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 98-99
PSBR Technical Specifications 6.6.1
License R-2, Docket No. 50-5

December 20, 1999

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

Dear Sir:

Enclosed please find the Annual Operating Report for the Penn State Breazeale Reactor (PSBR). This report covers the period from July 1, 1998 through June 30, 1999, as required by technical specifications requirement 6.6.1. Also included are any changes applicable to 10 CFR 50.59.

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

Sincerely yours,

C. Frederick Sears

C. Frederick Sears
Director, Radiation Science
and Engineering Center

Enclosures

cc. E. J. Pell
D. N. Wormley
L. C. Burton
E. J. Boeldt
M. Mendonca
T. Dragoun

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PENN STATE BREAZEALE REACTOR

Annual Operating Report, FY 98-99
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 two 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 2900 visitors tour the PSBR facility each year.

RESEARCH/SERVICE 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.

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/service projects.

Summary of Reactor Operating Experience - Tech Specs requirement 6.6.1.a.

Between July 1, 1998 and June 30, 1999, the PSBR was

critical for	895 hours	or 3.3 hrs/shift
subcritical for	396 hours	or 1.5 hrs/shift
used while shutdown for	404 hours	or 1.5 hrs/shift
not available	62 hours	or 0.2 hrs/shift
Total usage	1758 hours	or 6.4 hrs/shift

The reactor was pulsed a total of 29 times with the following reactivities:

< $2.00	7
$2.00 to $2.50	14
> $2.50	8
>= $3.00	0

The square wave mode of operation was used 14 times to power levels between 100 and 500 KW.

Total energy produced during this report period was 365 MWH with a consumption of 19 grams of U-235.

Unscheduled Shutdowns - Tech Specs requirement 6.6.1.b.

The 11 unplanned shutdowns during the July 1, 1998 to June 30, 1999 period are described below.

July 20, 1998 – Control Computer (DCC-X) reactor trip initiated by a East Bay Radiation Alarm when the N-16 pump stopped.

July 29, 1998 – Reactor operator shutdown the reactor when an increase was noted on the bay radiation monitors. N-16 pump had stopped.

August 14, 1998 – Reactor operator tripped the reactor when an increase was noted on the bay radiation monitors. N-16 pump had stopped.

September 9, 1998 – Reactor operator shutdown the reactor when an increase was noted on the bay radiation monitors. N-16 pump had stopped.

September 14, 1998 – Reactor operator tripped the reactor when an increase was noted on the bay radiation monitors. N-16 pump had stopped.

September 14, 1998 – Reactor operator tripped the reactor when an increase was noted on the bay radiation monitors. N-16 pump had stopped.

September 21, 1998 – Reactor operator tripped the reactor when an increase was noted on the bay radiation monitors. N-16 pump had stopped.

October 26, 1998 – Reactor Safety System (RSS) reactor trip due to a broken fuel element thermocouple wire. Instrumented fuel element was being rotated to find maximum reading when wire broke.

November 30, 1998 – Reactor trip when reactor operator pushed the safety rod scram button instead of the safety rod up button.

December 15, 1998 – Control Computer (DCC-X) tripped the reactor at 790 kW, the current overpower trip point. An operator had inadvertently entered decades instead of kW as an input to the automatic control system, and the control system increased power towards 1000 kW.

March 10, 1999 – Reactor operator tripped the reactor when a campus area wide electrical power disruption occurred. Although the UPS system maintained the reactor instrumentation, the operator anticipated that the roof ventilation fans (not on UPS) would cause a reactor trip when their louvers closed.

Major Maintenance With Safety Significance - Tech Specs 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 - Tech Specs requirement 6.6.1.d.

Facility Changes -

During August of 1998, facility modifications were made to open beam port #7 for use. A new aluminum extension tube attached by flange to beam port #7 was added. The tube interfaces with the D_2O tank through a graphite interface box that was added to the back side of the D_2O tank. The interface box was needed to optimize the intersection of the aluminum extension tube with the D_2O tank. The safety analysis determined that any failures associated with this modification would not increase the probablity of an accident or malfunction, would not introduce an accident or malfunction of a different type, or reduce the margin of safety as defined in the facility's SAR.

During March of 1999, modifications were made to the transient rod mechanism in an effort to improve drop times. The piston rod seal was replaced with a duplicate part, and the cylinder end gland was replaced with a duplicate part except that the gland diameter was increased to reduce friction. The safety analysis determined that any failures associated with this modification would not increase the probablity of an accident or malfunction, would not introduce an accident or malfunction of a different type, or reduce the margin of safety as defined in the facility's SAR.

Procedures -

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.

New Tests and Experiments -

None

Radioactive Effluents Released - Tech Specs requirement 6.6.1.e.

Liquid

There were no planned liquid effluent releases under the reactor license for the report period. The demineralizer resins were changed in October of 1998. Any pool water or other water used to facilitate the resin change, is evaporated and the distillate recycled for pool water makeup. The evaporator concentrate is dried and the solid salt residue disposed of in the same way as other solid radioactive waste at the University. Presently, the demineralizer beds are replaced when depleted. The depleted beds are solidified for shipment to licensed disposal sites.

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, air in dry irradiation tubes, air in neutron beam ports, and air leakage to and from the carbon-dioxide purged pneumatic sample transfer system. 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 275 mCi and 834 mCi of Ar-41 is calculated for July 1, 1998 to June 30, 1999, resulting in an average concentration at ground level outside the reactor building that is 0.4 % to 1.3 % of the effluent concentration limit in Appendix B to 10 CFR 20.1001 - 20.2402. The concentration at ground level is estimated using only dilution by a 1 m/s wind into the lee of the 200 m^2 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 284 mCi. Since this production occurred in a stagnant volume of air confined by close fitting shield plugs, much 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; some of the Ar-41 releases from the tubes are part of rather than in addition to the release figures quoted in the previous paragraph. Even if all of the 284 mCi were treated as a separate release, the percent of the Appendix B limit given in the previous paragraph would still be no more than 1.7 %.

Production and release of Ar-41 from reactor neutron beam ports was minimal. Beam port #7 has only three small (1/2 inch diameter) collimation tubes exiting the port and any argon-41 production in these small tubes in negligible.. When beam port #7 was used, the door to beam port #4 was closed. The estimated argon-41 production in beam port #4 for reactor runs using beam port #7 is 19 mCi. It is assumed that this argon-41 decayed in place since Radiation Protection Office air measurements taken during beam port #7 operation found no presence of argon-41. Reactor runs with beam port #4 door open were minimal, and the estimated argon-41 release is estimated to be 3 mCi. The use of the pneumatic transfer system was minimal during this period and any Ar-41 release would be insignificant since the system operates with CO-2 as the fill gas.

Tritium release from the reactor pool is another gaseous release. The evaporation rate of the reactor pool was checked 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 59236 pCi/l (the average for July 1, 1998 to June 30, 1999) the tritium activity released from the ventilation system would be 1049 μCi. A dilution factor of 2 x 10^8 ml s^{-1} was used to calculate the unrestricted area concentration. This is from 200 m^2 (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	1049 μC
Average concentration, unrestricted area	1.7 x 10^{-13} μCi/ml
Permissible concentration, unrestricted area	1 x 10^{-7} μCi/ml
Percentage of permissible concentration	1.7 x 10^{-4} %
Calculated effective dose, unrestricted area	8.3 x 10^{-5} mRem

Environmental Surveys - Tech Specs requirement 6.6.1.f.

The only environmental surveys performed were the routine TLD gamma-ray dose measurements at the facility fence line and at control points in a residential area several miles away. This reporting year's measurements (in millirems) tabulated below represent the July 1, 1998 to June 30, 1999 period. The higher Fence South readings for the 1st and 2nd quarter of 1999 are due to radioactive demineralizer resins that were stored in the evaporator building. The resins stored in the evaporator building were located about eight feet inside of the exclusion area fence holding the Fence South dosimeters. The nearest area where public occupancy might occur on a regular basis is a university research building located about 120 feet from the location of the Fence South dosimeters. The fence north dosimeters were assumed stolen during the 1st quarter of 1999 and TLD results were not available for the 1st quarter. Following that event, all fenceline TLD dosimeters were placed in locked cages to increase security of the devices.

	3rd Qtr '98	4th Qtr '98	1st Qtr '99	2nd Qtr '99	Total
Fence North	26.2	25.8	-------	25.9	77.9 (3of 4 qtrs)
Fence West	28.7	25.5	26.8	25.4	106.4
Fence East	28.2	22.4	35.8	33.2	119.6
Fence South	22.9	29.0	56.2	50.3	158.4
Control	27.0	18.7	35.2	24.7	105.6

Personnel Exposures - Tech Specs 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.

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RADIATION SCIENCE AND ENGINEERING CENTER

COLLEGE OF ENGINEERING

FORTY-FOURTH ANNUAL PROGRESS REPORT

AUGUST 1999

CONTRACT DE-AC07-94ID-13223
SUBCONTRACT C88-101857

U. Ed.ENG 00-74

FORTY-FOURTH ANNUAL PROGRESS REPORT

PENN STATE RADIATION SCIENCE AND ENGINEERING CENTER

July 1, 1998 to June 30, 1999

Submitted to:

United States Department of Energy

and

The Pennsylvania State University

By:

C. Frederick Sears (Director)
Terry L. Flinchbaugh (Co-Editor)
Alison Helton (Co-Editor)
Penn State Radiation Science and Engineering Center
Department of Nuclear Engineering
The Pennsylvania State University
University Park, PA 16802

August 1999

Contract DE-AC07-94ID-13223
Subcontract C88-101857
U.Ed.ENG 00-74

Penn State is committed to affirmative action, equal opportunity, and the diversity of its workforce.

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PREFACE

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

The Forty-Fourth Annual Progress Report (July 1998 through June 1999) of the operation of The Pennsylvania State University Radiation Science and Engineering Center is submitted in accordance with the requirements of Contract DE-AC07-94ID-13223 between the United States Department of Energy and Lockheed Idaho Technologies Company (LITCO), and their Subcontract C88-101857 with The Pennsylvania State University. This report also provides the University administration with a summary of the utilization of the facility for the past year.

Numerous individuals are to be recognized and thanked for their dedication and commitment in this report, especially Terry Flinchbaugh and Alison Helton who co-edited the report. 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 IX.

INTRODUCTION

I. INTRODUCTION

MISSION

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

VISION

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

Safety	Actively promote safety in everything we do.
Education	Further develop innovative programs to advance societal knowledge through resident instruction and continuing education for students of all ages and their educators throughout the nation.
Research	Expand leading edge research that increases fundamental knowledge and technology transfer through our diverse capabilities.
Service	Expand and build a diverse array of services and customers by maintaining excellence, quality, customer satisfaction, and efficient service to supplement income and enhance education and research.

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

- The reporting period began in July 1998, as numerous high school groups participated in educational programs at the RSEC under the direction of Candace Davison. This continued into the spring when high school science classes on educational field trips visited and performed experiments. The student chapter of the American Nuclear Society, with Ms. Davison's support, also used the RSEC for educational events such as Boy Scout and Girl Scout merit badge programs. A complete list of groups hosted is presented in Appendix B.

- A new reactor core fuel loading (configuration #50) was put into service in October 1998. This was an effort to reduce excessive power concentration in the center of the reactor core where for the previous core loading fuel elements with a heavier uranium loading were located. The core now has elements with a lesser uranium loading in the inner ring of the core, with the elements with the higher loading in the next two rings out from the core center. Fuel temperature measurements of the new core confirmed computer code predictions and the assumptions of a revised Safety Analysis Report (SAR) and revised Technical Specifications (TS) that were approved by the NRC in the previous reporting year (March 1998).

- Dr. Jack S. Brenizer was hired as Professor of Nuclear Engineering effective January 1, 1999. His research and service activities were transferred to Penn State from the now shutdown University of Virginia research reactor. This necessitated many enhancements to the facility. In October 1998, the south end of the reactor pool was drained for the installation of a collimator arrangement to provide three small diameter neutron beams to utilize beam port #7 to conduct neutron transmission measurements. In the early part of 1999, a new shield wall and shield roof was installed around beam port #4 to enhance facilities for conducting neutron radioscopy. Both neutron transmission measurements and radioscopy are provided as research and service tools to manufacturers of metals containing boron. These boron containing metals are used in the nuclear industry in spent fuel pools, fuel shipping casks and other applications.

- A major building addition was made to the machine shop, doubling the work area and greatly enhancing capabilities to build education, research and service equipment.

- Extensive Hot Cell use continued as Materials Engineering Associates investigated the properties of irradiated reactor pressure vessel metals.

- Construction of a thermal hydraulic loop in the Cobalt Bay as a student design project was completed. It serves as both a teaching and research tool, simulating features of advanced reactor concepts. Further enhancements to the loop are planned.

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II. PERSONNEL

Pamela Stauffer retired from her Administrative Assistant II position effective June 30, 1999. Susan Ripka joined the staff on June 21, 1999, as her replacement. Sue had been serving as secretary to the department head of Mechanical and Nuclear Engineering, and had previously worked at the reactor.

Professor William A. Jester retired on June 30, 1999, after 34 years of service. He served as a technical consultant to the reactor facility during those 34 years. Professor Jack S. Brenizer joined the Mechanical and Nuclear Engineering Department on January 1, 1999. Professor Brenizer came to Penn State from the University of Virginia.

Alison Helton, Reactor Operator Intern, was promoted to the staff position of Reactor Operator/Research and Service Support Specialist on February 1, 1999. Paul Rankin was hired as a wage payroll technician on August 24, 1998. He was promoted to the staff position of Radiation Measurement Technician effective February 1, 1999.

T. Michael Engle, Reactor Operator Intern, resigned from his position on December 16, 1998, upon completion of his undergraduate studies. Dave Werkheiser was hired as a Reactor Operator Intern on June 22, 1999.

The following personnel worked in wage payroll positions during the year. Erin Carlin, Dianna Hahn, Kaydee Kohlhepp, Lois Lunetta, Jerrold McCormick and Wayne Nixon assisted Candace Davison in facility educational programs for high school students. Kaydee and Diana also worked with Candace Davison, Jack Brenizer and Edward Klevans as WISER (Women in Science and Engineering Research) students. They learned about the reactor facility and worked on research projects, such as the Lion's Paw, (a neutron radioscopy experiment). Jack Lee served as the facility's Computer Support Specialist. Shane Hanna served as a Neutronics Inspection Technician. Nick Armstrong assisted Ken Rudy in facility service activities. Lee Armstrong and Bill Underwood assisted the administrative staff in clerical duties. Matt Hooper assisted Dan Hughes in technical support areas.

