C. Davison	23	4
Summer	1994	NucE 444-Nuclear Reactor Operations	D. E. Hughes	3	12
Fall	1994	NucE 451-Reactor Physics	R. M. Edwards W. A. Jester	23	67
Fall	1994	Food Science 313-Process Plant Production	R. B. Beelman	21	2
Spring	1995	NucE 444-Nuclear Reactor Operations	D. E. Hughes	8	32
Spring	1995	NucE 450-Radiation Detection and Measurement	M. H. Voth W. A. Jester	23	66
Spring	1995	NucE 401-Introduction to Nuclear Engineering	E. S. Klevans	8	4
Summer	1995	SciEd 497-Exploring the Nuclear Option	C. C. Davison	24	4

In January and February of 1995, a total of 42 University Police Services personnel were given training and retraining sessions by C. C. Davison at the RSEC to ensure familiarity with the facilities and to meet Nuclear Regulatory Commission requirements.

During the 1994-95 academic year, one IAEA fellow and two other visiting professors were hosted by the RSEC and Nuclear Engineering Department.

Ms. Faridah Idris, Research Officer for the reactor at the Malaysian Institute for Nuclear Technology Research in Kajank, Malaysia, arrived in January 1995 for a four month visit. She was sponsored as an International Atomic Energy Agency Fellow. Her mission was to study safety analysis technique in preparation for upgrading their one megawatt TRIGA to two megawatts. In addition to working with the RSEC staff, she worked closely with Dr. Haghighat in applying Monte Carlo techniques and using the MCNP code for power distribution and shielding calculation.

Dr. Evgueni Shabalin of the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research in Dubna, Russia, arrived in May 1995 for a five-month visit. He is an intern in the Special American Business Internship Training Program (SABIT) with Penn State, funded by the U.S. Department of Commerce. The purpose of Dr. Shabalin's visit is to receive training in commercial aspects of operation of a research reactor. He has also furnished technical expertise to the reactor staff and the physics department as they design a Cold Neutron Irradiation Facility.

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 will be here for at least one year in the context of a collaboration between Penn State and the Federal University of Rio Grande do Sul to study defects in interrnetallic 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 he is working with Dr. Arthur T. Motta and Dr. Gary L. Catchen.

TABLE 5

University Reactor Sharing Program
College and High School Groups
1994-1995 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	4	Harrisburg Academy Barbara Thrush	29
	7	Harmony HS Chad Weiwiora	23
	7	IU-9 Karen Kelly	50
November	9	Glendale HS Paul Conway	53
	14	State College HS Jan Hildenbrandt	8
	16	IU-9 JoAnn Castle	7
	18	Williamson HS Bob Burket	31
	21	Greensburg-Salem HS Cheryl Harper	39
December	1	Lock Haven University	4
	15	Dubois HS Physics	3
	16	Carlisle HS Robert Barrick	70
March	1	Germantown Friends Gary Garber	10
	6	Redland HS Robert Lighty	19
	13	Berwick HS Jeff Snyder, Dave Dobler	14
	15	Bermudian Springs HS Jeanne Suehr	16
	20	Daniel Boone HS Larry Tobias	13
	22	Eastern Lebanon HS Richard Schwalm	8
	22	Peters Township HS Walter Jennings	18
	28	State College HS Tod McPherson	42

TABLE 5

University Reactor Sharing Program
College and High School Groups
1994-1995 Academic Year
(Continued)

Month		School and Teacher	Number of Students & Teachers
March	29	Cumberland Valley HS Albert Thompson	10
	31	Jersey Shore HS Gary Heyd	10
April	5	Loyalsock HS John German	19
	5	Bradford HS	35
	10	Portage HS Herman Carl	8
	12	Harborcreek HS Dave Sidelinger	11
	19	Carmichaels HS Pat Gibson	29
	21	East Stroudsburg HS Heather Skeldon	11
	27	Franklin Area HS Beth Green	22
	28	Ridgway HS Ernest Koos	21
	28	St. Mary's HS William Scilingo	26
May	1	Northern Bedford HS Keith Little	19
	2	Indiana University of PA Frank Fazio	9
	4	Marion Center HS John Petrosky	10
	5	Camp Hill HS Philipp Schmelzle	10
	8	Westmont Hilltop HS Tom Moore	13
	10	Somerset HS Jon Critchfield	22
	12	Berlin Brothersvalley HS J. Neil Crowell	8
	12	Dallastown HS Mark Ilyes	16
	15	Muncy HS Harold Shrimp, Larry Greico	24
	23	State College HS Marguerite Ciolkosz	18
	29	Twin Valley Middle School Doug Mountz	34

NEUTRON BEAM LABORATORY

VI. NEUTRON BEAM LABORATORY

The Neutron Beam Laboratory (NBL) is one of the experimental facilities that is a part of the RSEC. A well collimated beam of neutrons, thermalized by a D_20 thermal column, is passed into the NBL for use in non-destructive testing and evaluation. Work now being done utilizes a Real Time Neutron Image Intensifier, by Precise Optics, Inc., for real time radiography. The beam is also being used for static neutron radiography and neutron attenuation studies, and flash radiography utilizing pulsing. New 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. In association with this project, Bettis arranged to borrow a second image intensifier which allows different camera arrangements and will enhance utilization. We continue to have funded service work utilizing the beam to measure neutron attenuation of boraflex materials that have seen service in fuel storage pools.

DOE and University matching funds will be used to build a new D_20 thermal column to enhance the neutron beam in the NBL. It is expected that at least an order of magnitude increase in beam flux will result.

Dr. Sokol of the Penn State Physics Department, in conjunction with Argonne National Laboratory, is designing a Cold Neutron Irradiation Facility (CNIF) to study the moderating properties of solid methane at low temperatures. This project will initially benefit from the versatility of the movable core and in later stages of the project will benefit from the ability to open another beam port for use.

New equipment for digitizing and enhancing the real time radiography images has been purchased using DOE and University matching funds. This system will allow image processing for both single frames and real time sequences of the image.

Dr. Prescott of the Penn State Mechanical Engineering Department is 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 utilize some type of radionuclear technique in their research. The majority of these research projects involve neutron activation, but the staff is able to provide services in radioactive tracer techniques, radiation gauging, radiation processing, and isotope production for laboratory, radionuclear medicine and industrial use. Laboratory personnel continue to supply support for the operation of the RSEC doing analyses of water, air monitor filters, and other samples.

Approximately 175 irradiations of semiconductors were performed during the past year. 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.

The facility performed 19 isotope production runs for industrial use during the past year. The isotopes produced included 2 Na-24 runs, 12 Br-82 runs, and 5 Ar-41 runs.

Penn State students and faculty members continue to use the services offered by the radionuclear applications laboratory. During the past year, analysis work was performed for graduate and undergraduate students in the Nuclear Engineering and Materials Science department. Analysis work has also been performed to support various projects which will be started shortly.

The Penn State Radionuclear Applications Laboratory has continued to be involved with the Armed Forces Radiobiology Research Institute in activation analysis work of the St. Mary's City, Maryland site. NAA was used to investigate the arsenic concentrations found in hair samples. In addition to the St. Mary's City work, Penn State has also been involved with AFRRI in a preliminary study to determine the feasibility of using Dysprosium as a tracer material for bomb blasts.

The EG&G Ortec Omnigam neutron activation analysis software is being used for routine analyses; however, additional work is still needed to make better use of the software. An in-house inter comparison program has been initiated with the LLRML to verify counting procedures.

The benchmarking of the reactor neutron energy spectrum following ASTM procedures is complete. Results from two different independent analyses have been received and the final report draft has been written. This draft is currently being reviewed before a final report is submitted.

Activation foils have been irradiated and analyzed for the D_2O tank to determine the neutron flux over the axial length of this fixture. This information will be used for the design of the new D_2O tank. Activation foils have also been irradiated and analyzed for three core locations: the central thimble, the coreface, and the R1 position. These irradiations were performed to determine the flux distribution throughout the core.

