REED REACTOR FACILITY

ANNUAL REPORTS

September 1, 1991 – August 31, 1992
September 1, 1992 – August 31, 1993
September 1, 1993 – August 31, 1994

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EXECUTIVE SUMMARY

This report covers the period from September 1, 1991 to August 30, 1994. Reports should be issued every year, but annual reports were not prepared in 1992 and 1993 due to personnel shortages, operating exigencies, and other events. This report consolidates the three annual reports into one triennial report. Information contained in this report is intended to fulfill several purposes including the reporting requirements of the U. S. Nuclear Regulatory Commission (USNRC), the U. S. Department of Energy (USDOE), and the Oregon Department of Energy (ODOE).

The reactor staff consists of a Director, an Associate Director (appointed in March 1992), a contract Health Physicist, and approximately ten Reed College undergraduate students as hourly employees. The Director and Associate Director positions were each part-time positions until July 1994. Michael Pollock was Acting Director until April 1994, when Stephen Frantz assumed the position. The Associate Director position was filled by Paul Terdal (3/92 – 9/93), Juliet Brosing (10/93 – 5/94), and Josh Filner (June 94 – Present).

There were 2709 visits of the Reactor Facility by individuals during the three year period. Most of these visitors were students in classes at Reed College, area universities, colleges, and high schools. Including tours and research conducted at the facility, the Reed Reactor Facility contributed to the educational programs of 12 colleges and universities and 23 pre-college groups. Most of the reactor use by non-Reed personnel was conducted under the auspices of the Nuclear Science Consortium of the Willamette Valley, supported by a grant from the U. S. Department of Energy through the Reactor-use Sharing Program.

During the three years, the reactor was operated 476 separate times on 211 days. The total energy production was 30.90 MW-hours.

The only fuel leaks in the reactor's history occurred during the reporting period: one in November 1991 and one in January 1994. Some fission product gasses were detected but no personnel exposure or release limits were exceeded. Repeated attempts to recreate the leak or identify the leaking element were unsuccessful. After a thorough discussion with the regulating agencies, normal operations have resumed.

The whole-body radiation exposures to all individuals working at the Facility during this period were below the detection limit reported by the dosimetry service. There were no releases of liquid radioactive material from the facility and airborne releases (primarily ^{41}Ar) were within regulatory limits. No radioactive waste was shipped from the facility during this period.

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INTRODUCTION

The Reed College Reactor Facility has been a facility for research and educational projects in the Portland metropolitan area since its establishment in 1968. Cooperative programs between Reed and several public and private high schools, colleges, and universities in northwestern Oregon were established in 1970. These programs, fostered by the reactor staff, have been an increasingly important part of the educational picture of the region. Partial funding from the U. S. Department of Energy's Reactor Use Sharing Program to enable use of the reactor by educational institutions other than Reed, is provided through the Nuclear Science Consortium of the Willamette Valley.

Through the efforts of the late Dr. Arthur F. Scott, private and corporate funding was obtained for the original construction of the Reactor Building, which was completed in April, 1968. On July 2, 1968, uranium fuel elements were loaded into the core and a self-sustaining chain reaction was achieved. The reactor came into immediate use in a number of ways: it served as a key instrument in a Summer Institute in Nuclear Science for College Teachers of Physics and Chemistry, supported by the National Science Foundation; it was used to train Reed faculty members and students for Atomic Energy Commission (now Nuclear Regulatory Commission) operator licenses; and it was employed to activate serum and tissue samples for a medical research project. Similar and expanded activities continue to this day.

The Reed College TRIGA Mark I nuclear reactor is a water-cooled, "swimming pool type" which uses zirconium hydride/uranium hydride fuel elements in a circular grid array. The uranium fuel is enriched to 19.9% in uranium-235. The reactor is situated near the bottom of a 25-foot-deep tank and is surrounded by a ring of graphite which serves to minimize neutron leakage by reflecting neutrons back into the core.

The Reed Reactor operates at various steady power levels. The reactor is brought up to a desired power level (up to the license ceiling of 250 kW-thermal) and is kept at that power until the experiment or irradiation is completed. This makes it possible to provide a defined neutron flux, as required for the experiment. This level is usually maintained for periods ranging from a few minutes up to eight hours. However, continued or repeated operation over several days can be arranged for long-term irradiations.

The main uses of the Reed Reactor Facility are instruction, research, and industry, including, especially, trace-element analysis. Since initial start-up, the reactor, in addition to providing student research opportunities, has worked to educate the surrounding community on the principles of nuclear energy and fission-reactor operation.