The following changes to the membership of the Penn State Reactor Safeguards Committee (PSRSC) were effective on January 1, 1999. Forrest J. Remick (Professor, Nuclear Engineering, Penn State – retired) left the committee after serving one term. Richard C. Benson (Department Head of Mechanical and Nuclear Engineering, Penn State) was appointed to fill the vacant position.

TABLE 1

Personnel

	Faculty and Staff	Title
	J. S. Brenizer	Professor, Nuclear Engineering
**	M. E. Bryan	Research Engineer/Supervisor, Reactor Operations
	G. L. Catchen	Professor, Nuclear Engineering
**	T. H. Daubenspeck	Activation and Irradiation Specialist/Supervisor, Reactor Operations
**	C. C. Davison	Research and Education Specialist/Supervisor, Reactor Operations
	W. R. Donley	Staff Assistant VI
**	T. M. Engle (resigned)	Reactor Operator Intern
**	T. L. Flinchbaugh	Manager, Operations and Training
*	M. P. Grieb	Engineering Aide
**	B. J. Heidrich	Reactor Operator Intern
*	A. R. Helton	Reactor Operator/Research and Service Support Specialist
**	D. E. Hughes	Senior Research Assistant/Manager of Engineering Services
	W. A. Jester (retired)	Professor, Nuclear Engineering
	J. Lebiedzik	Research Support Technician III
**	G. M. Morlang	Reactor Engineer/Supervisor, Reactor Operations
	P. R. Rankin	Radiation Measurement Technician
	S. K. Ripka	Administrative Assistant II
*	K. E. Rudy	Supervisor of Facility Services
**	C. F. Sears	Director
	P. J. Stauffer (retired)	Administrative Assistant II
	D. L. Werkheiser	Reactor Operator Intern

* Licensed Operator
** Licensed Senior Operator

Technical Service Staff	Title
J. E. Armstrong	Experimental and Maintenance Mechanic
R. L. Eaken	Machinist A

TABLE 1 (cont.)

Wage Payroll	Title
L. Armstrong	M. Hooper
N. Armstrong	J. Lee
E. Carlin	L. Lunetta
D. Hahn	J. McCormick
S. Hanna	W. Nixon
K. Kohlhepp	B. Underwood

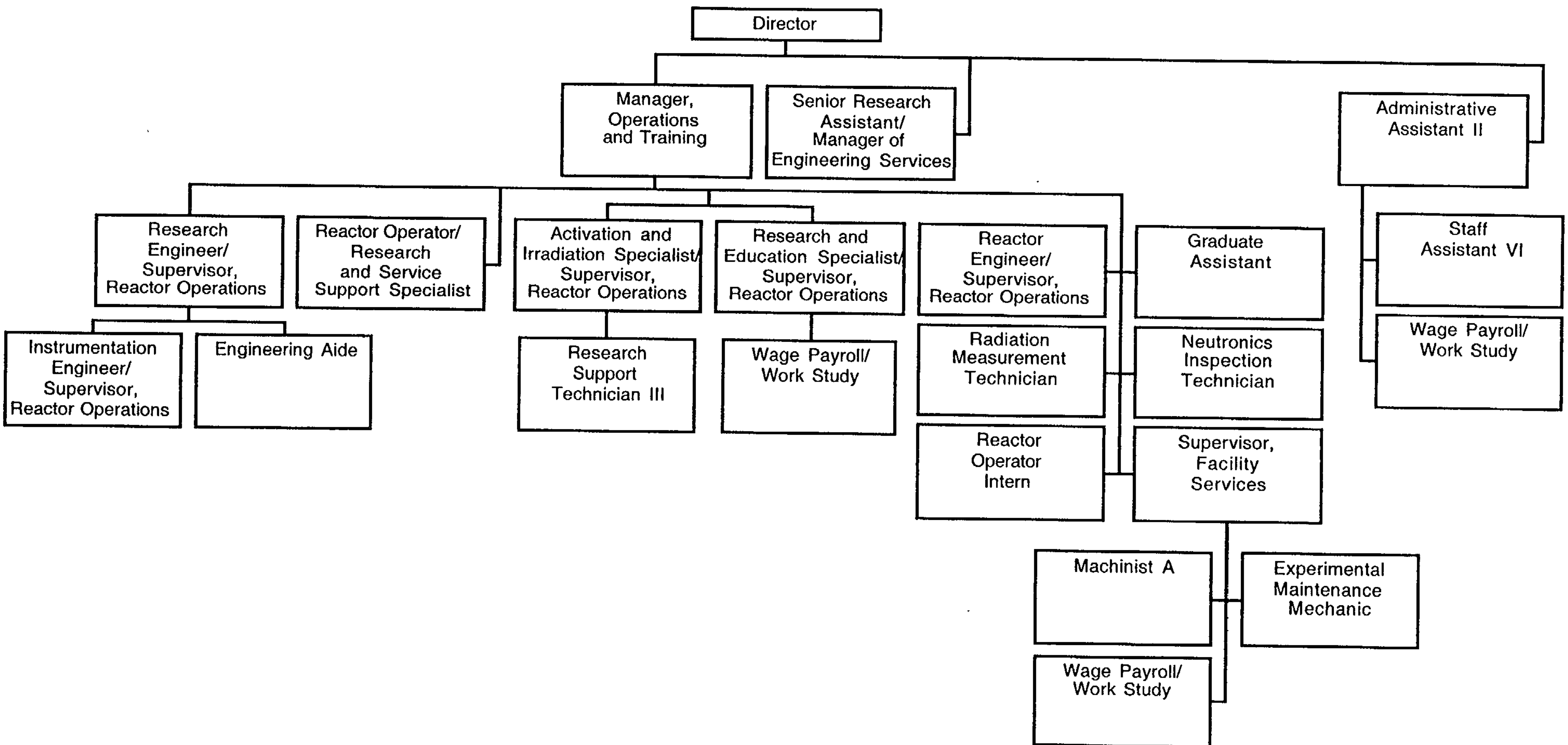
Penn State Reactor Safeguards Committee

**	R. C. Benson	Professor and Department Head, Mechanical and Nuclear Engineering, Penn State
	E. J. Boeldt	Manager of Radiation Protection, Environmental Health and Safety, Penn State
	T. C. Dalpiaz	Manager, Nuclear Maintenance, Pennsylvania Power and Light Susquehanna Steam Electric Station
	P. J. Donnachie, Jr.	Health Physicist, General Public Utilities
	A. Haghighat	Professor, Nuclear Engineering, Penn State
	L. Hochreiter	Professor, Nuclear Engineering, Penn State
*	F. J. Remick	Professor, Nuclear Engineering, Penn State (retired)
	S. Rupprecht	Manager of Nuclear Safety Analysis, Westinghouse
	D. Sathianathan	Assistant Professor, Engineering Graphics, Penn State
	C. F. Sears	Ex officio, Director, Penn State Radiation Science and Engineering Center
	W. F. Witzig	Chairman, Professor, Nuclear Engineering, Penn State (retired)

* Served through January 1, 1999

** Appointed January 1, 1999

RSEC Organization Chart



REACTOR OPERATIONS

III. REACTOR OPERATIONS

Research reactor operation began at Penn State in 1955. In December 1965, the original 200 kW reactor core and control system was replaced by a more advanced General Atomics TRIGA core with an analog control system. TRIGA is the acronym for Training, Research, Isotope Production, built by General Atomics Company. The new core was capable of operation at a steady state power level of 1000 kW with pulsing capabilities to 2000 MW for short (milliseconds) periods of time.

In 1991, the control system was upgraded to an AECL/Gamma-Metrics dual digital/analog system. This system provided for improved teaching and research capabilities and features a local area network whereby console information can be sent to laboratories and emergency support areas.

Utilization of the Penn State Breazeale Reactor (PSBR) falls into four 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. Examples of these classes would be the irradiation and analysis of a sample, non-destructive examinations of materials using neutrons or x-rays, transient behavior of the reactor, or the calibration of a reactor control rod.

Research 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 maintaining competence among PSBR Reactor Operators and Reactor Supervisors.

Service involves Radionuclear Applications, Neutron Transmission Measurements, Radioscopy, Semiconductor Irradiations, Isotope Production and other applications by the industrial sector.

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. A pneumatic transfer system offers additional possibilities. A heavy water tank and Neutron Beam Laboratory provide for neutron transmission and neutron radioscopy activities. Core rotational, east-west, and north-south movements provide flexibility in positioning the core against experimental apparatus.

In normal steady state operation at 1000 kW, the thermal neutron flux available varies from approximately 1 x 10^{13} n/cm^2/sec at the edge of the core to approximately 3 x 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 x 10^{16} n/cm^2/sec with a pulse width of 15 msec at 1/2 maximum.

Support facilities include hot cells, a machine shop, electronic shop, darkroom, 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.

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. Unplanned Scrams from Personnel Action are due to human error. Unplanned Scrams Resulting from Abnormal System Operation are related to failure of experimental, electronic, electrical or mechanical systems.

Table 3, Part A, Reactor Usage, describes total reactor utilization on a shift basis. The summation of Hours Critical and Hours Subcritical gives the total time the reactor console key is on. Hours Shutdown includes time for instruction at the reactor console, experimental setup, calibrations or very minor maintenance that occupies the reactor console but is done with the key off. Significant maintenance or repair time spent on any reactor component or system that prohibits reactor operation is included in Reactor Usage as Reactor Not Available.

Part B gives a breakdown of the Type of Usage in Hours. The Mechanical and 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, Users/Experimenters, reflects the number of users, samples and sample hours per shift. Part D shows the number of eight hour shifts for each year.

INSPECTIONS AND AUDITS

During November 15 to 17 of 1998, an audit of the PSBR was conducted to fulfill a requirement of the Penn State Reactor Safeguards Committee charter as described in the PSBR Technical Specifications. The audit was conducted by –

Randy T. Tropasso, Manager-Shift Engineering, Three Mile Island Nuclear Generating Station

Richard L. Holm, Reactor Administrator, University of Illinois Urbana-Champaign Campus Nuclear Reactor Laboratory.

The reactor staff is implementing changes suggested by that report, all of which exceed NRC requirements.

During March 22 to 26, 1999, a NRC routine inspection by Thomas F. Dragoun was conducted of activities authorized by the reactor's R-2 license. No items of non-compliance were identified.

TABLE 2

Reactor Operation Data
July 1, 1996 - June 30, 1999

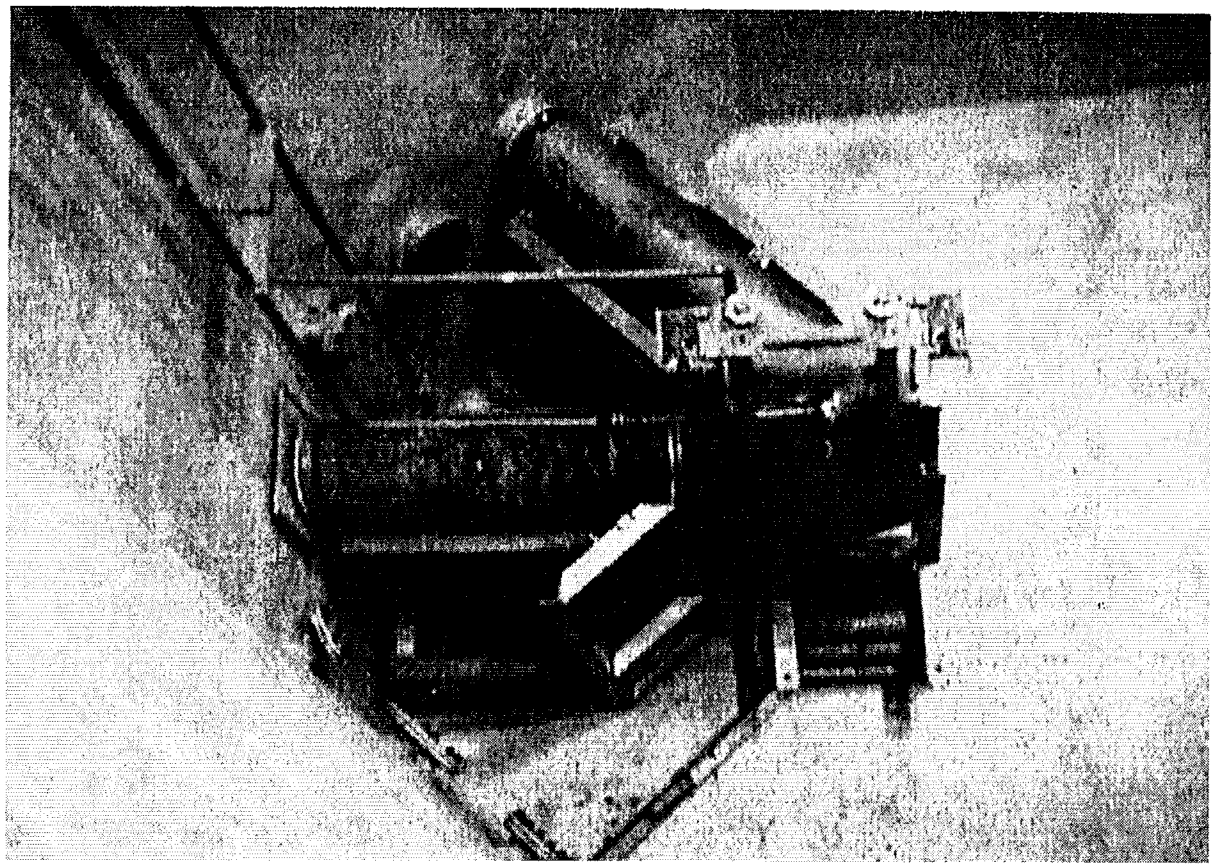
		96-97	97-98	98-99
A.	Hours of Reactor Operation			
	1. Critical	440	755	895
	2. Subcritical	348	517	396
	3. Fuel Movement	22	28	17
B.	Number of Pulses	76	56	29
C.	Number of Square Waves	35	40	14
D.	Energy Releases (MWH)	182	326	365
E.	Grams U-235 Consumed	9	17	17
F.	Scrams			
	1. Planned as Part of Experiments	15	5	9
	2. Unplanned - Resulting From			
	a) Personnel Action	1	4	2
	b) Abnormal System Operation	3	2	7

TABLE 3

Reactor Utilization Data
Shift Averages
July 1, 1996 - June 30, 1999

		96-97	97-98	98-99
A.	Reactor Usage			
	1. Hours Critical	1.7	2.6	3.3
	2. Hours Subcritical	1.3	1.8	1.5
	3. Hours Shutdown	1.4	2.0	1.5
	4. Reactor Not Available	1.4	0.4	0.2
	TOTAL HOURS PER SHIFT	5.9	6.8	6.5
B.	Type of Usage - Hours			
	1. Industrial Research and Service	1.4	2.6	3.4
	2. University Research and Service	1.0	1.0	0.4
	3. Instruction and Training	0.7	1.2	0.7
	4. Calibration and Maintenance	2.7	1.9	1.9
	5. Fuel Handling	0.1	0.1	0.1
C.	Users/Experiments			
	1. Number of Users	2.0	2.4	2.4
	2. Pneumatic Transfer Samples	1.2	0.3	0.1
	3. Total Number of Samples	2.9	3.2	2.7
	4. Sample Hours	1.3	2.6	2.8
D.	Number of 8 Hour Shifts	265	287	273

D_2O thermal column



GAMMA IRRADIATION FACILITY

IV. GAMMA IRRADIATION FACILITY

The Gamma Irradiation Facility includes in-pool irradiators and a dry shielded GammaCell 220 irradiator. The Gamma Irradiation Facility is designed with a large amount of working space around the irradiation pool. This is where the GammaCell 220 is located along with workbenches and the usual utilities.