LOW LEVEL RADIATION MONITORING LABORATORY

VIII. LOW LEVEL RADIATION MONITORING LABORATORY

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.

The laboratory provides analyses for gross alpha and gross beta activity in reactor pool water, cobalt-60 pool water, and the reactor secondary heat exchanger water. Gamma spectroscopy is performed on these samples if alpha or beta action level limits are exceeded. Tritium content in the reactor pool water and the D_2O tank heavy water is determined on a monthly basis. Gamma spectroscopy analyses are performed on a quarterly basis on the reactor pool water and on a water sample from the 6000 gallon holding tank for pool make-up water.

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 was re-certified this year via the RMP exam for radon test operators and the laboratory under his leadership is listed in the EPA posting of certified radon testing labs/individuals. Ms. Harsha Senaratne, a volunteer part-time staff member, is working on the calibration of new diffusion barrier charcoal radon monitoring canisters purchased to replace the existing open face canisters currently in use. Radon in water analysis, and tritium analysis of ground water are also provided to laboratories involved in water testing as well as individual clients on a regular basis. Certification for the analysis of radon in water has been proposed but not yet required by the EPA.

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 of New Jersey with its zirconia supplier, Morgan Matroc Limited, Warwickshire, England.

The uranium-thorium content in enriched soils was determined by gamma spectroscopy analyses for North American Refractories and their supplier, Muscle Shoals Minerals, Inc., and for Control for Environmental Pollution, Inc. The LLRML's results of analyses were found to be the most reliable to the NARCO project. The further shipment of samples will depend on the evaluation of all the data from all the testing laboratories.

Cesium-134 and cesium-137 concentrations in several soil samples were determined by gamma spectroscopy for the Forest Resource Laboratory, and a new set of samples is expected to be analyzed during the next fiscal year.

A two gram speciment of sand/soil collected by professor Witzig at the site of the first A-bomb testing in Almagordo, New Mexico was analyzed using gamma spectroscopy to establish the presence of plutonium in the sample. The daughter of plutonium-241 (americium-241) was detected in the soil sample.

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 the laboratory's capability to analyze soil, silt and clay samples for these elements.

Nancy K. Umisedo, visiting staff member of Saint Paul University in Brazil, is working under the direction of Dr. Jester and Rodger Granlund. She is evaluating environmental gamma radiation data from previous years and taking measurements around the Breazeale Nuclear Reactor using TLD's and EIC's.

Dr. Jester's nuclear engineering graduate student Uditha Senaratne will be working on a project to separate and quantify strontium-89 and strontium-90 in reactor ion exchange resin samples. He is using the Dionex Dx-100 Ion Chromatograph in the reactor facility to separate the strontium isotopes from ion exchanger resin extracts. The LKB Wallac Spectral 1219 scintillation counter unit at the LLRML will be used to count these separated strontium samples.

THE ANGULAR CORRELATIONS LABORATORY

IX. THE ANGULAR CORRELATIONS LABORATORY

The Angular Correlations Laboratory has been in operation for approximately 9 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 seven years, measures four coincidences concurrently using cesium fluoride detectors. A second spectrometer was acquired three years ago, and it measures four coincidences concurrently using barium fluoride detectors. A third spectrometer was set up last year 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. Two federal agencies, the National Science Foundation and the Office of Naval Research, are sponsoring this program.

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

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

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

Current Activities

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

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

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 2 technical presentations, 5 reports, 14 papers, 10 publications, 2 patent disclosures, 4 masters' theses, and 15 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, 51 faculty and staff members, 46 graduate students and 6 undergraduate students have used the facility for research. This represents a usage by 17 departments or sections in 5 colleges of the University. In addition, 50 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

Biochemistry and Molecular Biology

GENETIC AND MOLECULAR CHARACTERIZATION OF MUSCLE DEVELOPMENT

Participants: S. M. Abmayr
B. A. Bour
M. Grill

Service Provided: Gamma Irradiation

Our laboratory focuses on genes involved in embryonic muscle development of drosophila melanogaster. Gamma irradiation is used to induce damage to chromosomal DNA. Most often this damage is in the form of a deletion. In order to select for a deletion in the desired region of a chromosome, we utilize genetic markers. Gamma-irradiated flies are mated and their progeny are scored for loss of a genetic marker located in the region we are studying. If this marker lies near a gene involved in muscle development, there is a good chance that this muscle gene will be removed when the genetic marker is removed. The deletions obtained by this method are then assessed for the loss of the muscle-specific gene.

Doctoral Thesis:

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

Sponsors:	March of Dimes	\$60,000
	American Cancer Society	\$90,500

Biochemistry and Molecular Biology

GENETIC AND MOLECULAR ANALYSIS OF A DROSOPHILA HOMOLOG OF MYOD

Participants: S. M. Abmayr
D. G. Heyser
M. S. Erickson

Service Provided: Gamma Irradiation

Gamma irradiation of Drosophila will cause damage to the DNA with some frequency; approximately 1/10,000 flies will have damage in our area of interest. This damage can be detected by scoring the progeny of the irradiated flies for the loss of a genetic marker which would normally be present on an intact chromosome. By irradiating male Drosophila which are then mated to double-balancer females, it is possible to obtain some progeny with deletions of DNA in the desired area. These will then be used to determine if the missing DNA contains genes which are essential to muscle development, which is our area of interest.

Doctoral Thesis:

Erickson, M. S., and S. M. Abmayr, advisor. The Cloning of MBC, A Gene Involved in Fusion of Drosophila Somatic Muscle. In progress.

Presentations:

Erickson, M. S. The Role of *Nautilus* in *Drosophila* Muscle Development. Presentation at Graduate Student Symposium for Biochemistry and Molecular Biology Department. The Pennsylvania State University, June 12, 1995.

Abmayr, S. M. Genes Controlling Embryonic Development of the Larval Body Wall Muscles. Plenary Session Speaker, 36th Annual Drosophila Research Conference, Atlanta, Georgia, April 5-9, 1995.

Publication:

Rushton, E., R. Drysdale, S. M. Abmayr, A. M. Michelson and M. Bate. (1995) Mutations in a Novel Gene, *Myoblast City*, Provide Evidence in Support of the Founder Cell Hypothesis for *Drosophila* Muscle Development. In press, 1995.

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

Biology Department

CLONAL ANALYSIS OF THE TRAMTRACK MUTATIONS IN DROSOPHILA

Participants: Z.-C. Lai
Y. Li

Service Provided: Gamma Irradiation

The tramtrack (ttk) gene acts as a negative regulator in the Drosophila eye development. Inactivation of the ttk gene results in the development of extra R7 cells. It is known that the sina gene is a positive regulator of R7 cell specification. To understand how ttk and sina may act together in determining the R7 cell fate, we used gamma radiation to generate ttk and sina double mutants, and found that the formation of extra R7 cells in ttk mutants does not require the sina gene activity. Thus, ttk may act downstream of sina, or in a parallel signaling pathway.

Publication:

Lai, Z.-C., S. D. Harrison, F. Karim, Y. Li and G. M. Rubin. The Formation of Extra R7 Cells in Tramtrack Mutants Does Not Require the Activity of Sina. Submitted.

Chemistry Department

SYNTHESIS AND CHARACTERIZATION OF ANIONIC POLY(ORGANOPHOSPHAZENE) HYDROGELS

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

Service Provided: Gamma Irradiation

A series of poly[(propyloxybenzoate) (methoxyethoxyethoxy)-phosphazenes], 2a - 5a, was synthesized and characterized. These water-insoluble polymers were then hydrolyzed to yield the anionic derivatives, poly[(oxybenzoate)-(methoxyethoxyethoxy)phosphazenes], 2b - 5b, which were glassy and water-soluble. The polymers were crosslinked by ^{60}Co gamma irradiation and the swellability of the cross-linked polymers, $2b_x$ - $5b_x$, was determined as a function of composition, pH, ionic strength and cation charge. Polymers $2b_x$ - $5b_x$ formed hydrogels which had higher equilibrium degrees of swelling in basic than in acidic buffer solutions. Polymers with the higher loading of the oxybenzoate side groups showed higher swellability than those with a lower loading of this side group. The degree of swelling of the polymers was reduced when the ionic strength of the swelling medium was increased. A similar reduction in the swelling of the hydrogels was observed when the charge on the cation in the swelling solution was increased. The *in vitro* release of Biebrich Scarlet from hydrogels $2b_x$ and $4b_x$ was investigated. In pH 2 citrate buffer solutions, the dye was steadily released for the first 12 hours. Thereafter, the release curve plateaued reaching appproximately 75% release after 3 days. In contrast, the release rate in pH 7.4 phosphate buffer solutions was rapid with release of all the dye from hydrogels $2b_x$ and $4b_x$ after 70 and 60 minutes respectively.