In-Pool Irradiators

For the in-pool irradiators, the source rods are stored and used in a pool 16 feet by 10 feet, filled with 16 feet of demineralized water. The water provides a shield that is readily worked through and allows great flexibility in using the sources. Due to the number of sources and size of the pool, it is possible to set up several irradiators at a time to vary the size of the sample that can be irradiated, or vary the dose rate. Experiments in a dry environment are possible by use of either a vertical tube or by a diving bell type apparatus. Four different irradiation configurations have been used depending on the size of the sample and dose rate required. The advantage of the in-pool irradiators is that the dose rate can be varied which is optimal for agricultural and life science research.

The University, in March of 1965, purchased 23,600 curies of Cobalt-60 in the form of stainless steel clad source rods to provide a pure source of gamma rays. In November of 1971, the University obtained from the Natick Laboratories, 63,537 curies of Cobalt-60 in the form of aluminum clad source rods. These source rods have decayed through several half-lives, and the dose rates available are summarized in the table below.

GammaCell 220 Dry Irradiator

The GammaCell 220 dry irradiator has a dose rate considerably higher than that currently available in the RSEC in-pool irradiators or with other dry irradiators on campus. Other advantages of the GammaCell 220 include a large irradiation chamber (approximately 6 inches diameter and 7.5 inches high), an automatic timer to move the sample chamber away from the source and the ability to conduct in-situ testing of components during irradiation.

The GammaCell 220 was donated to Penn State in July of 1995, by the David Sarnoff Research Center in Princeton, New Jersey. The maximum dose rate is summarized in the table below.

TABLE 4

Summary of Current Gamma Irradiation Facilities		
Facility	Maximum Dose Rate in KRads/hour*	Sample Limitations
North Tube 6-inch	42.0	Must be less than 6 inches in diameter
South Tube 3-inch	72.0	Must be less than 3 inches in diameter
10-inch Chamber	1.6	Cylinder approximately 10 inches in diameter by 12 inches in height
GammaCell Dry Cell Irradiator	275.0	Cylinder approximately 6 inches in Diameter by 7.5 inches in height
*as of 7/1/99		

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

TABLE 5

Cobalt-60 Utilization Data
July 1, 1996 - June 30, 1999

	96-97 Pool Irradiator	96-97 GammaCell	97-98 Pool Irradiator	97-98 GammaCell	98-99 Pool Irradiator	98-99 GammaCell
A. Time Involved (Hours)						
1. Set-Up/Admin. Time	40	23	35	20	28	30
2. Total Sample Hours	721	752	1318	696	1473	978
B. Numbers Involved						
1. Samples Containers Run[1]	415	766	1919	243	1644	287
2. Different Experimenters	16	20	24	28	12	17
3. Configurations Used	3	NA	3	NA	3	NA
C. Per Day Averages						
1. Experimenters	0.4	0.6	0.4	0.4	0.4	0.4
2. Samples	1.6	3.0	7.7	1	6.6	1.1

The sample hours for the GammaCell for 1998-1999 would be equivalent to 6,500 sample hours in the large pool irradiation tube.

[1] Note that each sample container may contain multiple samples and that multiple samples may be run together in one batch.

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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.

Operator Training:

The RSEC operating staff has maintained reactor operator competence and safe facility operation through training and requalification. During a two-year training cycle, theory, principles, regulations and actions needed for the safe operation of the reactor facility are covered. Training sessions during the year include lectures, exercises and other activities. In-house reactor operator requalification during October and November of 1998, consisted of an oral examination on abnormal and emergency procedures given by T. L. Flinchbaugh and an operating test given by C. F. Sears. A written requalification examination was given in January 1999, by Thierry Daubenspeck and Ken Rudy.

Reactor operator intern Dave Werkheiser entered the reactor operator training program in June of 1999

Governor's School:

The thirteenth session of the Pennsylvania Governor's School for Agricultural Sciences (PGSAS) was held at Penn State's University Park campus during the summer of 1998. Sixty-four high school scholars participated in the five-week program at Penn State. The Governor's School for Agricultural Sciences includes introduction and experience in many different agricultural disciplines. There are several parts of the program including core courses, elective courses and Independent Study Projects (ISP's).

All participants of the Governor's School received a tour of the Reactor facility with some time for hands-on instruction. A fourteen-hour elective course, "Atomic Applications in Agriculture" was conducted for 16 scholars. The course was conducted at Penn State's RSEC by Candace Davison along with Jerrold McCormick, a student in Environmental Resource Management, and Erin Carlin a graduate student in the College of Education. The students performed a series of experiments focusing on the fundamentals of radiation interaction and principles of radioisotope applications. Several topics were covered: Radiation Basics, Food Irradiation, Radon Gas, Radioactive Waste Disposal (high and low-level), and Reactor Operations. Students performed different experiments and/or activities to reinforce some of the concepts learned during the short-course. The radiation fundamental experiments and activities included cloud chamber;

penetrating ability of alpha, beta and gamma radiation; half-life simulation and calculation of the half-life of activated silver. To understand the effect of radiation on food two separate experiments were conducted. Several beef samples were irradiated and then cultured to determine the effectiveness of different doses of gamma radiation on beef. Black raspberries were also irradiated and a visual comparison of mold growth was made between the two different doses of irradiated fruit vs. the control group. Other activities included a computer simulation of nuclear reactor, a demonstration of real reactor operations with the TRIGA reactor, radon decay product collection (radioactive ball) and discussion of current issues. The students also learned about imaging using many types of radiation such as neutron radiography, x-ray, and gamma-ray imaging. Radiographs from the St. Mary's City Lead Coffin Project were examined, and a field trip to Radiology Associates was conducted.

Four students conducted independent study projects related to radiation and nuclear science. Two students focused on the Applications of Radioactive Materials at Penn State and The Disposal of Low-Level Radioactive Waste for their projects. The students examined uses of radioactive materials within the College of Agriculture and political decisions concerning radioactive waste disposal including Pennsylvania's decision to halt the process of siting a Low-Level Radioactive Waste Disposal facility. Their projects were "Where Does Radioactive Waste Come From and Where Is It Going?" and "Applications of Low-Level Radioactive Materials and the Disposal of their Waste". A second independent study project undertaken by two other students examined the effect of radiation on food. "Neopasteurization: The Effects of Gamma Irradiation on Food" and "The Truth about Food Irradiation: A First Hand Perspective". Faculty and students in the Food Science department including Dr. Stephen Knabel and Dr. Bob Roberts facilitated this project. Nuclear Engineering faculty and staff including the PELLRAD and ACURI program assisted with the different aspects of the projects by providing time, expertise and resource material. The Radiation Protection Office personnel were very helpful in assisting with the projects by conducting a tour of Penn State's low-level radioactive waste storage and processing facility, as well as providing information to the PGSAS Scholars.

Reactor Sharing:

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.

Eight hundred students and teachers from 24 different high schools and 4 colleges came to the RSEC for experiments and instruction (see map). Candace Davison, Jerry McCormick and Erin Carlin were the main instructors for the program. Lois Lunetta and Ai Morii assisted with several tours and experiments. Thierry Daubenspeck, Jana Lebiedzik, and other reactor staff provided instruction and technical assistance for experiments.

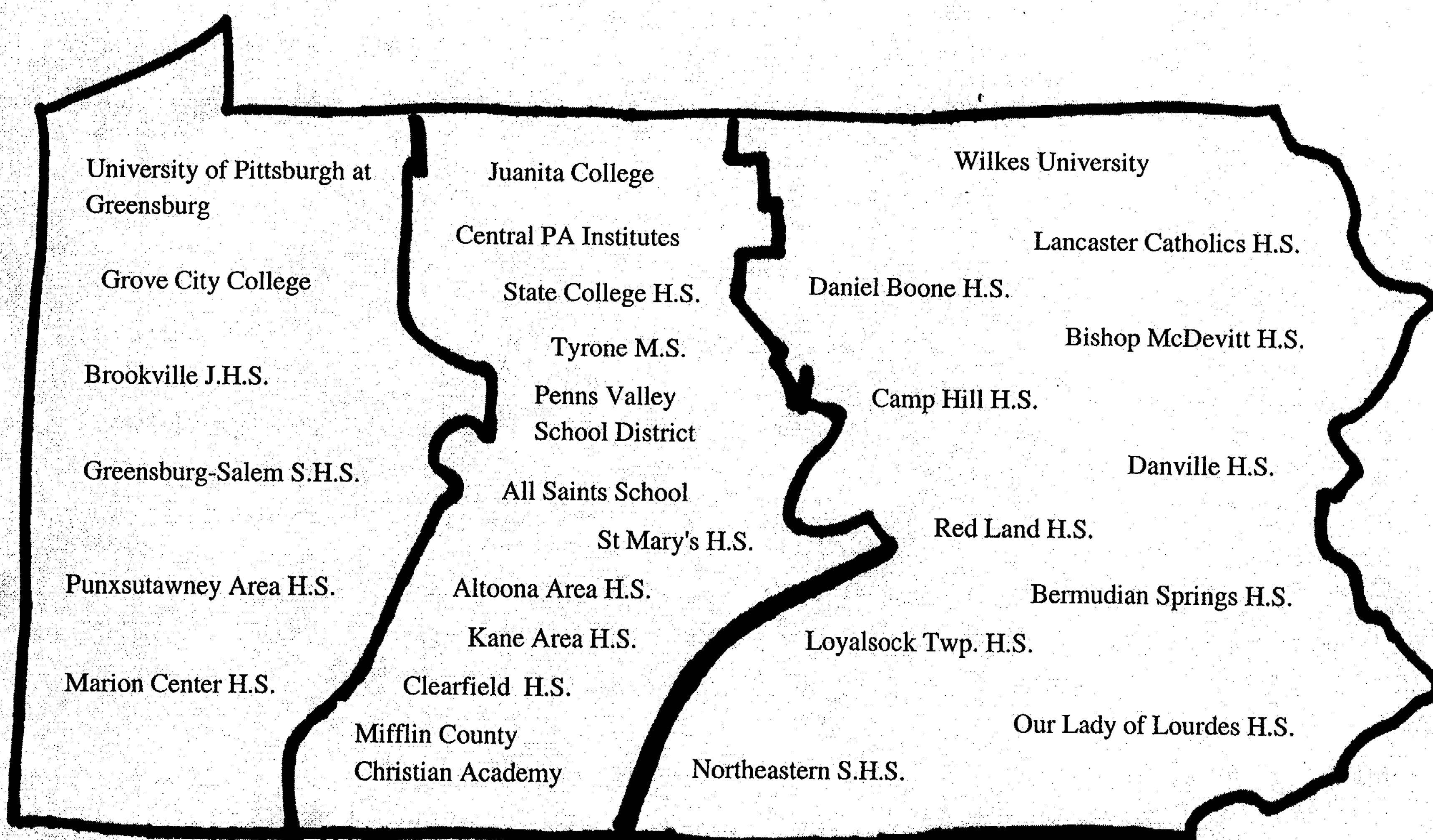
The RSEC staff utilized the facilities and equipment to provide educational opportunities and tours for student and teacher workshops, many of which were conducted as part of other programs on campus. These programs are typically conducted through the Penn State College of Engineering, the Women in Science and Engineering (WISE) Institute, the Continuing and Distance Education Program, Campus Admissions and the University Relations Offices. The student programs included: the Kodak BEST (Business, Science, Engineering and Technology) program for minority students, the High School Summer Internship, the VEC-tour (Venture in Engineering Camp) program, the VIEW (Visit in Engineering Week for students of color) program, WISE (Women in Science and Engineering) week, Upward Bound, Talent Search, Pennsylvania Junior Academy of Sciences, SOARS (Special Opportunities and Research for Space), and other programs associated with campus activities.

Candace Davison and Erin Carlin conducted a workshop that provided instruction and free Geiger Counters along with educational materials to eighteen teachers. This workshop was made possible through partial support from the American Nuclear Society. Other teacher workshops included a special on-site program as part of the Pennsylvania Alliance for Environmental Education and a pilot program for educational materials on low-level radioactive waste disposal conducted by the PELLRAD program.

Tours:

In addition to the full or half-day programs with experiments, educational tours were conducted for elementary and high school students and teachers, university classes, and the general public. All groups, including the groups detailed in the above sections, which toured the facility, are listed in Appendix B. The RSEC operating staff and Nuclear Engineering Department conducted 185 formal or group tours for 2699 persons. In addition approximately 160 informal tours were provided to 265 people.

Educational Institutions Visiting the RSEC



Over 800 students and educators from the above institutions participated in a tour of the reactor facility. Many conducted educational experiments during their visit.

Academic Instruction:

The RSEC TRIGA reactor and Cobalt-60 irradiation facilities were used by several Nuclear Engineering courses and courses in other departments of the university.

Semester	Course	Instructor	Students	Hours
Summer 1998	NucE 444-Nuclear Reactor Operations	D. E. Hughes	3	25
Fall 1998	NUCE 097D – Test Loop	L. Hochreiter	7	700
Fall 1998	STS(Science & Technology in Society) 150	Various	22	1
Fall 1998	Engineering Science 433H	Vasu Varadan	7	1
Fall 1998	NucE 451-Reactor Physics	R. M. Edwards W. A. Jester	8	25
Fall 1998	Food Science 413-Process Plant Production	R. B. Beelman	28	2
Spring 1999	NucE 444-Nuclear Reactor Operations	D. E. Hughes	2	18
Spring 1999	NucE 450-Radiation Detection and Measurement	W. A. Jester J. S. Brenizer	15	7
Spring 1999	NUCE 097B – Atomic Adventures	E. Klevans	5	20
Spring 1999	HIS 445 - Occupational Health	T. Weyandt	5	1
Spring 1999	NUCE 097D – Test Loop	L. Hochreiter	3	300
Spring 1999	NUCE 420 – Radiological Safety	R. Granlund	3	4
Spring 1999	STS(Science & Technology in Society) 150	Various	15	1

Police Training:

Training sessions were conducted in April of 1999 at the RSEC for University Police. In order to accommodate the officers and their schedules, the two-hour training session was conducted four times. A total of 31 University Police personnel participated in the training given by Candace Davison and Russ Dunkleberger from the Radiation Protection Office. The training is provided to ensure familiarity with the facilities and to meet Nuclear Regulatory Commission requirements.

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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. Well-collimated beams of neutrons, thermalized by a D_20 thermal column, are passed into the NBL for use in nondestructive testing and evaluation. A Real Time Neutron Image Intensifier, by Precise Optics, Inc. is available for real time radiography. 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. Flash radiography utilizing pulsing is also available.

A new D_20 thermal column to enhance the neutron beam for beam port #4 in the NBL was installed in April of 1997. This thermal column can take advantage of the extra degrees of freedom provided by the bridge upgrade completed in the Summer of 1994. The reactor core is coupled to the thermal column in a position tangential to the beam line thereby improving the neutron to gamma ratio. A significant increase in the neutron beam intensity has resulted. Characterization of the neutron beam continues. In early 1999, a new shield wall and shield roof were installed around beam port #4 to provide facilities for conducting neutron radioscopy, neutron radiography, and other research and service activities.

In October 1998, a collimator arrangement was installed to couple beam port #7 to the D_20 thermal column via a graphite scatterer. Three small diameter neutron beams are provided for conducting neutron transmission measurements of borated metals and other borated materials.

Projects utilizing the NBL during the year included the following:

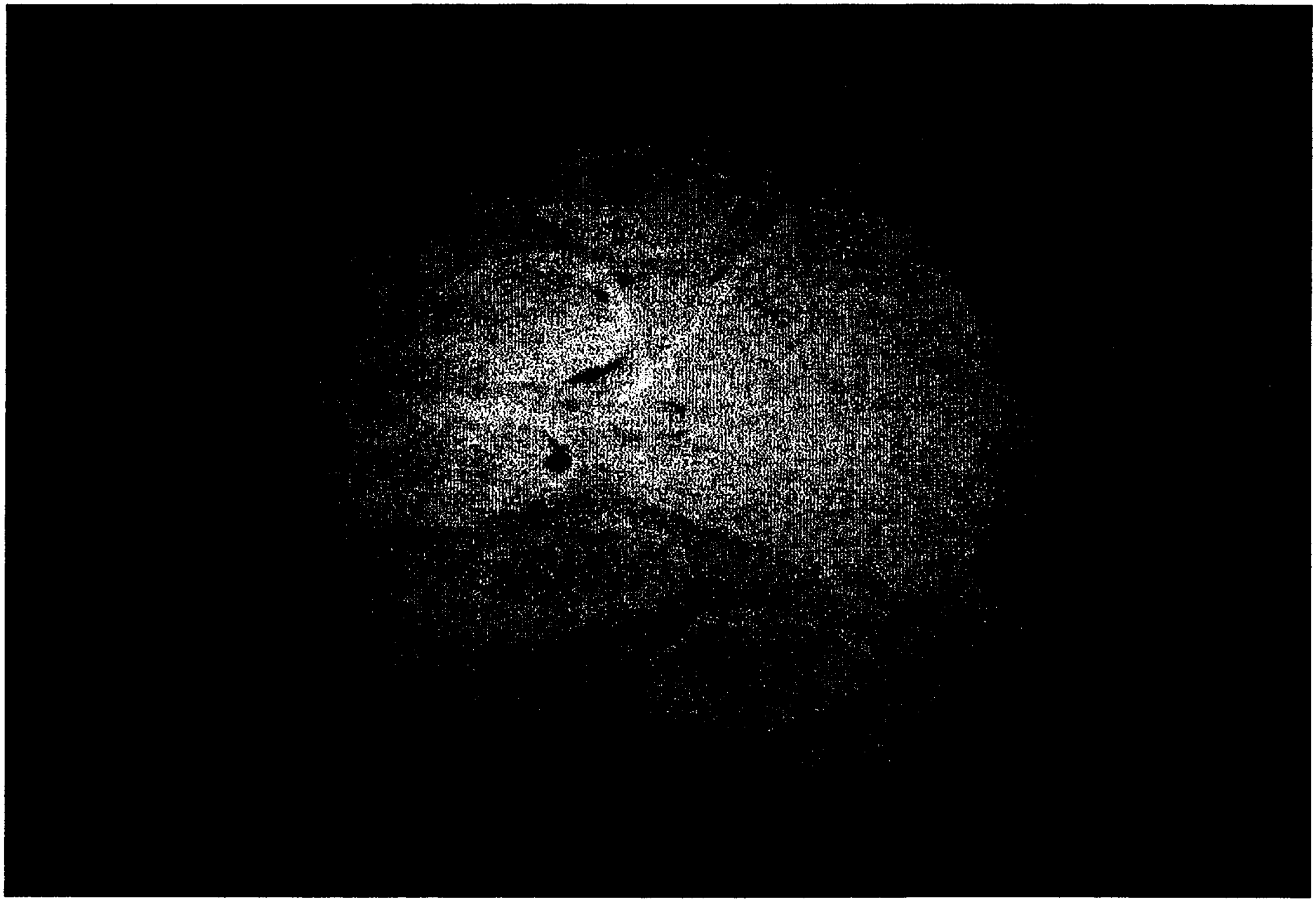
- Bettis Atomic Power Laboratory used the RSEC to evaluate two phase flow. An upgraded flow loop was built, and flow pressure measurements up to 2000 psi are ongoing. A second project during the year studied reflood in a hot channel at atmospheric pressure. Additional testing of heat pipes has also begun.

- Neutron transmission measurements and neutron radioscopy were conducted for borated metals and other borated materials for Northeast Technology Corporation, Eagle-Picher Industries, Transnuclear, NY, and Transnucleaire, France.

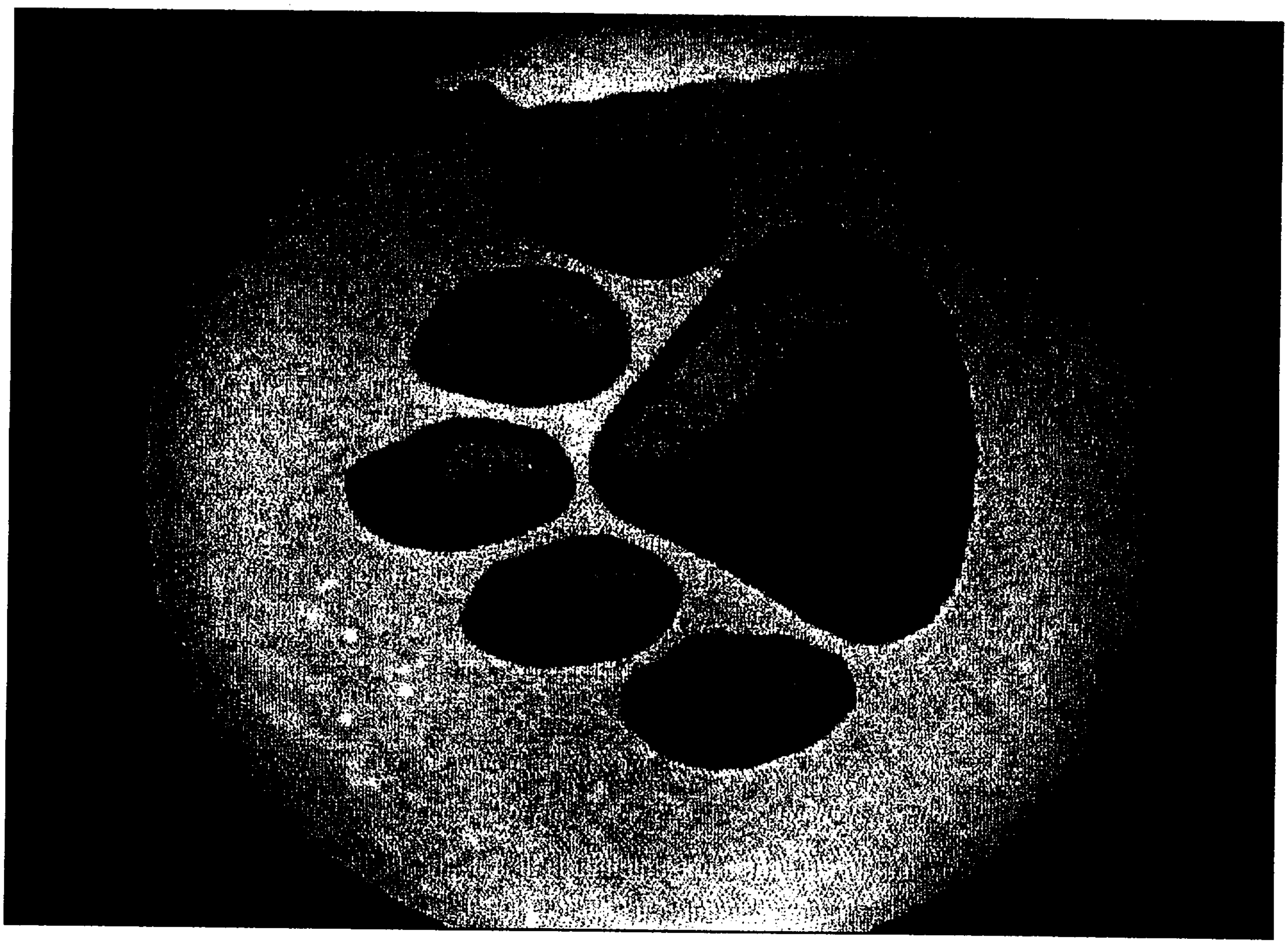
- A prototype neutron radiography camera was tested by Industrial Quality and by the Savannah River Company.

- Radiographic and radioscopic techniques were demonstrated as part of several student projects. In one such project, neutron radioscopic techniques were used by two WISER students. A deep groove outline in the shape of a Lion's Paw was milled out of a rectangular half-inch aluminum plate. Inside each outline, three areas were milled out and machined in three varying depths. A thin aluminum cover with a gasket was placed over the paw shape and the area was filled with water. The following photos represent neutron radioscopic images of the various stages of filling and draining. The first photo is of the paw being filled after a previous fill and drain. The second photo is of the paw completely filled with water. The third photo is of the paw while the water is draining. The dark areas on these photos are the areas of thinnest metal and highest attenuation, (most water). The areas where the attenuation is lowest and metal is thickest, (least water) appear lighter.

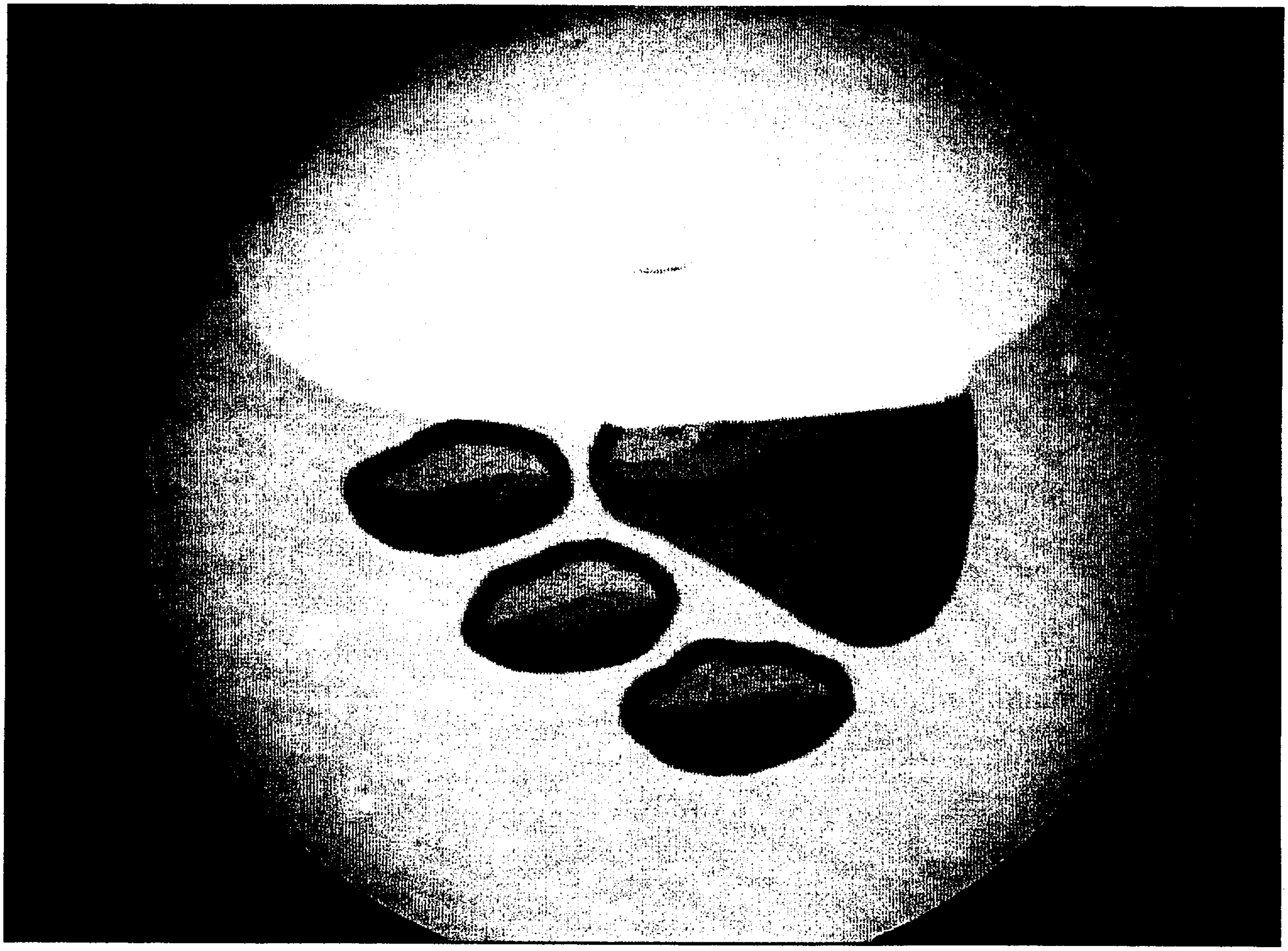
Lion Paw: Filling



Lion Paw: Filled



Lion Paw: Draining



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RADIONUCLEAR APPLICATIONS LABORATORY

VII. RADIONUCLEAR APPLICATIONS LABORATORY

The Radionuclear Applications Laboratory (RAL) provides consulting and technical assistance to University and industry personnel who wish to use radionuclear techniques in their research.