Doctoral Thesis:

Ambrosio, A. A., and H. R. Allcock, advisor. Synthesis of Biomedical Polyphosphazenes. In progress.

Chemistry Department

LOWER CRITICAL SOLUTION TEMPERATURE OF POLYMERS

Participants: H. R. Allcock
G. R. Dudley

Service Provided: Gamma Irradiation

Alkyl ether phosphazene polymers were exposed to gamma radiation to crosslink the polymers. The crosslinked polymers were then immersed in water and the rate of swelling was measured. The degree of swelling was then related to the structure of the polymer. The swollen polymers were also placed in water at different temperatures and examined. This project is complete.

Doctoral Thesis:

Dudley, G. K., and H. R. Allcock, advisor. Phosphazene Compounds and Polymers. In progress.

Chemistry Department

SURFACE MODIFICATION OF POLYPHOSPHAZENES

Participants: H. R. Allcock
C. Morrissey

Service Provided: Gamma Irradiation

The surface modification of polyphosphazenes was examined. These materials may find use as blood or bio compatible surfaces. The modifications were carried by chemical modification of bulk polymers that were uncrosslinked or crosslinked by ^{60}Co γ irradiation. Bulk hydrolysis of the polymers led to the formation of novel hydrogels. Surface modification of the polymers led to increased hydro philicity.

Doctoral Thesis:

Morrissey, C. T., and H. R. Allcock, advisor. Synthesis and Characterization of Polyphosphazenes. In progress.

Chemistry Department

GAMMA IRRADIATION CROSSLINKING OF MEEP-PHOSPHAZENE POLYMER FILMS

Participants: H. R. Allcock
M. Olshavsky

Service Provided: Gamma Irradiation

Project involved trapping of CDS particles inside a host polymer matrix, which has a fixed pore size as determined by both the constituents making up the polymer and the length of time the polymer host was exposed to gamma irradiation. These particles were then further used for novel optical studies.

Doctoral Thesis:

Olshavsky, M. A., and H. R. Allcock, advisor. Synthesis of Quantum Confined Cadmium Sulfide Nanoclusters in a Phosphazene Polymer Host Matrix. In progress.

Sponsor: NASA Graduate Student Fellowship Program

Chemistry Department

CHEMICAL INITIATED INCLUSION POLYMERIZATION WITHIN CYCLOTRIPHOSPHAZENE COMPOUNDS

Participants: H. R. Allcock
A. P. Primrose
E. N. Silverberg

Service Provided: Gamma Irradiation

Vinyl and acrylic monomers included within the host compound tris(o-phenylenedioxy)cyclotriphosphazene were polymerized through thermal activation of free radical initiators. Separate mixtures of acrylonitrile, 4-bromostyrene, butylacrylate and 2,3-dimethylbutadiene containing selected free radical initiators were included by direct contact imbibition. Resultant oligiomers characterized through Gel Permeation Chromatography and ^{13}C NMR analysis are shown to have increased stereoregularity over comparable oligiomers formed in bulk. Average molecular weights are shown to be dependent upon the amount of initiator present. 2,3-poly(dimethylbutadiene) synthesized within the host adduct over a 50-90 degree temperature range using AIBN as the initiator is found to be consistently trans. Electron spin resonance (ESR) analysis of oligiomeric 4-bromostyrene species within the clathrate structure indicates the presence of radicals stable for weeks within the tunnels of the crystal lattice.

Chemistry Department

POLY(ORGANOPHOSPHAZENE) POLYMER ELECTROLYTE ALLOYS: POLYMER BLENDS AND INTERPENETRATING POLYMER NETWORKS

Participants: H. R. Allcock
K. B. Visscher
S. M. O'Connor
D. Olmeijer

Service Provided: Gamma Irradiation

The synthesis of several new polymer blends and interpenetrating polymer networks (IPN) containing poly(organophosphazenes) and various organic polymers including poly(vinyl ethers), poly(1-alkenes) and poly(vinyl benzo crown ethers) are reported. Polymer blends were prepared by mixing poly[bis(2-(2-methoxy ethoxy)ethoxy)phosphazene], poly[bis(2,3-di(2-methoxyethoxy)propoxy)phosphazene], poly[bis(2,3-di(2-(2'-methoxyethoxy)ethoxy)propoxy)phosphazene] or poly [bis(2,3-di(2-(2'-(2"-(methoxyethoxy)ethoxy)ethoxy) propoxy)phosphazene] with poly(vinyl ethers), poly(1-alkenes) or poly(vinyl benzo crown ethers) in a common solvent and casting films of the resulting polymer blends. Full, sequential IPNs were prepared by polymerizing vinyl ether, 1-alkene or vinyl benzo crown ether monomers within the cross-linked matrix of poly[bis(2-(2-methoxy ethoxy)ethoxy)phosphazene], poly[bis(2,3-di(2-methoxyethoxy)propoxy)phosphazene], poly[bis(2,3-di(2-(2'-methoxyethoxy)ethoxy) propoxy)phosphazene] or poly[bis(2,3-di(2-(2'-(2"-(methoxyethoxy)ethoxy)ethoxy)propoxy)phosphazene]. These materials were characterized by NMR and FT-IR spectroscopy, DSC, electron microscopy and x-ray microanalysis. The conductivity of these materials was measured by impedence analysis.

Doctoral Thesis:

Visscher, K. B., and H. R. Allcock, advisor. Poly(Organophosphazene) Alloys: Polymer Blends and Interpenetrating Polymer Networks, 1993.

Publication:

Allcock, H. R., S. M. O'Connor, K. B. Visscher and D. Olmeijer. Synthesis and Characterization of Poly(Organophosphazene) Polymer Electrolyte Alloys. To be submitted to *Chemistry of Materials*, 1995.

Food Science

EVALUATION OF KINETICS OF 0157:717 IN ACTIVATION IN COLICIN-TREATED BEEF PATTIES/HAMBURGERS

Participants: R. Roberts
S. Murinda
R. Wilson

Service Provided: Gamma Irradiation

Gamma irradiation is used to kill all background microflora on beef hamburgers before deliberately inoculating the hamburgers with pathogenic *Eschesi Eli a Coli* of serotype 0157:117. The hamburgers (which are not for consumption) are also inoculated with colicins, which are inhibitory proteins produced by other strains of *E coli*: Our hypothesis is that (some of) the colicins will kill the *Eschesichi a coli* contaminating hamburgers. Conditions for the recovery of *E coli* and colicins from the hamburgers are being studied so as to establish optimal levels of *E coli*: added/g and colicin activity units/g of hamburger.

Treatment of the hamburger with gamma irradiation, 4 k gy dose, was found to be adequate to kill all background microflora.

Hamburgers have been associated with foodborne illness involving contamination by *E coli* , mostly of serotype 0157:717. Our goal is to come up with a method for controlling or killing *E coli* using hamburger as a model system.

Doctoral Thesis:

Murinda, S. E., and R. Roberts, advisor. Potential for Colicins to Inhibit Diarrheagenic Verotokigenic *Eschenchia Coli* Strains of Serotype 015, 026, 011, Including 0157:717. In Progress.