Service Capabilities:

- Gross Alpha/Beta Counting
- Gamma Spectroscopy
- Neutron Activation Analysis (NAA)
- Radioactive Tracer Techniques
- Radon in Water Analysis

Support Services to the RSEC - 1998/1999

- Weekly analysis of gross alpha/beta activity for reactor pool water, Cobalt-60 pool water, and the reactor's secondary heat exchanger
- Gamma spectroscopy on above samples quarterly, or when alpha/beta action limits are exceeded
- Monthly analysis of tritium concentration determinations in the Deuterium Oxide (D_20) tank and reactor pool water
- Above analyses performed on 6000 gallon holding tank water used for pool make-up at least one time each year
- Neutron Activation Analysis to determine the suitability of materials for reactor facility systems or experiments
- Qualitative and quantitative gamma spectroscopy on radioactive waste prior to transfer to the Office of Radiation Protection

University Activities – 1998/1999

- NAA to determine impurities in materials used in the Pipe Wall Thinning Project, (Nuclear Engineering)
- NAA to determine specific element concentrations in various obsidian and rhyolite samples in an effort to match artifacts from dated archaeological sites to sources of raw materials, (Anthropology Department)
- NAA to look at impurity activation in plastic polymers to be used in neutron track etching, (Chemistry Department)
- Analyses of thermal and fast neutron foils used to characterize the neutron spectrum of the Fast Neutron Irradiator (FNI)

- NAA demos for high school and college tours and various other groups

Industrial Activities – 1998/1999

- 398 semiconductor irradiations for Harris Semiconductor, TRW, Raytheon, and Raytheon/E-Systems (1MeV Silicon equivalent fluence)
- 11 isotope production runs for Tru-Tec
- 2 isotope production runs for NWT Corporation
- Determination of half value thickness, tenth value thickness, and gamma energy emission ratio of Yb-169 specimens for Best Medical
- Irradiated Argon and Krypton clathrate crystals and de-ionized water for sources for use by NRC Corporation to characterize a gamma detector
- NAA to determine impurities in borated aluminum specimens for Northeast Technology Corporation
- Gross alpha and gross beta counting and gamma spectroscopy of zirconia materials used in producing femoral heads in hip-joint replacement pieces. Howmedica, Inc. of New Jersey, requires these analyses of materials from its zirconia suppliers, Morgan Matroc Limited, Warwickshire, England and Norton Desmarquest, France
- Westinghouse Science and Technology Center worked with RAL personnel to irradiate electronic devices being developed as radiation detectors

THE ANGULAR CORRELATIONS LABORATORY

VIII. THE ANGULAR CORRELATIONS LABORATORY

The Angular Correlations Laboratory has been in operation for approximately 13 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 13 years, measures four coincidences concurrently using cesium fluoride detectors. A second spectrometer was acquired nine years ago, and it measures four coincidences concurrently using barium fluoride detectors. A third spectrometer was set up six years ago to accommodate the increased demand for measurement capability. The detectors and electronics provide a nominal time resolution of 1 nsec FWHM, which places the measurements at the state-of-the-art in the field of Perturbed Angular Correlation Spectroscopy.

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

The PAC technique is based on substituting a radioactive probe atom such as 111In or 181Hf 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 (efg's) 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. In solids, these interactions can provide information about defect and ionic transport. In liquids these interactions can provide information about, for example, the conformations of macromolecules such as polymers. 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 or by molecules tumbling in a solution, 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 antiferromagnetic bulk and thin-film materials, are used to study the mechanisms that cause the transition between the magnetically-ordered phase and the disordered phase.

Current laboratory research is detailed in Section A of this report.

RADIATION SCIENCE & ENGINEERING

CENTER RESEARCH

IX. RADIATION SCIENCE AND ENGINEERING CENTER RESEARCH AND SERVICE UTILIZATION

Research and service continues to be the major focus of the RSEC. A wide variety of research and service projects are currently in progress as indicated on the following pages. The University oriented 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 users by industry and other universities.

The reporting of research and service information to the editor of this report is at the option of the user, and therefore the projects in Sections A and B are only representative of the activities at the facility. The projects described involved 7 technical reports, presentations, or papers, 11 publications, 9 master's theses, and 5 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, 54 faculty and staff members, 27 graduate students and 30 undergraduate students have used the facility for research. This represents a usage by 12 departments or sections in 4 colleges of the University. In addition, 47 individuals from 24 industries, research organizations or other universities used the RSEC facilities.

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

Anthropology

PREHISTORIC METARHYOLITE USE AND MIGRATION IN THE MID-ATLANTIC

Participants: K. Hirth
G. Bondar

Services Provided: Neutron Irradiation, Radiation Counters and Laboratory Space

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

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

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

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

Throughout the past year, the methodology for this research has been confirmed through one test run consisting of standard reference materials. This methodology was then applied to one data run consisting of eighteen archaeological and geologic samples. These results were presented at the 1999 Mid-Atlantic Archaeological Congress meeting in Harrisburg, PA in the paper titled: "A Preliminary Look at the Characterization and Distribution of Eastern Metarhyolites" authored by Gregory Bondar. A series of up to fifteen additional runs of similar materials will extend this research throughout the following year.

Paper:

Bondar, G.H., "A Preliminary Look at the Characterization and Distribution of Eastern Metarhyolites". Paper presented at the 1999 meetings of the Mid-Atlantic Archaeological Congress in Harrisburg, PA 1999.

Doctoral Thesis:

Bondar, G.H., and K.G. Hirth, adviser. Tracing the Transitional: Examining Meta-Rhyolite Use Along the Atlantic Seaboard During the Archaic-Woodland Transition. In progress.

Applied Research Laboratory

BIOMONITORING OF GRANULAR ACTIVATED CARBON FROM AIR POLLUTION CONTROL SYSTEM AT MARINE CORPS MULTI-COMMODITY MAINTENANCE CENTER, BARSTOW, CA

Participants: Janice Schneider
William Burgos

Service Provided: Gamma Irradiation

Granulated activated carbon is used in an air pollution control system at the Marine Corps Multi-Commodity Maintenance Center in Barstow, CA. The Applied Research Laboratory at Penn State performed studies in order to determine if bioactivity is present and responsible for the degradation of volatile organic compounds within the granulated activated carbon bed. Gamma radiation was used to sterilize some carbon samples to be used as controls for this experimentation. Project was completed in December 1998.

Publication:

Schneider, J.M., R.E. Keay. Performance Understanding of the Barstow Air Treatment System – Testing and Analysis Summary Report. Applied Research Laboratory Technical Memorandum TM-99-033. March 1999.

Sponsor: Navy MANTECH REPTECH Program $225,000

Biology

GENETIC ANALYSIS OF THE DROSOPHILA EYE DEVELOPMENT

Participant: Z. C. Lai

Service Provided: Gamma Irradiation

Gamma radiation was used to induce mitotic recombination between homologous chromosomes. This method allows mutant cells to be generated in heterozygous animals, (fruit flies), and mutant phenotypes can be analyzed in order to address whether a gene is required for proper development of tissues such as the eye.

Publications:

Lai, Z.C., and Y. Li. Tramtrack69 is Positively and Autonomously Required for Drosophila Photoreceptor Cell Development. Genetics, 152: 299-305. 1999.

Lai, Z.C., M. Fetchko, and Y. Li. Repression of Drosophila Photoreceptor Cell Fate Through Cooperative Action of Two Transcriptional Repressors Yan and Tramtrack. Genetics, 147: 1131-1137. 1997

Sponsor:

National Science Foundation $285,000

Chemistry Department

SYNTHESIS AND CHARACTERIZATION OF POLYPHOSPHAZENES FOR TISSUE ENGINEERING APPLICATIONS

Participants: H. R. Allcock
W. R. Laredo
R. Draughn

Service Provided: Gamma Irradiation

Polyphosphazenes are currently being investigated for their use as temporary scaffolds for fibroblast cell growth. The aim is to grow cells on a polymer matrix in vitro followed by implantation of the device into an area of the body that has undergone trauma or degenerative decay. The body can then use its own mechanisms to further the growth and proliferation of the cells to form the desired tissue (cartilage, endothelial cells, smooth muscle, etc.). The polymer is designed to degrade slowly over time, leaving the regenerated tissue intact and conforming to the dimensions of the once-present polymer matrix. The polyphosphazenes synthesized and tested have a wide variety of side groups ranging from biodegradable amino acid derivatives to bioinert fluorinated components. One of the key requirements for these polymers prior to testing is sterility that can be achieved a number of ways, including gamma radiation. In addition to sterilizing the polymers, this irradiation will often lead to crosslinking, which can significantly alter the degradation characteristics. Studies are in progress to determine what levels of irradiation are sufficient for sterility and what, if any, levels of crosslinking will have a positive influence on the desired time of degradation.

Master's Thesis:

Draughn, R.L. and H.R. Allcock, adviser. Immobilization of β-Cyclodextrin On Polymer Substrates, 1998. In progress.

Doctoral Thesis:

Laredo, W.R. and H.R. Allcock, adviser. Polyphosphazenes for Biomedical Applications, 2000. In progress.

Chemistry Department

SYNTHESIS OF POLYPHOSPHAZENES FOR USE AS FUEL CELL MEMBRANES

Participants: H. R. Allcock
E. C. Kellam, III
R. V. Morford
A. M. Cannon
M. A. Hofmann

Service Provided: Gamma Irradiation

Polyphosphazenes are being examined as new candidates for fuel cell membranes. This work focuses specifically on the direct methanol fuel cell, which requires a highly specialized polymer membrane. The membrane must remain hydrated at elevated temperatures and transport protons in order for the fuel cell to function. Additionally the membrane must not allow the crossover of methanol, which drastically reduces efficiency. It is believed that methanol crossover can be reduced significantly through crosslinking; however, too much will prevent the polymer from conducting. Varying exposures to gamma irradiation are currently being examined to explore the range of properties and identify the most viable candidates.

Chemistry Department

SYNTHESIS OF POLYPHOSPHAZENES FOR USE AS GEL ELECTROLYTES

Participants: H. R. Allcock
E. C. Kellam, III
R. V. Morford

Service Provided: Gamma Irradiation

Polyphosphazenes are being examined for use as gel electrolyte materials for potential lithium battery applications. In order to achieve high and commercially viable levels of conductivity, a gel must be formed by mixing a polymer and a small molecule additive. Some of the gel systems being examined possess limited mechanical stability and are therefore inadequate for use in batteries. These systems can be crosslinked through gamma irradiation to improve their dimensional stability and make them more viable components in a battery. It is important to find a level of crosslinking that improves the mechanical stability of the gel, but does not interfere with the system's ability to conduct ions. Finding this middle ground is an important part of this research project.

Doctoral Theses:

Kellam, III, E.C. and H.R. Allcock, adviser. Ionically Conducting Polyphosphazene Membranes, 2001.

Morford, R.V. and H.R. Allcock, adviser. Ionically Conducting Polyphosphazene Membranes, 2002.

Horticulture

EVALUATION OF ARABIDOPSIS THALIANA PHOSPHATASE MUTANTS

Participants: J. Lynch
J. Tomscha
B. Knupp

Service Provided: Gamma Irradiation

Acid phosphatases are secreted by plants and soil microbes in response to phosphorus deficiency. These enzymes can liberate phosphorus from organic sources within the soil, making them available for uptake. There is debate in our field as to whether the phosphatases produced by plants are significant for plant nutrition given that the microbial pool in soils is considerable. We have plant mutants (Arabidopsis thaliana) that either cannot secrete these enzymes or secrete them all the time. We are using sterile (gamma irradiated) and non-sterile soil to evaluate the performance of these mutants, and to determine whether plant phosphatases can liberate a significant amount of phosphorus in sterile soil when compared to the microbially active non-sterile soil. This work is currently in progress. Preliminary results show a significant plant response to the sterile soil treatment.

Doctoral Thesis:

Tomscha, J.L., Lynch J.P., and Guiltinan, M.J., co-advisers. The Role of Acid Phosphatases in Arabidopsis Thaliana. 2000.

Nuclear Engineering

FLAT PANEL IMAGING OF THERMAL NEUTRONS

Participants: H. Berger
J. S. Brenizer
K. M. Gibbs
J. Haskins
T. Jones
D. Polansky
D. Schneberk

Services Provided: Neutron Radiography

An initial investigation for the use of an amorphous silicon flat panel as an imaging detector for thermal neutrons was performed. A dpiX Model SS2200 imaging panel was used with a Li-6 enriched, LiF-ZnS(Ag) scintillator screen for a thermal neutron imaging investigation using the Breazeale Nuclear Reactor and the neutron radiography facility at Penn State University's Radiation Science and Engineering Center. Good quality thermal neutron images were obtained at exposures slightly in excess of 10^6 n/cm^2, a value less than normally required for a medium-speed film result. Spatial resolution observed was in the order of 2 line pairs/mm, a value consistent with the resolution limitation of the imaging screen. The neutron images showed excellent quality, as determined with radiographs of the modified Type A gauge test piece, often used to evaluate thermal neutron radioscopic images. Observation of twelve to fourteen holes in the "A" gauge test piece was easily observed, and excellent result as compared to typical neutron radioscopic systems.

Electronic methods for x-ray image detection are exhibiting increased use, in order to take advantage of prompt response, digital processing, storage and retrieval and to minimize environmental problems in handling of film processing chemicals. Similarly, development efforts for electronic methods for detection of thermal neutron images are increasing rapidly. Reported work includes detection with scintillator screen-camera systems, photoluminescent storage phosphor screens, and other semiconductor detectors. Preliminary thermal neutron imaging work with an amorphous-silicon flat panel is reported here.

A dpiX Model SS2200 flat panel was used, with a Li-6 enriched LiF-ZnS(Ag) screen. The 7 x 9 inch screen, as used in early scintillator – CCD camera studies, covered most of the active 8 x 10 inch imaging area of the flat panel. An MTF test of the imaging screen showed a resolution of about 2.5 lp/mm. Imaging software for the flat panel was developed by the group at Lawrence Livermore National Lab, as part of their evaluation of flat panel imaging for x-rays and neutrons.