<u>Materials Science and Engineering</u>

DETERMINATION OF STRONTIUM-BARIUM RATIO IN CRYSTALS

Participants: D. Purdy
T. Daubenspeck

Service Provided: Neutron Irradiation

SrBa crystals were irradiated to determine the feasibility of using neutron activation to determine Strontium-Barium ratio in crystals without producing large amounts of radioactivity. These same crystals will also be analyzed using x-ray diffraction. Preliminary tests worked out and analyses of crystals will begin.

<u>Mechanical Engineering</u>

NEUTRON RADIOGRAPHIC ANALYSIS OF MACROSEGREGATION IN BINARY METAL ALLOYS

Participants: P. J. Prescott
V. K. Singh
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.

Master's Thesis:

Singh, V. K., and P. J. Prescott, advisor. Convective Transport Phenomena During Binary Alloy Solidification, 1994.

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.

<u>Nuclear Engineering</u>

INTERACTIONS OF $^{111}In \rightarrow ^{111}Cd$ PROBE ATOMS ON GaAs (111)B RECONSTRUCTED SURFACES MEASURED USING PERTURBED-ANGULAR-CORRELATION SPECTROSCOPY

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

Service Provided: Laboratory Space

The radiochemistry laboratories of the RSEC were used to prepare special sources of ^{111}In. Specifically, $^{111}InCl_3$ was reduced to atomic In under a hydrogen atmosphere in a closed tube. As part of the reduction process the In atoms diffused into a small polycrystalline copper foil. This ^{111}In-loaded foil was transported to the Electronic Materials and Processing Research Laboratory, where it was used in a specially built ^{111}In effusion source, which was used to effuse atomic ^{111}In under ultrahigh vacuum conditions onto GaAs surfaces. Subsequently, we used $^{111}In \rightarrow ^{111}Cd$ Perturbed-Angular-Correlation (PAC) spectroscopy to measure hyperfine interactions at surface sites on GaAs (111)B (As-terminated) surfaces. The (111)B surfaces form two reconstructions, 2×2, which is formed under As-rich conditions and is stable below ≈ 700 K, and $\sqrt{19} \times \sqrt{19}$ R 23.4°, which is formed under Ga-rich conditions above this temperature. These nearly-atomically-flat surfaces were grown using molecular-beam epitaxy. During each experiment, the ^{111}In probe atoms were effused onto the GaAs surface, and a series of thermal anneals was performed. A laboratory-temperature PAC measurement was made after each anneal. The PAC measurements performed on the 2×2 reconstructed surfaces show two well-defined nuclear electric-quadrupole interactions that occur at two inequivalent Ga-sites on the surface. The corresponding electric-field gradients (EFGs) are large and asymmetric: $V_{zz} \approx 8.6 \times 10^{17}$

Vcm^{-2}, and $\eta \approx 0.47$ and $V_{zz} \approx 16.5 \times 10^{17}$ Vcm^{-2} and $\eta \approx 0.85$; the respective site fractions are $\approx 50\%$ and $\approx 30\%$. The measurements performed on the $\sqrt{19} \times \sqrt{19}$ R 23.4° reconstructed surfaces show one well-defined interaction that involved 82% of the probes. The corresponding EFG is also large and asymmetric: V_{zz} 16.7 × 10^{17} Vcm^{-2} and η 0.8, and the EFG z-axis is oriented essentially perpendicular to the surface. Annealing experiments were performed to convert one reconstruction to the other and then to reconvert it back to the original reconstruction, e.g., $2 \times 2 \rightarrow \sqrt{19} \times \sqrt{19}$ R 23.4°$\rightarrow 2 \times 2$. The PAC measurements that followed each annealing step show the characteristic frequencies for each reconstruction. This result indicates that these probe sites are thermodynamically stable. Additionally, at high annealing temperatures and during these thermal-cycling experiments, a small fraction of the probes appear to diffuse into the bulk crystal. The interpretation of the probe-site assignments does not agree with a model of the $\sqrt{19} \times \sqrt{19}$ R 23.4° reconstructed surface developed using scanning-tunneling microscopy. These experiments represent the first measurements of group III bonding symmetries on a compound III-V semiconductor surface. The corresponding analysis indicates that these symmetries differ qualitatively from the conventional picture.

Doctoral Thesis:

Adams, J. M., and G. L. Catchen, advisor. Bond Symmetries and Crystal Structure of Gallium Arsenide (111)B Semiconductor Surfaces Characterized by Surface Electric-Field Gradients, 1995.

Publication:

Adams, J. M., G. L. Catchen, J. Fu and D. L. Miller. Interactions of $^{111}In \rightarrow ^{111}Cd$ Probe atoms on GaAs (111)B Reconstructed Surfaces Measured Using Perturbed-Angular-Correlation Spectroscopy. *Surface Science*, in press, 1995.

Sponsor: National Science Foundation $199,000

Nuclear Engineering

O-ANION TRANSPORT MEASURED IN SEVERAL $R_2M_2O_7$ PYROCHLORES USING PERTURBED-ANGULAR-CORRELATION SPECTROSCOPY

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

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

We have used perturbed-angular-correlation (PAC) spectroscopy to measure static and fluctuating electric-field gradients (EFGs) at the M-sites in the pyrochlore ceramic materials, $R_2M_2O_7$ (R = Nd,Sm,Eu, and Gd; M = Zr and Hf). Samples were doped with a small concentration of $^{181}Hf \rightarrow ^{181}Ta$ PAC probe ions, and the M-site nuclear electric-quadrupole interactions were observed primarily at elevated temperatures that ranged up to approximately 1300 K. At temperatures below several hundred degrees, the perturbation functions for the Sm-, Eu-, and Gd-, containing compounds show broadened lines that indicate primarily the presence of static, disordered O ions. At somewhat higher temperatures, the perturbation function show attenuated lines that fluctuating EFGs produce, which arise from the hopping motion of O-ions. At very high temperatures, the perturbation functions show sharp lines, which have shapes that reflect the presence of axial symmetry, and these lineshapes indicate that the EFG fluctuation rates have increased to the motional-narrowing limit. Analysis of the attenuation rates, which were measured in the fast fluctuation regime, give activation energies with the electrostatic barriers that O-ions encounter when they jump to a vacant site. In contradistinction, the measurements on $Nd_2Zr_2O_7$

show sharp lines over the entire temperature range. This result indicates that the O-ions are ordered in the Nd crystal and that low-temperature kinetic pathways to disordered structures are not accessible to the O-ions. The magnitudes of the measured activation energies are not consistent with the results of theoretical calculations and with electrical-conductivity-measured energies reported earlier. Thus, the O-anion transport effects, which we used PAC spectroscopy to measure, provide new benchmarks for future theoretical calculations, and these effects suggest that pyrochlores such as $Gd_2Zr_2O_7$ may become the basis for compounds from which new types of ionic-conducting materials could be developed.

Publication:

Catchen, G. L., and T. M. Rearick. O-Anion Transport Measured in Several $R_2M_2O_7$ Pyrochlores Using Perturbed-Angular-Correlation Spectroscopy. To be published in *Physical Review B*, October 1995.

Sponsor: Office of Naval Research $249,416

Nuclear Engineering

ANALYSIS OF ROCK TAKEN FROM THE WUPATKI PUEBLO RUIN IN ARIZONA

Participants: T. H. Daubenspeck
Q. L. Hartwig

Services Provided: Neutron Irradiation and Radiation Counters

Numerous sandstone pueblos were abandoned around 1100 AD for no obvious reason. Many hypotheses have been suggested, but none proven. The presence of uranium deposits in the southwestern United States raises the possibility that the rock composition of the pueblos may have subjected the occupants to a level of radioactivity that some how caused them to leave.

During a visit to the Wupatki Pueblo ruin in northern Arizona, Dr. Hartwig collected two rocks, one of basalt, one of limestone and sent them to the RSEC for analysis for natural radioactivity. The samples did not exhibit inherent radioactivity. The analysis did reveal the presence of various trace elements and a survey of them is still ongoing.

Nuclear Engineering

POTENTIAL OF SILVER SULFADIAZINE (SILVADENE®) TO INCREASE SODIUM AND CHLORIDE IN BURN ESCHAR

Participants: T. H. Daubenspeck
Q. L. Hartwig

Services Provided: Neutron Irradiation and Radiation Counters

Silver sulfadiazine, a topical antibiotic, is routinely applied to burned tissue to prevent infection. Preliminary data from RSEC of neutron activated, thermally burned skin (eschar) suggested that the silver drew significant amounts of sodium and chloride into the eschar.

Since reports of electrolyte imbalance have been associated with the application of silver nitrate, a topical antibiotic, but not silver sulfadiazine, this preliminary finding prompted a follow-up of a more extensive study.

Twelve samples of eschar and normal tissue were obtained from surgery, processed, and sent to the RSEC for neutron exposure and counting to determine the silver, chlorine, and sodium concentrations in each based on the irradiation of Standard Reference Material 1566a, Oyster Tissue. Examination of the data did not support the thesis that the silver in silver sulfadiazine entrapped sodium and chloride into the burn tissue.

Still, the concept of attracting or preventing movement or organisms/substances through the burn eschar could have application to the continuing problem of eschar infection. Thus, the time interval between antibiotic application and tissue collection will be further examined and possibly lead to another experimental design, collection and neutron activation.

Nuclear Engineering

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

Participants: T. H. Daubenspeck
M. Moore
H. Miller
S. D. Harry

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

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

Last year, NAA was used to identify the composition of crystalline residue found on the remains. From activation analysis results and results of other tests, the composition and formation of the crystalline residue was able to be determined. Hair samples analyzed using NAA found unusual amounts of arsenic and silver in one of the hair samples. It was determined that the silver concentration was due to jewelry worn in the hair. The arsenic concentration led to an investigation that focused on the use of arsenic in medicines in colonial days. This year, further hair analysis continued.

Nuclear Engineering

ISOTOPE PRODUCTION FOR TRACER STUDIES

Participants: T. Daubenspeck
M. Bothe
J. Kolek
M. Flenniken
D. Bucior

Services Provided: Neutron Irradiation and Isotope Production

Fourteen isotope production runs were performed for Tru-Tec during the past year. These runs included 2 Na-24 runs, and 12 Br-82 runs. A total of 800 mCi of Na-24 and 3.7 Ci of Br-82 was produced. Five Ar-41 production runs were performed for Tracerco during the year with a total of 1.4 Ci of Ar-41 produced.

Nuclear Engineering

SEMI-CONDUCTOR IRRADIATIONS

Participants: T. Daubenspeck
F. Kalkbrenner
R. Diette
C. Uber

Service Provided: Neutron Irradiation

Semi-conductor irradiations for commercial and military applications numbered 175 for the year. There were 142 irradiations for Harris Semiconductor, 30 for Raytheon, and 3 for E-Systems.

Nuclear Engineering

NEUTRON ACTIVATION ANALYSIS - QUALITY ASSURANCE FOR ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE

Participants: T. Daubenspeck
M. Moore
R. George

Services Provided: Neutron Irradiation and Radiation Counters

The Armed Forces Radiobiology Research Institute (AFRRI) had various types of samples analyzed at the PSBR as part of a quality assurance program to compare the PSBR results to those of the AFRRI neutron activation analysis laboratory. Some of these analyses involved a project AFRRI is doing for the United States Nuclear Defense Agency to determine the feasibility of using Dysprosium to monitor the dispersion pattern of bomb blasts.

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

Rabbit runs of $Y(NO_3)_3$ solutions were performed for thesis work currently in progress (Senaratne, Jester).

Analysis of water samples for MEA project (Gould).

Stainless steel samples irradiated and analyzed to determine possible activation products created during Bittecker project (Hughes).

Activated and analyzed iron foils (Cumblidge).

Irradiated 3 pair (1 bare, 1 cd covered) of activation foils (AuAl, MnCu, and Fe) in core positions CT, B9 and R1 for determining the power distribution through core (Haghighat).

Irradiated 2 sets of activation foils (Ni, AuAl) on D_2O tank to determine flux distribution over axial length of tank for use in D_2O tank design project (Haghighat).

Performed a flux run using sulfur pellet dosimetry to determine the irradiation time required for devices to receive 2.5×10^{18} n/cm^2 in our bare 2" $\times$ 6" irradiation fixture. This flux run was part of a feasibility study conducted for a possible project (Draper Labs).

Irradiation and analysis of one Maalox sample and 2 unknown samples to determine the concentration of aluminum and magnesium based on the known Maalox concentrations (Fazio, Indiana University of Pennsylvania).

Irradiated various samples of aluminum to determine activation products created in Mercury source (Kahn, Kenney, Gould).

NAA was conducted on four air filters taken from the Great Lakes area. The analyses were performed to determine the feasibility of using this facility in a project which would determine the spread of pollution and air quality over the Great Lakes area (Ondov, University of Maryland).

Nuclear Engineering

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 1994, 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 unifies 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.

Sponsor: Tuition Surchage $6,690 (1994)

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 are participating.

Paper:

Edwards, R. M., K. Y. Lee and D. E. Hughes. An Experimental Testbed for Advanced Digital Nuclear Reactor Control. The Fifth International Joint ISA POWID/EPRI Controls and Instrumentation Conference, pp. 235-243, La Jolla, California, June 1995.

Publication:

Second Annual Progress Report on Experimental Development of Power Reactor Intelligent Control, ECS-9216504, Report to National Science Foundation, March 1995.

Sponsors:	FERMI	$12,000 (1992)	NSF/REU	(1995) $9,000
	FERMI	$18,000 (1994)	NSF/EPRI	(1993-1995) $300,000 for the following NSF/EPRI projects:

NSF/EPRI ADVANCED REACTOR TEMPERATURE CONTROL ALGORITHMS

Participants: R. M. Edwards
H. D. Gougar
K. Y. Lee
P. Ramaswamy
R. M. Johns
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.

Advanced reactor temperature control algorithms are 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 and assessment of enhanced observer-based PID and optimized feedforward control during the 94-95 academic year.

In addition, a new UNIX network compatible controller (same as adopted in the control experiment of the NucE451 laboratory course) was acquired in the Fall of 1994 and allows the utilization of a state-of-the-art CASE-based environment for controller design, testing, and implementation. The microprocessor-based controller uses the Wind River Systems VxWorks real-time operating system to implement a control strategy which is developed in a UNIX host computer CASE-based controller development environment. The VxWorks microprocessor is a general purpose and diskless 68040 Motorola-based microprocessor with ADC/DAC cards and standard ETHERNET network interface to the UNIX host development environment. The micro interfaces with the reactor secondary control rod (SCR) which travels in the central thimble while the licensed control and safety system is in a manual mode of operation. This new state-of-the-art CASE environment replaces the Bailey Network 90 system for many of the experiments conducted in previous years.

Advanced control algorithms, such as an optimal control algorithm, require a dynamic model of the process in order to achieve improved performance characteristics. The concept of robustness relates to how far can the actual process deviate from the *assumed* process model and still maintain required stability and desired performance improvement. Through extensive simulation, this optimal controller, which is based on a one-delayed neutron group model, has been shown to maintain desired performance for a factor of 10 variation in the power level and control rod worth for which it was designed.

Algorithms with improved reactor temperature performance developed for full range robustness testing in 1994-95 include: H -based μ-synthesis, fuzzy logic, neural network, PID and optimized feedforward/robust feedback.

Papers:

Edwards, R. M., R. M. Johns, S. J. Kenney and H. D. Gougar. Unconventional Digital Reactor Control without Conventional Programming. *Trans. Amer. Nucl. Soc.* 72: 298-300, June 1995.

Power, M. A., and R. M. Edwards. Implementation of Robust Control Experiments on a Nuclear Reactor. Proceedings of the Ninth Power Plant Dynamics and Control Conference, pp 30.01-30.15, Knoxville, Tennessee, May 1995.