A thermal neutron radiography beam at the Breazeale Reactor at Pennsylvania State University was used for the tests. The neutron beam was directed inside a shielded enclosure, approximately 12 x 13 x 8 feet in size. The characteristics of the reactor beam include a thermal neutron flux of 1.4 x 10^7 n/cm^2-s at a reactor power of 500kW, a gold cadmium ratio of 5 and an L/D of more than 150. Objects examined included a modified, large hole version of the Type A, double wedge acrylic gauge, as has been used in neutron radioscopy investigators. Also used was a cadmium hole gauge.

Paper:

Berger, H., J.S. Brenizer, J. Haskins, K. Gibbs, T. Jones, D. Polansky, and D. Schnebeck. Flat Panel Imaging of Thermal Neutrons. ANST Fall Meeting October 15, 1999, Phoenix, Arizona.

Nuclear Engineering

RECENT IMPROVEMENTS TO THE PENNSYLVANIA STATE UNIVERSITY'S NEUTRON RADIOGRAPHY FACILITY

Participants: J. S. Brenizer
D. E. Hughes
C. F. Sears
M. E. Bryan
T. L. Flinchbaugh

Services Provided: Neutron Radiography, Machine Shop

As a result of a need for increased neutron beam intensity for a sponsored two-phase flow research project, the D_2O thermal column and neutron radiography beam port were replaced with a new integral D_2O tank and beam port system in 1997. The new system was integrated with modifications to the reactor bridge and superstructure work completed in 1994. The bridge modifications permit movement of the reactor core in the lateral (east-west) directions and in the rotational direction. These added degrees of motion, coupled with the new D_2O thermal column, allowed the neutron radiography beam to be oriented tangential to the core thus reducing the gamma component of the beam. Currently, a 12.7-cm aperture is located adjacent to a bismuth gamma photon filter at the juncture of the port and the D_2O thermal column. At a power of 500 kW, the neutron flux is 1.4×10^7 with an L/D ratio of 155, the n/γ ratio is 3×10^6 n/cm2/mR, and the cadmium ratio measured with gold foils is 5. Efforts are underway to improve collimator design to increase the L/D ratio without significantly degrading the n/γ ratio. The higher flux levels produced with the new beam required complete replacement of the shielding to allow personal access in the neutron beam laboratory during neutron imaging and measurement experiments. The shield design permits flexibility with respect to the shielding configuration to accommodate present and future experiments. Characterization of the neutron beam and collimator design is ongoing.

Paper:

Brenizer, J.S, D.E. Hughes, M.E. Bryan, R. Gould, T.L. Flinchbaugh, and C.F. Sears. Recent Improvements to the Pennsylvania State University's Neutron Radiography Facility. Sixth World Conference on Neutron Radiography, Osaka, Japan. May 17-21, 1999.

Nuclear Engineering

EVALUATING TWO PHASE FLOW USING NEUTRON RADIOGRAPHY

Participants: M. E. Bryan
D. E. Hughes
J. H. Murphy
M. A. El-Ganayni

Services Provided: Neutron Radiography, Machine Shop and Electronics Shop

This project is using neutron radiography to observe 2-phase fluid flow experiments. An upgraded flow loop was built, and flow measurements at pressures up to 2000 psi are ongoing. A second project studied reflood in a hot channel at atmospheric pressure using the techniques developed for this work. Several other heat pipe test sections are also being studied.

Sponsor: Bettis Atomic Power Laboratory $70,436

Nuclear Engineering

STRESS CORROSION CRACKING IN NICKEL-BASED STAINLESS STEELS

Participants: M. E. Bryan
B. J. Heidrich
F. J. Loss
R. E. Taylor

Service Provided: Hot Cell Laboratory

This project is using Hot Cell #2 to house 3 autoclaves in which irradiated stainless steel fracture specimens are loaded to observe stress corrosion cracking in a PWR environment over a two year period. A Scanning Electron Microscope and a Fein-Focus X-ray inspection system have been installed and are being used to examine specimens. Expected completion date is September 30, 1999.

Sponsor: Materials Engineering Associates $122,226

Nuclear Engineering

STRESS CORROSION CRACKING OF ALLOY 750 AND 625

Participants: M. E. Bryan
R. Daum
A. T. Motta

Services Provided: Laboratory Space, Machine Shop, Hot Cell Lab, and Neutron Radiography

Stress corrosion cracking of reactor internals is a major threat to the continued safe operation of nuclear power plants beyond their design lives. Stress corrosion cracking requires the combined effects of stress, corroding environment and susceptible microstructure. In collaboration with the Materials Science Department at Penn State, an investigation was conducted of the stress corrosion mechanisms of Inconel X-750, under reactor conditions. Inconel X-750 is used in special reactor applications requiring great strength and hardness, such as springs and jet pump nozzles.

This research, investigated the role of Hydrogen in the cracking process by conducting both slow strain rate tests (SSRT) and compact tension type experiments. Other alloys investigated included alloys 718, 625 and 690. The cracking process was conducted in autoclaves where the electrochemical potential (ECP), temperature, and conductivity was monitored on-line, and where the Hydrogen content of the water was a parameter. Post corrosion examinations included an examination of fracture surface, hydrogen profiling with both Neutron Radiography and a LECO system.

Master's Thesis:

Daum, R., A.T. Motta, adviser. Hydrogen-Assisted Failure of Alloys X-750 and 625 Under Slow Strain Rate Conditions. December 1998.

Publication:

Daum, R., A.T. Motta, D.A. Koss, and D.D. Macdonald. Hydrogen-Assisted Failure of Alloys X-750 and 625 Under Slow Strain Rate Conditions. To be published in the Proceedings of the Ninth NACE International Symposium on Environmental Degradation of Materials in Nuclear Power Plants. Newport Beach. August 1999.

Nuclear Engineering

POINT DEFECTS IN Zr-Fe INTERMETALLIC COMPOUNDS STUDIED USING PERTURBED-ANGULAR-CORRELATION SPECTROSCOPY

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

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

We have measured the temperature dependencies of the electric and magnetic hyperfine interactions at ^{181}Ta nuclei substituted into the Zr site in the Laves-phase compound Fe_2Zr, using the perturbed angular correlation of γ-rays emitted after the β^-decays of ^{181}Hf probe nuclei. Although the overall crystal structure is cubic, a weak strongly damped electric-quadrupole interaction is observed, which shows no significant temperature dependence over the investigated temperature range from 290 K to 1300 K. Thus, below the magnetic ordering temperature T_C of 631(2) K, we observe combined magnetic-dipole and electric-quadrupole hyperfine interactions. Two separate magnetic components characterize the magnetic-dipole interactions. For the interaction at the primary site, which is occupied by 70-80% of the probes, the Larmor frequency measured at laboratory temperature has a value of $\omega_L = 407(1)$ MRad sec^{-1}. The secondary site is populated by the remaining 20-30% of the probes, for which the corresponding Larmor frequency has a 290K value of $\omega_L(0) = 579(3)$ MRad sec^{-1}. We attribute the primary interaction to the "perfect-crystal" probe environment at the Zr site, whereas we ascribe the secondary interaction to the enhancement of the transferred hyperfine field by the presence of Fe anti-site defects near the Zr site. At temperatures below but very close to T_C, those frequencies cannot be determined for either interaction, because the magnetic-hyperfine and the electric-quadrupole frequencies converge to comparable values and electron-spin disordering produces increased line broadening. We have now been investigating the compounds Zr_3Fe and $Zr(Fe,V)_2$.

Publications:

Motta, A.T., S.E. Cumblidge, G.L. Catchen, R.L. Rasera, A. Paesano, Jr., and L. Amaral. "Defects and Magnetic Hyperfine Fields in $ZrFe_2$ Studied Using Perturbed Angular Correlation Spectroscopy," Physical Review B, 60(2) 1999, 1188-1196.

Motta, A.T., S.E. Cumblidge, G.L. Catchen, L. Amaral, A. Paesano, Jr., "Investigating Crystal and Magnetic Hyperfine Fields in Zr_3Fe and $ZrFe_2$ using PAC Spectroscopy," XXI International Meeting on Condensed Matter Physics, Caxambu, Brazil, 1998.

Cumblidge, S.E., A.T. Motta, G.L. Catchen, L. Amaral, A. Paesano, Jr., R.L. Rasera, "Temperature Dependence of Magnetic Hyperfine Fields at ^{181}Ta in $ZrFe_2$," 11th International Conference on Hyperfine Interactions, Durban South Africa, 1998.

Cumblidge, S.E., G.L. Catchen, A.T. Motta, S.B. Legoas, L. Amaral, "Investigating Hyperfine Fields in Zr3Fe Using Perturbed Angular Correlation Spectroscopy," to be submitted to Physical Rev. B, 1999.

Sponsor: National Science Foundation Grant number INT-9503934, and support from the Brazilian National Research Council (CNPq).

Nuclear Engineering

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

Participant: T. H. Daubenspeck

Services Provided: Neutron Irradiation, Neutron Activation Analyses, Radiation Counters, Flux Monitoring, and Shielding Design

Eleven (11) radioisotope production runs were performed during the past year. A total of 3.55 curies of Bromine-82 (nine runs) and 1.3 curies of Sodium-24 (2 runs) were produced. (Tru-Tec: Flenniken, Kolek)

Two radioisotope production runs were performed producing a total of 1 curie of Sodium-24 to determine a chemical suitable for use in future work as well as verifying the design of the shipping cask shielding. (NWT: Jerry Palino)

A total of 398 semiconductor irradiations were performed during the past year.

(Harris Semiconductor-349, TRW Inc.-28, Raytheon Company-18, and Raytheon/E-Systems–3.)

Irradiation and analyses of obsidian and rhyolite samples. (Greg Bondar: Anthropology)

Neutron track etching feasibility study of plastic polymer. (RSEC: Dr. Brenizer, Candace Davison & Chemistry: Dr. Harry Allcock, Clay Kellam)

NAA demos for high school/college/miscellaneous tours. (RSEC: Davison)

NAA to determine impurities in materials used in the Pipe Wall Thinning Project. (Dr. Kenney, Dr. Klevans)

Determination of half value thickness, 1/10th value thickness, and gamma energy emission ratio of Yb-169 specimen. (Best Medical – Dr. Manny Subramanian)

Flux characterization work of Fast Neutron Irradiator (FNI) using thermal and fast neutron monitoring foils. (MN&E: Dr. Bojan Petrovic, Attya Abou-Zaid)

Irradiation of argon and krypton clathrate crystals and de-ionized water for sources to characterize gamma detector. (RSEC: Dr. Jester & NRC Corp: Dr. Jack Miller)

Determination of impurities in borated aluminum specimen. (NETCO: Dr. Ken Lindquist)

Gross alpha and gross beta counting and gamma spectroscopy of zirconia materials used in producing femoral heads in hip-joint replacement pieces. (Howmedica, Morgan Matroc Limited, Norton Desmarquest)

Nuclear Engineering

NEUTRON AND GAMMA RAY DOSIMETRY IN SPENT-FUEL RADIATION ENVIRONMENTS USING SILICON CARBIDE SEMICONDUCTOR RADIATION CONDUCTORS

Participants: A. R. Dulloo
F. H. Ruddy
J. G. Seidel
T. L. Flinchbaugh
C. C. Davison
T. H. Daubenspeck

Services Provided: Neutron Irradiation, Gamma Irradiation, Laboratory Space, Flux Monitoring, Machine Shop

Silicon Carbide semiconductor radiation detectors are resistant to radiation-induced damage and can be operated at elevated and changing temperatures. Silicon carbide radiation detectors have been shown to have linear responses to both neutrons and gamma rays. Furthermore, these responses are separable on the basis of pulse height making simultaneous monitoring of both neutrons and gamma rays possible. The neutron and gamma ray sensitivities of silicon carbide radiation detectors are well matched to the radiation environments characteristic of spent nuclear fuel. Measurements have been carried out in mixed gamma/ neutron fields in a hot cell and at the Penn State reactor facility under conditions chosen to approximate the radiation fields typically encountered in the vicinity of spent nuclear fuel assemblies.

Paper:

Dulloo, A.R., F.H. Ruddy, J.G. Seidel, T.L. Flinchbaugh, C.C. Davison, and T.H. Daubenspeck. Neutron and Gamma Ray Dosimetry in Spent-Fuel Radiation Detectors. Tenth International Symposium on Reactor Dosimetry. Osaka, Japan. September 12-17, 1999.

Nuclear Engineering

NE 451, UNDERGRADUATE LABORATORY OF REACTOR EXPERIMENTS

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

Services Provided: Laboratory Space, Machine Shop, Electronics Shop, SUN SPARC Server Computer System, Neutron Irradiation Using Subcritical Pile, Reactor Instrumentation and Support Staff

The Nuclear Engineering 451 course is the second of two 3-credit laboratory courses required of all Penn State Nuclear Engineering undergraduates. 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 1997, the TRIGA track included:

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

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

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

Nuclear Engineering

CHEMICAL CLEANING EFFECTS ON PERFORMANCE OF STEAM GENERATOR TUBES

Participants: L. E. Hochreiter
A. Sridharan

Services Provided: Laboratory Space and Machine Shop

Tubes used in steam generators of PWRs in nuclear power plants are subject to fouling after prolonged use during their life. These are chemically cleaned after stipulated hours of use and reused in the steam generators. Usually fouling on a heat exchanger surface is associated with performance degradation. However, it was observed that the performance of steam generators deteriorated when the cleaned tubes were used. This apparently has to do with the surface characteristics of the tube when it is new, chemically cleaned and fouled. Surface characteristics are significantly different in each of the three cases.

The present experiment studies boiling on the surface of all the three tubes – new, chemically cleaned and fouled. Refrigerant 123 is used as the working fluid. Boiling curves are plotted for each of the three tubes and compared. It is expected that the fouled tube has the best boiling performance followed by the chemically cleaned tube and the new tube.

Master's Thesis:

Sridharan, A.A, and L.E. Hochreiter, adviser. Chemical Cleaning Effects on the Performance of Steam Generator Tubes. In Progress.

Poster Session:

Poster presented at the Graduate Student Expo. The Pennsylvania State University. March 1999.

Nuclear Engineering

THE PENNSYLVANIA STATE UNIVERSITY LOW PRESSURE INTEGRAL SYSTEMS TEST FACILITY

Participants: L. E. Hochreiter
V. J. Bilovsky
A. J. Baratta
M. E. Bryan
C. C. Davison
R. L. Eaken
G. Morrison
K. E. Rudy

Service Provided: Reactor Time, Instrumentation and Support Staff

The PENN STATE Test Loop is an experimental thermal-hydraulic testing facility that began design in the fall of 1995. Three design iterations based on General Electric's SBWR (Simplified Boiling Water Reactor) were developed and construction began in the spring of 1997. Construction was completed and operation began in the summer of 1998. Over the past year the facility has been the central focus of two classes, NucE 497D and the freshman seminar NucE 097D.