Ramaswamy, P., R. M. Edwards, and K. Y. Lee. Performance Evaluation of Fuzzy Logic and Neural Network Controllers. Proceedings of the Ninth Power Plant Dynamics and Control Conference, pp 65.01-65.11, Knoxville, Tennessee, May 1995.

Johns, R. M., Y. Zhao and R. M. Edwards. Optimized Wide-Range Robust Control for a Nuclear Power Plant, pp 34.01-34.03, Proceedings of the Ninth Power Plant Dynamics and Control Conference, Knoxville, Tennessee. May 1995. (An updated version of the paper was not submitted in time to be included in the initially distributed printed proceedings.)

Power, M. A., and R. M. Edwards. Functional Prototype Testing of Model-Based Advanced Control For Nuclear Reactors. *Trans. Amer. Nucl. Soc.* 71:361-362, November 1994.

Ramaswamy, P., R. M. Edwards and K. Y. Lee. Validating Real-time Implementations of Diagonal Recurrent Neural Network and Fuzzy Logic Controllers. *Trans. Amer. Nucl. Soc.* 71:364-365, November 1994.

Weng, C. K., M. A. Power, R. M. Edwards and Asok Ray. Feedforward-feedback Control by Nonlinear Programming and Structured Singular Value Approach. *Trans. Amer. Nucl. Soc.* 71:365-366, November 1994.

Weng, C. K., R. M. Edwards and Asok Ray. Robust Wide-Range Control of Nuclear Reactors By Using the Feedforward-Feedback Concept. *Nuclear Science and Engineering*, 117:177-185, July 1994.

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 has been 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, advisor. An Intelligent Reconfigurable Reactor Power Controller. In progress.

Papers:

Kenney, S. J., and R. M. Edwards. An Intelligent Reconfigurable Reactor Power Controller. Proceedings of the Ninth Power Plant Dynamics and Control Conference, pp 32.01-32.16, Knoxville, Tennessee, May 1995.

Kenney, S. J., M. A. Power, H. E. Garcia and R. M. Edwards. Improved Reactor Temperature Response Using an Intelligent Reconfigurable Reactor Power Controller. *Trans. Amer. Nucl. Soc.* 71:362-364, November 1994.

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 1994-95, various concepts for adding the ability to manipulate TRIGA reactor coolant flow and temperatures, independently of rod reactivity control, were studied. The flow control mechanism which is being pursued will add a shroud around the periphery of the reactor with an adjustable flow area that manipulates the flow entering the side of the reactor. Analytic studies of the approach continue to be conducted. Initial installation and testing of the shroud have been approved by the reactor safeguards committee.

Nuclear Engineering

NSF/EPRI HYBRID SIMULATION OF BWR USING THE TRIGA REACTOR

Participants: R. M. Edwards
J. A. Turso
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. In 1994-95, the previously developed PC computer-based hybrid simulation capability was converted to the new UNIX network compatible controller. A more sophisticated hybrid BWR simulation was developed where the effect of manipulating BWR flow can be directly demonstrated. Results obtained from the HRS were utilized to validate a new method of BWR stability monitoring in the thesis of James A. Turso.

Doctoral Thesis:

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

Papers:

Turso, J. A., J. March-Leuba and R. M. Edwards. A Modal Based Reduced Order Model of BWR Out-of-Phase Instabilities. *Trans. Amer. Nucl. Soc.* 72:376-377, June 1995.

Turso, J. A., R. M. Edwards and J. March-Leuba. Hybrid Simulation of Boiling Water Reactor Dynamics Using A University Research Reactor. *Nuclear Technology*, 110:132-144, April 1995.

Turso, J. A., R. M. Edwards and T. W. Highlands. Boiling Water Reactor Stability Analysis via Kalman Filter Based Estimation and Maximum A Posteriori (MAP) Detection. *Trans. Amer. Nucl. Soc.* 71:442-444, November 1994.

Nuclear Engineering

NSF/EPRI INTELLIGENT CONTROL WORKSHOP #2

Participants: R. M. Edwards
K. Y. Lee
D. E. Hughes
H. D. Gougar
R. M. Johns
J. A. Turso
S. J. Kenney
P. Ramaswamy
M. Cecnas-Falcon
G. Meyers
R. Sanchez

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. A one day workshop for industry professionals was conducted on March 21, 1995. Representatives from the Department of Energy, National Science Foundation, Electric Power Research Institute, a utility, a national laboratory, the Nuclear Regulatory Commission, and a reactor manufacturer attended. The workshop included presentations and TRIGA reactor demonstrations of the NSF/EPRI research.

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 at 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 w/o, 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 case will be performed moving a fuel rod at power to simulate the operational mistake that happened at the University of Michigan plate-fueled reactor. 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.

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

Nuclear Engineering

TRIGA POWER PULSE EXPERIMENTS FOR CHARACTERIZATION OF FAST REACTIVITY INSERTION TRANSIENTS FOR TEST AND POWER REACTORS

Participants: M. A. Feltus
D. Ebert

Service Provided: Breazeale Reactor

At the request of Dr. David Ebert (NRC) a series of TRIGA pulses were performed to simulate fast reactivity insertion rates in research and large power reactors. Pulse shapes were qualitatively examined and derivations of pulse shape equations were supplied from NucE 597K Reactor Kinetics, course notes. This work was done to support the BWR fuel failures studies performed by the NRC on the Japanese and French test reactors to simulate large rapid reactivity insertions. These include BWR rod drop accidents in a high burnup core where fuel failures have occurred at low energy depositions, and PWR rod ejection accidents.

Publication:

Ebert, D. Pulse Shapes in Reactors, presentation to the ACRS Reactor Fuels Subcommittee, May 3, 1995. Presented RSEC Breazeale reactor pulse results and compared with other research reactors.

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.

Sponsor:	Nuclear Regulatory Commission	\$56,406	Phase I (11/93-11/94)
		\$69,878	Phase II (11/94 - 1/96)

Nuclear Engineering

PIPE WALL THICKNESS MEASUREMENT USING SCATTERED GAMMA RAYS

Participants: R. Gould
E. S. Kenney
E. H. Klevans
X. Xu
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 Summer 1995. Pending the outcome of these field tests, commercialization of the system is expected to be completed by Spring 1996.

Doctoral Theses:

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

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

Patent Disclosures:

Gould, R., E. S. Kenney, S. Khan and X. Xu. A Compton Back-Scatter Pipe Wall Thickness Gauge Employing Focusing Collimator and Annular Detector, July 1994.

Xu, X., E. S. Kenney and E. H. Klevans. A Compton Back-Scatter Pipe Wall Imaging System Using a Wide Aperture Annular Detector, April 1995.

Sponsor: FERMI $30,000

Nuclear Engineering

NON-DESTRUCTIVE EXAMINATION OF CHEMICAL REACTOR COMPONENTS

Participants: R. Gould
J. Li

Service Provided: Neutron Radiography

This project examined a clogged component from a chemical reactor. It was determined that toluene had carbonized, plugging the outlet of a liquid separator.

Nuclear Engineering

EVALUATING TWO PHASE FLOW USING NEUTRON RADIOGRAPHY

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

Services Provided: Neutron Radiography, Machine Shop and Electronics Shop

This project is using neutron radiography to 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

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.

Reports:

Jester, W. A. Mid-Year Peer Review of the Buried Waste Integrated Demonstration (BWID) Program. Submitted to EG&G Idaho, 22 pages, May 1994.

Jester, W. A. Evaluating Selected Technologies and Programs of the Buried Waste Integrated Demonstrated (BWID) Program. Submitted to Lockheed Idaho Technologies Program, 8 pages, December 1994.

Jester, W. A. Mid-Year Peer Review of the Buried Waste Integrated Demonstration (BWID) Program. Lockheed Idaho Technologies Program, 21 pages, March 1995.

Sponsor: Idaho National Engineering Laboratory $54,404

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, 1995.

Publication:

Basha, H. S., and W. A. Jester. Non-Conventional Approach for Determination of Several Key Exposure Parameters for LWR's. *Trans. Am. Nucl. Soc.*, ISSN:0003-018X, TANSO 70 1-458, 372-373, 1994.