Students were responsible for all aspects of the facility including development of procedures, calibration and testing of the instrumentation, interfacing the data acquisition, and operation. These tasks not only strengthened the students' technical knowledge base by providing hands on experience, but also helped in building teamwork, writing, and presentation skills.

There are over 1000 pages of documentation ranging from design reports to procedures. Several experiments were run this past year and subsequent lab reports have been written. The students are encouraged to submit work done in the class for publication. An article was published in a January 1999 GE engineering journal. A presentation was given at the March 1999 ANS Student Conference in Troy, NY. In addition an article about the facility was featured in the Spring 1999, edition of Penn State Engineering Magazine.

Two principal investigators, Dr. Anthony J. Baratta and Dr. Lawrence E. Hochreiter directed the project. Dr. Graham Morrison, a visiting professor from The University of New South Wales, Australia joined the effort for the Fall 1998 semester. Vince Bilovsky was the graduate student director until March 1999 when the position was turned over to two undergraduate students, Ryan Plum and Joe Sullivan.

The RSEC staff has also been actively involved. Candace Davison is the liaison between the RSEC and the test loop project, Mac Bryan is the electrical safety officer, Ron Eaken is the machine shop supervisor and trainer, and Ken Rudy is the general safety officer.

Presentation:

Bilovsky, V. Construction and Initial Operation of the Thermal Hydraulic Test Loop Faility. ANS Student Conference, Troy, New York. March 1999.

Publication:

Bilovsky, V. and G. Morrison. Penn State Low Pressure Thermal Hydraulic Test Loop Facility. GE Engineering Journal. 1999

Nuclear Engineering

FUEL MANAGEMENT STUDY OF PSU TRIGA REACTOR CORE

Participants: D. E. Hughes
S. H. Levine
G. M. Morlang
W. F. Witzig

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

During the recent operating history of Penn State's TRIGA reactor, the fuel temperature, at full power of one Megawatt as indicated by the in-core thermocouple, had risen close to the scram point of 600°C. Review of the Safety Analysis Report (SAR) also revealed that the maximum temperature analyzed for a source term release was 466°C. To reduce the indicated fuel element temperature the maximum power was de-rated to 75% (750 kW).

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

To allow a new core design, the Technical Specifications were altered to allow placing the 12 wt% instrumented element in a core position other than the B-ring. Additionally, the SAR and technical specifications have been revised to increase the number of permitted operating hours in a week.

The new core loading was accomplished in October 1998. Experimental measurements confirmed computer predictions. The new 12 wt% fuel elements used in the C-ring have exhibited a decrease in their steady-state peak fuel temperature following pulse operation of the core. Further pulses will be accomplished until the peak fuel temperature has stabilized.

Nuclear Engineering

NUCE 450, RADIATION DETECTION AND MEASUREMENT

Participants: W. A. Jester
J. S. Brenizer

Services Provided: Neutron Irradiation, Reactor Instrumentation, 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 radiation instruments studied in this course include GM detectors, gas flow proportional counters, NaI (Tl) detectors, BF3 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 computers with nuclear instrumentation.

Nuclear Engineering

COMPTON SCATTER GAUGE

Participants: E. H. Klevans
E. S. Kenney
K. Burkert
R. Baxter
W. He
S. Li
S. Kahn
V. E. Whisker
B. L. Wilks
M. E. Bryan
D. E. Hughes
R. L. Eaken
J. Armstrong
M. P. Grieb

Services Provided: Hot Cell Lab, Laboratory Space, Machine Shop and Electronics Shop

Measurement of pipe walls for erosion is accomplished without removing insulation by use of a gamma ray backscatter thickness gauge. The device can measure wall thickness in empty pipes or in fluid-filled pipes up to 0.5 inches thick. The isotope Hg-203 provides the gamma source, which is produced by irradiating approximately one gram of HgO at the Missouri University Research Reactor. These sources are removed in the hot cell at Penn State from the irradiation assembly and transferred to the shield used in the device. Performance problems developed during the past year related one unit having a cracked crystal and a second unit having an unstable photomultiplier tube. A new detector unit has been purchased and is showing stable performance. Detailed studies of statistical and system uncertainties in the measurements are in progress. New collimators that are much shorter have been built and tested. Accurate measurements in high radiation fields (3-5 mr/hr) remain a problem that will be tested with the new unit. Field tests were conducted at the Dresden Nuclear Station in February 1999. Measurements of wall thickness were performed on two feedwater heaters, one in a contaminated area. Further measurements are planned for October 1999.

Master's Theses:

Baxter, R.L., E.H. Klevans and E.S. Kenney, co-advisers. Design and Testing of the Compton Scatter Gauge. 1998.

Burkert, K.A., E.H. Klevans and E.S. Kenney, co-advisers. Source Development and System Field-Testing for the Compton Scatter Gauge. 1999.

He, W., E.H. Klevans and E.S. Kenney, co-advisers. Measurement of Wall Thickness with Varying Radiation Background. In progress.

Kahn, S., E.H. Klevans and E.S. Kenney, co-advisers. Non-Destructive Pipe Wall erosion Detection System Using Compton Backscatter. 1999.

Li, S., E.H. Klevans and E.S. Kenney, co-advisers. Studies of Uncertainties in Thickness Measurements with a Compton Scatter Gauge. In progress.

Whisker, V., E.H. Klevans and E.S. Kenney, co-advisers. Modeling Studies for Collimator and for Source Design. In progress.

Publication:

Klevans, E.H., E.S. Kenney, R.L. Baxter, K.A. Burkert, B. Petrovic, B. Wilks, W.J. Groszko. An Erosion-Corrosion Monitor Using Gamma Ray Backscatter. Proceedings of the EPRI Fifth Piping and Bolting Conference. June 25, 1999.

Sponsors:	Commonwealth Edison Company	$500,000
	Exxon Research Corporation	$19,000

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 is used as the basis for a computer model of Boraflex in the spent fuel pool environment. The data on solubility inhibitors serves as the basis for a demonstration program at a BWR spent fuel pool. Zinc acetate was added to the spent fuel pool water at Oyster Creek to reduce the dissolution rates and extend the useful service life of Boraflex. A demonstration at a PWR spent fuel pool is scheduled in the future.

Sponsor: Electric Power Research Institute

Nuclear Engineering

POST IRRADIATION INSPECTION AND TESTING OF NEUTRON ABSORBER MATERIALS

Participants: D. Kline
D. Vonada
K. Lindquist

Services Provided: Neutron Irradiation, Laboratory Space, and Machine Shop

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 modulus and neutron attenuation characteristics. The latter measurements are performed in the Neutron Beam Laboratory.

Sponsor: Various Electric Utilities

Nuclear Engineering

MEASURING PRESSURE VESSEL EMBRITTLEMENT USING POSITRON ANNIHILATION SPECTROSCOPY

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

Service Provided: Laboratory Space

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

We established a collaboration with Dr. Gerhard Brauer of the Rossendorf Research Center in Germany to conduct additional measurements of Fe model alloy from Germany, and to set up a new Doppler Broadening Spectroscopy system. In addition, we have set up a hardness indenter to study the mechanical properties of our samples.

Paper:

Cumblidge, S.E., A.T. Motta and G.L. Catchen, advisers. Examination of Irradiated Pressure Vessel Steel Using Positron Annihilation Lifetime Spectroscopy. Fall meeting of the Materials Research Society, Boston, Massachusetts. November 1998.

Sponsor: FERMI $25,000

Plant Pathology

FUSARIUM RESEARCH

Participants: J. Juba

Service Provided: Gamma Irradiation

Carnation leaves and birch leaves are irradiated in the Cobalt-60 facility in order to provide a sterile growing medium for Fusarium species at the Fusarium Research Center.

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

University or Industry	Type of Use
Best Industries, Inc.	Gamma Spectroscopy
Bettis Labs, Westinghouse	Neutron Radiography
Eagle-Picher	Neutron Radiography Neutron Radioscopy Neutron Transmission
Harris Semiconductor	Semiconductor Irradiation
Industrial Quality	Neutron Radiography Camera Development
Materials Engineering Associates	Hot Cells
McCrone Associates	Neutron Irradiation
Muscle Shoals	Radiological Analyses
Northeast Technology Corporation	Neutron Transmission
Nuclear Research Corporation	Isotope Production
NWT Corporation	Isotope Production Shielding Study
Oglevee Ltd.	Gamma Irradiation
Pennsylvania Power & Light	Gamma Irradiation
Philadelphia Electric Company	Isotope Production Shielding Study
Raytheon	Semiconductor Irradiation
Raytheon Systems Company	Semiconductor Irradiation
Transnucleaire, France	Neutron Radiography Neutron Radioscopy Neutron Transmission
Transnuclear, New York	Neutron Radiography Neutron Radioscopy Neutron Transmission
Tru-Tec	Isotopes for Tracer Studies
TRW	Semiconductor Irradiation
University of Maryland	Perturbed Angular Correlation
Westinghouse, Savannah River Company	Neutron Radiography Camera Development
Westinghouse STC	Neutron Irradiation

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APPENDIX A

APPENDIX A

Personnel Utilizing the Facilities of the Penn State RSEC.
Faculty (F), Staff (S), Graduate Student (G), Undergraduate (U),
Visiting Professor (VP), Visiting Scholar (VS), Faculty Emeritus (FE)

COLLEGE OF AGRICULTURE	
Agronomy:	
Bollag, Jean-Marc	F
Dail, Bryan	F
Ilaria, Braschi	G
Majchner, Emily	G
Horticulture:	
Knupp, Barbara	U
Lynch, Jonathan	F
Tomscha, Jennifer	G
Plant Pathology:	
Juba, Jean	S
Veterinary Science:	
Panek, Leigh	S
Wojchowski, Don	F

OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY	
Bertocchi, Dave	S
Boeldt, Eric	S
Dunkelberger, Russ	S
Hollenbach, Don	S
Jarwan, Ayman	S
Linsley, Mark	S
Morlang, Suzanne	S

COLLEGE OF SCIENCE	
Biology:	
Graham, Thomas	F
Lai, Zhi-Chun	F
Li, Yang	G
Williams, Janice	G
Chemistry:	
Allcock, Harry	F
Cannon, A	G
Draughn, Robin	G
Hofmann, M	G
Kellam, Clay	G
Laredo, Walter	G
Maher, Andrew	G
Morford, R	G
Manufacturing Science:	
Burgos, William	F
Schneider, Janice	S

COLLEGE OF LIBERAL ARTS	
Anthropology:	
Bondar, Gregory	G
Hirth, Kenneth	F

COLLEGE OF ENGINEERING	
Nuclear Engineering:	
Abou-Zaid, A	VS
Ambrocik, Jaclyn	U
Armstrong, Jeff	S
Baratta, Anthony	F
Baxter, Robert	G
Bell, Matthew	U
Bilovsky, Vincent	G
Bravo, Donald	U
Brenizer, Jack	F
Brown, Jason	U
Brunner, Adam	U
Bryan, Mac	S
Burkert, Kevin	G
Buschman, Francis	U
Carlin, Erin	U
Catchen, Gary	F
Cawley, Scott	U
Cumblidge, Stephen	G
Daubenspeck, Thierry	S
Daum, Robert	G
Davison, Candace	S
Eaken, Ronald	S
Edwards, Robert	F
Flinchbaugh, Terry	S
Granlund, Rodger	S
Grieb, Mark	S
Haghighat, Alireza	F
Hahn, Diana	U
Hanna, Shane	U
He, W	G
Heidrich, Brenden	G
Helton, Alison	S
Heverly, Matthew	U
Hochreiter, Larry	F
Hoffacker, Richard	U
Hooper, Matthew	U
Hughes, Daniel	F
Jester, William	F
Kahn, S	G
Kenney, Edward	FE
Klevans, Edward	FE
Kohlepp, Kaydee	U

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COLLEGE OF ENGINEERING Nuclear Engineering(cont.):	
Kwon, Junhyun	G
Lebiedzik, Jana	S
Levine, Samuel	FE
Li, S	G
Lobdell, Simon	U
Machemer, Shawn	U
Morlang, Michael	S
Morrison, Graham	VP
Motta, Arthur	F
Nixon, Wayne	U
Petersen, Jobie	U
Petko, Joshua	U
Petrovic, Bojan	F
Phillips, Matthew	U
Plum, Ryan	U
Rankin, Paul	S
Rasera, R	VP
Rieder, Michael	U
Rudy, Kenneth	S
Sanches, Adrianna	U
Sears, C. Frederick	F
Sridharan, Arunkumar	G
Stump, Gary	U
Sullivan, Joseph	U
Szathmary, Scott	U
Toner, Matthew	U
Tyler, Mark	U
Welling, Ronald	S
Whisker, Vaughn	G
Wilks, Ben	G
Williams, Monica	G
Witzig, Warren	FE
Zeisloft, Eric	U

MATERIALS RESEARCH LABORATORY	
Dougherty, Joseph	F

APPLIED RESEARCH LABORATORY	
Campbell, Harry	S
Schneider, Janice	F

MISCELLANEOUS

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

APPENDIX A

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INDUSTRIES, ETC.	
Best Industries, Inc.	Manny Subramanian
Bettis Labs, Westinghouse	M. A. El-Ganayni Stan Glickstein Jack Murphy
Eagle-Picher	Monte Hart Marvin Wachs
Harris Semiconductor, Mountaintop, PA	Frank Kalkbrenner Joe Macieunas
Harris Semiconductor, Findlay, OH	Frank Lau
Industrial Quality	Harry Berger Thomas Jones Daniel Polansky
Materials Engineering Associates	Frank Loss Bob Taylor
McCrone Associates	Mary Simpson
Muscle Shoals	Samuel Acres
Northeast Technology Corporation	Matt Harris Don Kline Ken Lindquist Doug Vonada
Nuclear Measurements Corporation	Donald DeMoss Marlin Hildebrande
NRC Corporation	Sudhakar Pandey
NWT Corporation	G. F. Palino
Oglevee, Ltd.	Vincent Grossi
Pennsylvania Power & Light	Mike Yatsko
Philadelphia Electric Company	Earl Abbott Mark Brisan
Raytheon	Guido Enriquez Chris Mikulski
Raytheon Systems Company	Craig Uber

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Transnuclear, New York	William Bracy Glenn Guerra Bill Sutherland
Transnucleaire, France	Gilles Bonnet Rene Chiocca Franck Martin Philippe Naigeon
Tru-Tec	Eric Growney Jerome Kolek Mike Flenniken
TRW	Russ Graham Don Randall
University of Maryland	Robert Rasera
Westinghouse Savannah River Company	Kenneth Gibbs Mark Goodell Dan Schnebeck
Westinghouse STC	Abdul Dulloo Frank Ruddy John Seidel

APPENDIX B

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
VEC Tour	07/28/98	23
Agronomy	07/28/98	2
PGSAS	07/28/98	17
PGSAS	07/29/98	15
Parents / Jr. & Sr. H.S. students	07/31/98	12
Baratta - Test Loop	08/04/98	3
Wayne Nixon – Interview	08/06/98	1
View	08/06/98	22
ARL	08/07/98	2
Rechel & Donley Family	08/11/98	5
Bryan Family	08/12/98	3
Angel Family	08/13/98	2
MEA Finnish Tour Group	08/13/98	3
NEWS 8 WGAL	08/13/98	2
Kurt Donley	08/14/98	1
Catherine Mitchko	08/14/98	1
Catherine Mitchko & Carol-Lynn Stevens	08/16/98	2
Dean's Office Tour	08/17/98	3
Telecommunications	08/18/98	1
Barbara Shaw	08/24/98	1
Eagle-Picher	08/24/98	2
Eagle-Picher	08/25/98	2
NucE Recruiting Tour	08/25/98	14
NucE Recruiting Tour	08/25/98	19
EN Dunlap	09/01/98	1
OPP – Sprinkler System	09/03/98	3
Food Science Class	09/10/98	28
OPP	09/10/98	4
Open House	09/11/98	1
Open House	09/11/98	6
Telecommunications	09/16/98	1
Ed Breazeale	09/21/98	1
Centre Daily Times	09/21/99	2

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
OPP	07/01/98	1
Drake Family - OPP	07/01/98	6
Matthew Carter	07/01/98	1
PGSAS	07/02/98	17
PGSAS	07/02/98	17
PGSAS	07/02/98	17
PGSAS	07/02/98	17
VEC Tour	07/07/98	14
ANI	07/07/98	2
Asbel Family	07/09/98	2
High School Interns	07/10/98	11
Big Winner	07/10/98	1
PGSAS Parents	07/12/98	25
PGSAS Parents	07/12/98	13
VEC Tour	07/14/98	13
OPP	07/16/98	3
View	07/16/98	17
Food Science	07/16/98	1
PGSAS	07/20/98	16
PREF	07/21/98	18
PGSAS	07/21/98	17
BEST	07/22/98	24
View	07/23/98	16
WISE (group B)	07/23/98	22
PGSAS Elective	07/23/98	17
WISE (group A)	07/23/98	20
PGSAS	07/24/98	17
Parents / Jr. &Sr. H.S. Students	07/24/98	10
Carlin Family	07/25/98	3
Heidrich Family	07/25/98	3
PGSAS	07/27/98	17
Parents / Jr. & Sr. H.S. Students	07/27/98	16
PSU Student Tour	07/28/99	1

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
Parents' weekend	09/26/98	508
Eastern Meat Packers Assn.	09/28/98	15
EngSci 433H Class	09/30/98	7
Marc Goldberg	10/01/98	1
Catchen Tour	10/01/98	1
Hochreiter Tour	10/01/98	1
Bishop McDevitt H.S.	10/02/98	14
Radiation Education Workshop	10/05/98	7
PSU EHS	10/05/98	1
Hochreiter Tour	10/08/98	1
ANS - Boy Scout Workshop	10/10/98	7
Hochreiter Tour	10/10/98	1
German Visitors (Lunetta)	10/12/98	35
Italian Group (Baratta)	10/12/98	26
Italian Group (Baratta)	10/12/98	29
Vector	10/15/98	25
Swati Modi	10/16/98	3
Rhett Butler	10/16/98	1
Rick Holt	10/16/98	1
Murphy Family	10/16/98	2
Sears Tour	10/18/98	1
Hochreiter Tour	10/22/98	1
Tabitha McCormick	10/24/98	1
Engineering Open House	10/24/98	147
Lori Schoch	10/27/98	1
Thayer Family	10/29/98	2
Sears Tour	10/30/98	2
Redland H.S.	11/02/98	8
RBHT	11/03/98	2
University of Pitt. Greensburg	11/05/98	6
Fermi Tour	11/05/98	7
Hochreiter Tour	11/05/98	1
Health Physics	11/06/98	1

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
PA Alliance for Environmental Education	11/06/98	3
Larry Myers – Interview	11/09/98	1
Randall McCullough – Interview	11/12/98	1
Jonathan Reed – Interview	11/12/98	1
Lee Cuddy	11/12/98	1
Bettis	11/12/98	2
Mike Lowry - HP Tour	11/13/98	1
Health Physics – Interview	11/13/98	1
Eric Page (State College HS)	11/13/98	1
Cornell / Harris	11/16/98	2
PSU Student Tour	11/17/98	1
Office of Telecommunications	11/19/98	1
Sears Tour	11/20/98	1
Punxsutawney HS	11/20/98	26
NRC	11/20/98	2
Environmental Health & Safety	11/20/98	1
Health Physics	11/23/98	1
Ron Welling – Interview	11/24/98	1
Health Physics	11/24/98	2
Rudy Family	11/25/98	3
Carlin Family	11/30/98	1
Visual Inspection Tech.	11/30/98	1
Catchen Tour	11/30/98	1
NRC	11/30/98	2
ANS Meeting	11/30/98	1
Sue Swartz	12/02/98	1
Pipe Wall Thinning Project	12/03/98	11
Hochreiter Tour	12/03/98	1
Pipe Wall Thinning Project	12/04/98	11
STS 150 Tour	12/07/98	20
Engineering Science Interest House	12/08/98	11
NUC E 590 Guest Speaker	12/10/98	1
EMS Training Drill	12/10/98	3

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
Scott Floray	12/10/98	1
Altoona Area H.S.	12/11/98	40
STS 150 Tour	12/11/98	2
WISE Interview	12/14/98	1
WISE Interview	12/14/98	1
Health Physics	12/15/98	1
NUCE 405 Final Exam	12/16/98	4
Plum Family	12/17/98	1
PSU Students – Catchen	12/18/98	2
Kane High School	12/21/98	9
General Stores	12/22/98	1
Christmas Tour	12/26/98	8
Nittany Office	01/04/99	1
Penny Bauman	01/05/99	1
ANS Tour	01/06/99	1
Crane Operators	01/07/99	2
Canberra	01/07/99	1
Monica Mazzullo – New NucE Staff	01/07/99	1
NucE 450	01/12/99	6
Hoag's	01/12/99	2
CMT Labs	01/12/99	1
Sheesley Concrete	01/13/99	1
Preston	01/13/99	1
All Crane Rental	01/20/99	1
Sheesley Concrete	01/21/99	2
Wayne Nixon	01/21/99	1
All Crane Rental	01/25/99	1
Harris Semiconductor	01/25/99	1
NucE Recruiting	01/25/99	24
Brookville Jr. High School	01/25/99	87
NWT	01/26/99	1
Environmental Health and Safety	01/26/99	1
Telecommunications	01/27/99	1

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
Mifflin County Christian Academy	01/27/99	23
Transnuclear/ PECO	01/29/99	4
Todd Family	01/29/99	2
Overhead Door	02/01/99	2
Test Loop Class	02/02/99	6
Julian Catchen	02/02/99	1
Lee McCoy	02/02/99	1
Motta Tour	02/03/99	1
Study Group	02/03/99	2
Oxford	02/04/99	2
Rod Bundle	02/04/99	3
Colloquium Speaker	02/04/99	1
General Stores	02/05/99	1
MG Industries	02/05/99	1
EMS	02/05/99	1
Lee Cuddy's Class	02/09/99	9
Brenizer Tour	02/09/99	2
NRC Meeting	02/09/99	1
Lee Cuddy's Class	02/09/99	11
Tyrone Middle School	02/10/99	18
Guest Speaker	02/11/99	1
TWM Inc	02/11/99	1
NRC Corp	02/11/99	1
Prospective Student Tour	02/12/99	1
Cellular One	02/15/99	1
Colloquium Speaker	02/16/99	1
Oxford Instruments	02/17/99	1
Catchen – Visiting Professor Tour	02/19/99	1
IPAC	02/19/99	10
Nittany Office	02/19/99	2
Health Physics	02/19/99	1
Nittany Office	02/24/99	2
College of Engineering Executive Committee	02/25/99	14

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
DUS	02/25/99	5
Wooten – Home-School Students	02/26/99	5
Tabitha McCormick	02/26/99	1
Sean Fox – Video Tour	02/26/99	1
Graduate Student Open House	02/27/99	5
State College High School	03/01/99	32
NRC	03/01/99	2
PECO Nuclear	03/01/99	2
PECO Nuclear	03/02/99	2
Solid Foundation	03/03/99	27
PJSHS	03/04/99	14
OPP	03/05/99	2
OPP	03/05/99	2
Central PA Institute of Science & Technology	03/05/99	9
Donahoe Family	03/08/99	2
Cumblidge Tour	03/09/99	2
Tabitha McCormick	03/11/99	1
Philip Plack	03/11/99	1
Wilkes University	03/12/99	3
OPP	03/15/99	1
Centre Concrete	03/15/99	1
OPP	03/17/99	1
Bill Nealen Tour	03/17/99	1
Photographs	03/18/99	3
Nittany Office	03/19/99	2
Environmental Health & Saftey	03/19/99	1
Prospective Student Tour	03/19/99	1
Catchen Tour	03/19/99	1
Engineering Open House	03/20/99	44
Spend an Engineering Day Open House	03/20/99	9
STS Open House	03/20/99	7
STS Open House	03/22/99	1
FOX News	03/22/99	3

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FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
Material Research Institute	03/25/99	1
HC Hood Company	03/29/99	2
Prospective NucE Students	03/29/99	3
Legislative Director Tour	03/30/99	2
Todd Tour	03/31/99	1
Navy ROTC	04/01/99	12
Navy ROTC	04/01/99	25
OPP	04/02/99	3
Hochreiter Tour	04/02/99	1
Chemistry Group	04/02/99	3
Juniata College	04/06/99	6
Grove City College	04/06/99	13
Colloquium Speaker	04/08/99	1
Electrical Engineering	04/08/99	5
Penns Valley	04/09/99	160
Niagara Mohawk	04/12/99	1
Sheesley's	04/12/99	1
All Saints Catholic School	04/12/99	28
University Police - Training	04/13/99	10
University Police - Training	04/13/99	6
Daniel Boone High School	04/14/99	17
AECL	04/15/99	3
Nuclear Measurements	04/16/99	5
Dr. Weyandt's Class	04/16/99	5
Miller Family	04/16/99	1
Penns Valley	04/16/99	104
Nuclear Measurements	04/16/99	5
Prospective Student Tour	04/16/99	1
Occupational Health	04/16/99	5
David Stiehler	04/19/99	1
Greensburg-Salem High School	04/19/99	18
Nuc E 420	04/20/99	3
Our Lady Of Lourdes High School	04/20/99	4

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
University Police – Training	04/20/99	7
Alvin Weinberg	04/20/99	1
Marion Center High School	04/21/99	10
Lancaster Catholic HS Science Club	04/22/99	7
Police Service Training	04/22/99	10
Hochreiter Tour	04/22/99	1
Take Our Daughters to Work	04/22/99	21
Rudy Family	04/23/99	1
Bermudian Springs High School	04/23/99	7
Dames & Moore	04/26/99	2
PSU Student Tour	04/27/99	1
Catchen Tour	04/27/99	1
STS Tour	04/27/99	4
Nittany Office	04/27/99	2
Jeff Shallenberger	04/28/99	1
Loyalsock Township High School	04/28/99	15
STS Tour	04/29/99	7
STS Tour	04/29/99	4
Baratta Tour	04/29/99	1
Hughes Tour	04/30/99	2
Tabitha McCormick	04/30/99	1
St. Mary's High School	04/30/99	45
PSU Student Tour	04/30/99	1
Mechanical Engineering Group	05/03/99	3
Nuclear Measurements	05/03/99	1
Westinghouse	05/04/99	1
EG&G ORTEC	05/04/99	1
Human Resources	05/05/99	2
GPU Nuclear	05/06/99	2
Northeastern High School	05/12/99	13
Camp Hill High School	05/14/99	13
Graduation Open House	05/14/99	14
Veterinary Science	05/14/99	1

APPENDIX B
FORMAL TOUR GROUPS

Tour Group Name	Date	Number of Participants
Bloom Family	05/14/99	4
Baratta Tour	05/14/99	2
Pam Koleno	05/14/99	1
Hoag's Catering	05/14/99	1
Cawley Family	05/14/99	4
Quigley Family	05/14/99	9
Centre Glass	05/14/99	1
Valic	05/17/99	1
Camp Hill High School	05/17/99	2
Science Fair	05/17/99	2
Wengerd Family	05/19/99	1
David Everhart – NRC	05/19/99	1
Transnuclear	05/19/99	1
Motta Tour	05/20/99	2
Methology of Transportation Group	05/21/99	4
Morlang Tour	05/22/99	2
Teacher Workshop	05/22/99	18
Danville HS	05/24/99	16
Prospective Student Tour	05/24/99	2
EG&G	05/25/99	1
University Police	05/27/99	2
Faculty Tour	06/01/99	2
ARL	06/02/99	1
Clearfield H.S.	06/02/99	16
Mitchko Family	06/02/99	3
PSU Student Tour	06/03/99	2
Don Hollenbach – 25th Anniversary	06/04/99	16
Bettis/Jack Murphy	06/07/99	2
OPP	06/08/99	1
Marcia Coleman	06/09/99	1
Japanese Tour	06/09/99	2
Frank Loss Group	06/11/99	3
Dave Werkheiser – Interview	06/11/99	1

APPENDIX B
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Tour Group Name	Date	Number of Participants
Carlin Family	06/14/99	1
Catchen Tour	06/15/99	1
FFA	06/15/99	3
Carlin Family	06/16/99	1
Edwards Tour	06/16/99	1
Dave Werkheiser - Interview	06/17/99	1
Nittany Office	06/18/99	2
Rudy Family	06/18/99	4
SOARS	06/22/99	25
Judy Lee	06/23/99	1
Judy Lee	06/24/99	1
Boy Scouts	06/25/99	18
Judy Lee	06/25/99	1
Judy Lee	06/29/99	1
Judy Lee	06/30/99	1
Total		2964

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