Report:

Basha, H. S., and W. A. Jester. Plant-Life Extension Technology: Flux and Fluence Determination Using Scrapings from Inservice Components. Final report presented to project FERMI, 8 pages, April 1995.

Nuclear Engineering

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

Participants: W. A. Jester
R. W. Granlund
M. Peagler
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 femoral heads used in hip joint replacement. The 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.

Report:

Jester, W. A., M. Peagler and R. W. Granlund. Radiological Analysis of Vitallium® Alloy Disk and Femoral Heads. Final report submitted to Howmedica, Inc., 13 pages, March 1995.

Sponsor: Howmedica, Inc. $20,000

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. Separation of Strontium and Cesium from Reactor Ion Exchanger Resins, and their Quantification, Using High Performance Liquid Chromatography and Beta and Gamma Spectroscopy.

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

Nuclear Engineering

CALIBRATION OF NEW DIFFUSION BARRIER CHARCOAL CANISTERS FOR THE LLRML RADON MONITORING SERVICE

Participants: W. A. Jester
H. Senaratne

Services Provided: Radon Calibration Chamber, NaI(t1) Radon Counter and Laboratory Space

During this year, Ms. Harsha Senaratne has been calibrating the LLRML's diffusion barrier charcoal canisters that have better radon adsorption characteristics then the current open face charcoal canisters. This work involves the exposure of canisters to a known radon concentration for a known amount of time and a known relative humidity. The resulting data will be used to generate a set of calibration curves that will be used to convert the lead-214 and bismuth-214 activity detected on the filters along with the canister weight gain information to determine the average radon concentration of the monitored location.

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 is a visiting scientist from the Institute de Fisca da Universidade Sao Paulo, Brazil. She is working 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 is designed to determine the sources of these low intensity radiation fields.

Nuclear Engineering

RESEARCH IN ENVIRONMENTAL MONITORING FOR IODINE-129 NEAR POWER PLANT AND WASTE DISPOSAL SITES

Participants: W. A. Jester
R. H. Yahner
J. Kwon

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

The objective of this project is to develop a method for the detection of iodine-129 in the radioactive environment near nuclear power plants and waste disposal sites. Iodine-129, the longest-lived radioisotope of iodine, has a half-life of 1.57×10^7 years. Because of its very slow rate of decay, and since Iodine-129 emits only very low energy beta and gamma radiation, accurate detection and measurement are difficult and tedious. It can be detected most readily in animal and human thyroid glands, since these endocrine organs exhibit the highest concentrations of iodine. Accordingly, the thyroids of the environmental animals can be suitable samples for the detection of radioactive iodines.

The thyroid usually contains iodine in the form of organically bound iodide. Several procedures are being considered for the separation of iodine from organic materials and for preparing the resulting samples for neutron activation analysis. One of the possible methods being considered is to employ wet chemistry. The other new analytical approach involves the use of high performance ion chromatography (HPIC).

Once the iodine in the thyroid has been isolated it will be analyzed using neutron activation. The high analytical sensitivity for iodine-129 by neutron activation analysis permits concentration measurements at levels much lower than those obtained by the direct monitoring of iodine-129 radiation.

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 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.

Publication:

Edwards, R. M., and W. A. Jester. Evolution of Nuclear Engineering Laboratory Courses at the Pennsylvania State University. *Trans. of Am. Nucl. Soc.* ISSN: 0003-018X, TANSO 70 1-458, 28-29, 1994.

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 is being tested in the Cobalt-60 pool. After this initial testing, the device will be shipped to a utility for testing in a spent fuel pool.

Sponsor: Electric Power Research Institute

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
Biopore Inc.	Gamma Irradiation
Boswell Water Authority	Environmental Analyses
CB-Tech	Neutron Activation Analyses
Centre Analytical	Environmental Analyses
Control for Environmental Pollution, Inc.	Radiological Analyses
E-Systems	Semiconductor Irradiation
Gannett Flemming	Environmental Analyses
Geochemical Testing	Environmental Analyses
Harris Semiconductor	Semiconductor Irradiation
Howmedica	Radiological Analyses
Indiana University of Pennsylvania	Neutron Activation Analyses
Isotec Incorporated	Neutron Activation Analyses
Macrobac Bradford	Environmental Analyses
Morgan Matroc Limited	Radiological Analyses
Muscle Shoals Minerals, Inc.	Radiological Analyses
North American Refractories	Radiological Analyses
Northeast Technology Corporation	Neutron Radiography
Nuclear Regulatory Commission	Reactor-Reactivity Insertion Transients
Pottsville Environmental Testing Lab	Environmental Analyses
Raytheon	Semiconductor Irradiation
SEMTECH	Gamma Irradiation
St. Mary's City Museum	Neutron Radiography Neutron Activation Analyses
Tracerco	Isotopes for Tracer Studies
Tru-Tec	Isotopes for Tracer Studies
United Water of Pennsylvania	Environmental Analyses
University of Maryland	Perturbed Angular Correlation Neutron Activation Analyses
US Bureau of Mines	Gamma Irradiation

APPENDIX 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)

COLLEGE OF AGRICULTURE

Food Science

Beelman, Robert	(F)
Murinda, Shelton	(G)
Roberts, Robert	(F)
Wilson, Richard	(F)

Forest Resource Laboratory

Cole, Andrew	(S)

Plant Pathology

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

Wildlife Management

Yahner, R. H.	(F)

COLLEGE OF EARTH AND MINERAL SCIENCES

Materials Science and Engineering

Purdy, Dave	(G)

Metals Science and Engineering

Ryba, Earle	(F)

Fuel Science

Li, John	(G)

COLLEGE OF ENGINEERING

Electrical Engineering

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

Mechanical Engineering

Kim, Byoung-Su	(G)
Prescott, Patrick	(F)
Ray, Asok	(F)
Singh, V. K.	(G)
Weng, Chen-Kao	(G)

Nuclear Engineering

Adams, James	(G)
Alpan, Arzu	(G)
Basha, Hassan	(G)
Baratta, Anthony	(F)
Boyle, Patrick	(S)
Bryan, Mac	(S)
Catchen, Gary	(F)
Cumblidge, Steven	(U)
Cecenas-Falcon Miguel	(G)
Daubenspeck, Thierry	(S)
Davison, Candace	(S)
Edwards, Robert	(F)
Feltus, Madeline	(F)
Flinchbaugh, Terry	(S)
Fowler, Dave	(G)
Gougar, Hans	(G)
Gould, Robert	(F)
Grieb, Mark	(S)
Haghighat, Ali	(F)
Harbach, Brian	(U)
Hollinger, Ed	(G)
Hughes, Dan	(F)
Idris, Faridah	(IAEA)
Jester, William	(F)
Johns, Richard	(G)
Kahn, Saif	(G)
Kenney, Edward	(F)
Kenney, Stephen	(G)
Kim, Young-Su	(G)
Klevans, Edward	(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

Kwon, Junhyun	(G)
Lebiedzik, Jana	(S)
Lee, Kwangho	(G)
Lunetta, Lois	(S)
Meyers, Gary	(U)
Miller, David	(S)
Morlang, Mike	(G)
Moyer, John	(U)
Norland, Mark	(G)
Paesano, Andrea	(VF)
Page, Danielle	(U)
Peagler, Maurice	(S)
Power, Mike	(G)
Rearick, Todd	(G)
Rudy, Kenneth	(S)
Sanchez, Roberto	(G)
Senaratne, Harsha	(VS)
Senaratne, Uditha	(G)
Shabalin, Evgueni	(VF)
Shoop, Undine	(G)
Soucy, Scott	(U)
Turso, James	(G)
Umisedo, Nancy	(VS)
Voth, Marcus	(F)
Wulsch, Dan	(G)
Witzig, Warren	(F)
Wright, Bob	(U)
Xu, Xiangjun	(G)
Zhao, Yangping	(G)

School of Engineering Technology and Commonwealth Campus Engineering

Sathianathan, Dhushy	(F)

COLLEGE OF LIBERAL ARTS

Anthropology

Hirth, Kenneth	(F)

COLLEGE OF SCIENCE

Biology

Lai, Zhi-Chun	(F)
Li, Ying	(G)

Chemistry

Allcock, Harry	(F)
Ambrosio, Archel	(G)
Dudley, Gary	(G)
Morrisey, Chris	(G)
O'Connor, S. M.	(PD)
Olmeijer, D.	(G)
Olshavsky, M.	(G)
Primrose, Aaron	(G)
Silverberg, Eric	(G)
Visscher, Karyn	(PD)

Biochemistry and Molecular Biology

Abmayr, Susan	(F)
Bour, Barbara	(G)
Erickson, Mary Ruth	(G)
Grill, M.	(S)
Heyser, Deidre	(S)

Physics

Dimeo, Rob	(G)
Fu, Jiaming	(G)
Sokol, Paul	(F)

INTERCOLLEGIATE PROGRAMS

Health Physics

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

APPENDIX A
(Continued)

INDUSTRIES		
American Inspection Agency	....	Harris, George
Armed Forces Radiobiology	....	George, Robert
Research Institute	....	Miller, Steven
	....	Moore, Mark
Bettis Labs, Westinghouse	....	Glickstein, Stan
	....	Murphy, Jack
BH Labs	....	Brunk, Scott
Biopore, Inc.	....	Gill, S.
CB-Tech	....	Bleistein, Charles
Centre Analytical	....	Robb, Shawn
Control for Environmental Pollution, Inc.	....	Acres, Samuel
E-Systems	....	Dobson, Robert
		Uber, Craig
Gannett Flemming	....	Lane, David
	....	Abbe, Dough
Geochemical Testing	....	Gearhard, Susan
Harris Semiconductor	....	Borza, Peter
	....	Kalkbrenner, F.
Howmedica	....	Wang, Kathy
Isotec Incorporated	....	Smith, Keith
Microbac Bradford	....	Anderson, J. L.
Morgan Matroc Limited	....	Murray, Michael
Muscle Shoals, Inc.	....	Kreig, Mitch
North American Refractories	....	Wealand, L.
Northeast Technology Corporation	....	Harris, Matt
	....	Kline, Don
	....	Lindquist, Kenneth O.
	....	Vonada, Doug
Nuclear Regulatory Commission	....	Ebert, Dave
Pottsville Environmental	....	Sobian, Michael
Raytheon	....	Bibalt, Jacques
	....	Black, Bruce
	....	Diette, R.
	....	Enriquez, Guido
	....	Guravage, John
	....	Lieto, Tony
	....	Mulford, Stewart
	....	Stransky, D. F.
SEMTECH	....	Manders, Sharon
St. Mary's City Museum	....	Harry, Silas D.
	....	Miller, Henry
Tracerco	....	Bucior, Dave
Tru-Tec	....	Bothe, Mike
	....	Kolek, Jerome
	....	Flenniken, Mike
US Bureau of Mines	....	Brickett, Lynn

UNIVERSITIES

University of Maryland	Ondov, John	Professor of Chemistry
University of Maryland	Rasera, Robert L.	Professor of Physics
Indiana University of Pennsylvania	Fazio, Frank	Professor of Chemistry
Indiana University of Pennsylvania	Hartwig, Quentin	Professor of Biology

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 1994 JUNE 1995	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
July	1	Vectour Group	20
	8	Aerospace Engineering	9
	11	Nuclear Concepts	23
	13	IHI-EPRI	5
	14	Vectour Group	26
	16	Alumni Reunion	36
	20	BEST Program	26
	21	Vectour Group	22
	21	Atoms Program	49
	21	Water Systems Group	15
	25	Science Tech. & Soc. Class	18
	27	SSPS Engineering	12
	27	Upward Bound	44
	28	Atoms Program	52
	28	Vectour Group	9
	29	Enter 2000	36
August	2	Human Resources	4
	3	Aerospace Engineering	8
	4	Vectour Group	20
	4	Atoms Group	42
	11	PSU Transportation Academy	11
	18	Denmark Physics Students	2
	23	Fall 1994 Freshmen Tour	2
	30	Emergency Plan Drill Critique/Police Services	2
September	8	Food Science	21
	12	Harris Township Lions Club	18
	13	Nuclear Engineering Student Tour	7
	21	DER/RRT	15
	22	Alumni Fellow	2
	22	Russian Guests	5
	23	Programs Office Tour	2
	26	Bio Science III Class	16
October	1	Fall 1994 Open House	145
	4	Harrisburg Academy	29
	6	Ben Ten	19
	6	Science and Technology 420	18
	7	Harmony High School	23
	7	IU-9	50
	10	Scholars and Parents	5
	10	Outstanding Alumnus	1
	17	Pennsylvania Planning Group	4
	18	497-D Tour	7
	19	497-D Tour	7
	20	FERMI Meeting	5

APPENDIX B
FORMAL TOUR GROUPS
(Continued)

JULY 1994 JUNE 1995	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
October	20	NRC Representative	1
	26	Ferguson Elementary School	56
	28	Ferguson Elementary School	51
	31	PA Jr. Science Symposium	41
November	3	Engineering 100 Freshmen	9
	7	American Institute of Chemical Engineering	4
	9	Glendale High School	53
	14	State College High School-Chemistry Class	8
	15	Science and Technology-200 Open House	82
	16	IU-9 Gifted Students	7
	18	Williamson High School	31
	21	Greensburg-Salem High School	39
December	1	Lock Haven University	4
	12	Catchen's Research Group	5
	15	DuBois Physics Class	3
	16	Carlisle High School	70
January	19	College of Engineering Dean's Office Personnel	3
	19	Police Services Training	22
	19	Potential Graduate Student	1
	27	Evaluation Committee	5
February	1	NucE 444 Class Tour	19
	2	Police Services Training	20
	3	E-Mech 440 Class Tour	13
	7	Civil Engineering 270	12
	8	Civil Engineering 270	10
	9	Civil Engineering 270	20
	17	Com 486	4
March	1	Germantown Friends School	10
	6	Redlands High School	19
	13	Berwick High School	14
	15	Bermudian Springs High School	16
	18	Upward Bound	14
	20	Daniel Boone High School	13
	21	Intelligent Control Workshop #11	15
	22	Eastern Lebanon High School	8
	22	Peters Township High School	18
	24	Nuclear Engineers - NE 401	3
	28	NucE 401 Console ROT	5
	28	State College High School	42
	29	Cumberland Valley High School	10
	31	Jersey Shore High School	10
April	1	Spring 1995 Open House	225
	4	Graduate Tour	21

APPENDIX B
FORMAL TOUR GROUPS
(Continued)

JULY 1994 JUNE 1995	DAY	NAME OF TOUR GROUP	NUMBER OF PARTICIPANTS
April	5	Loyalsock High School	19
	5	Bradford High School	35
	10	Portage High School	8
	12	Lewistown High School	2
	12	Harbor Creek High School	11
	19	Carmichaels High School	29
	21	East Stroudsburg High School	11
	25	Boy Scout Tour Group	32
	27	Franklin Area High School	22
	28	Ridgeway and St. Mary's High School	47
May	1	Northern Bedford High School	19
	2	Indiana University of Pennsylvania	9
	4	Marion Center High School	10
	5	Camp Hill High School	10
	8	Westmont Hilltop High School	13
	10	Somerset High School	22
	12	Berlin High School	8
	12	Dallastown High School	16
	15	Bensalem High School	1
	15	Muncy High School	24
	17	PSU Computer and Information Systems	15
	18	General Public Utilities	7
	22	Sacred Heart Fifth Grade	25
	23	State College High School	18
	26	Bucks County (Council Rock High School)	4
	29	Twin Valley High School	34
June	6	Clifton Fine High School	7
	22	GPU Course	25
	22	Vectour	23
	23	Transport Conference	6
	28	MEA Project	6
	29	Vectour	21
	29	GPU NCTII	4
	30	Wise Group	37
	30	High School Summer Interns	10