STAFF

During the period from September 1991 through the present, the facility staff consisted of:

Director:	Stephen Frantz (7/94 - Present)
Acting Director:	Stephen Frantz (4/94 - 6/94)
	Michael Pollock (8/91 - 3/94)
Associate Director:	Josh Filner (6/94 - Present)
	Juliet Brosing (10/93 - 5/94)
	Paul Terdal (3/92 - 9/93)
Reactor Supervisor:	Phil Wilk (9/94 - Present)
	Josh Filner (3/94 - 9/94)
	Ernest Argetsinger (9/93 - 3/94)
	Paul Terdal (5/92 - 9/93)
	Ernest Argetsinger (12/91 - 5/92)
	Jeffrey Bradford (1/91 - 12/91)
Radiation Safety Officer:	Cindy Savage (4/93 - Present)
	Marshall Parrott (8/91 - 4/93)
Contract Health Physicist:	Marshall Parrott (8/91 - Present)
Assistant Health Physicist:	Traci Hilton (10/94 - Present)
	Aubin Whitley (9/94 - 10/94)
	Andy Funk (9/93 - 9/94)
	Sorab Gollogly (3/91 - 9/93)
Senior Reactor Operators:	Reactor Operators:
Ernest Argetsinger	Justina Bolz
Josh Filner	Juliet Brosing
Andy Funk	Wendy Evans
Aaron Mackey	Chris Ghormley
Michael Pollock	Morning Howard
Paul Terdal	Noah Iliinsky
Phil Wilk	Kathy Reeves

Operators who held licenses during the period but who no longer have licenses:

Eric Anderson
Jeffery Bradford
Jed Johnson
Anna LeRoux
Inga Sidor
Valerie Risk

In addition to serving as Acting Director since April of 1990, Mr. Pollock previously served as Associate Director of the Reactor Facility. Mr. Frantz was Acting Director from April to June 1994, and Director since July 1994. Mr. Filner graduated from Reed in May 1994 and was hired as Associate Director in June. Dr. Parrott works on contract to Reed College as Reactor Health Physicist. Ms. Savage is the Reed Campus Safety Officer. Dr. Brosing is a Professor of Physics at Pacific University and served as Associate Director during her sabbatical from Pacific University. All other staff members were Reed College undergraduates during the report period.

FACILITIES

In addition to the reactor, the Reed Reactor Facility has associated laboratory space for radiochemistry and nuclear science labs. A floor plan appears as Figure 1. The laboratory space was removed as part of construction of a new Chemistry Building, and is scheduled to be restored in the near future.

The equipment available at the reactor facility uses a variety of instrumentation including a gamma spectrometer (with Ge and NaI detectors), a surface barrier detector, SiLi X-ray detector, and several G-M tubes. Electronic equipment includes scalars and rate meters. The instruments are used for experiments in basic nuclear science and radiation detection. A liquid scintillation detector is available for use by faculty and students in the chemistry department and serves the campus radioisotope committee.

Figure 1 - Reed Reactor Facility Floor Plan

REACTOR USERS

Reactor Visitors

A total of 2709 individuals visited the Reed Reactor Facility during the three year period, as derived from the visitors log (Entry List B). A display of visitors by month is shown in Figure 2. Visitors include all individuals who are not listed as facility staff above. A large percentage of these were students in classes at area universities, colleges, and high schools as discussed below.

Figure 2- Visitor to RRF by Month.

Reactor Operations Seminar

The Reed Reactor Facility conducts a seminar series which is attended by students and faculty from Reed and other area educational institutions. This non-credit course serves as an introduction to nuclear reactor theory, health physics, and reactor operation. Some of the students may continue with in-depth reactor operator training in the spring and subsequently be recommended and apply for a reactor operator license. If successful, the individual may be hired to operate the reactor as a member of the facility staff. In addition, existing reactor operators may take the NRC senior reactor operator exam to upgrade their licenses. For those NRC exams administered during this reporting period, all eight reactor operator candidates and all four senior reactor operator candidates passed. One applicant had to retake a section of the exam after an initial failure, and subsequently passed.

Nuclear Science Consortium

In order to better use the resources of the Reed Reactor Facility, Dr. Scott and representatives of several area colleges and universities established the Nuclear Science Consortium of the Willamette Valley in 1970. Funding for the Consortium has been derived from Reactor Use Sharing Grants of the U. S. Department of Energy. This made the facility available without charge to classroom groups and unfunded research projects for consortium members.

The following institutions have participated in facility tours, experiments, and research projects in the reporting period. Additional colleges and universities which have been members of the Consortium or active in Consortium activities in the past include the University of Portland, Western Oregon State College, and Willamette University. A chronological listing is attached.

COLLEGE TOURS

Clackamas Community College
George Fox College, Chemistry
Lewis and Clark College, Chemistry
Lewis and Clark College, Physics
Mt. Hood Community College, Occupational Safety & Health, Hazardous Waste Management
Mt. Hood Community College, Chemistry
Oregon Health Sciences University
Oregon State University
Pacific University, Physics
Portland Community College
Portland State University, Geology
University of Oregon
V.A. Hospital and Oregon Health Sciences University, Nuclear Medicine
Warner Pacific College, Chemistry

HIGH SCHOOL & MIDDLE SCHOOL TOURS

<i>Cub Scouts</i>	<i>Jefferson H.S.</i>
<i>Beaverton H.S.</i>	<i>Lakeridge H.S.</i>
<i>Cleveland H.S.</i>	<i>Lake Oswego H.S.</i>
<i>David Douglas H.S.</i>	<i>Lincoln H.S.</i>
<i>Evergreen H.S.</i>	<i>McNary H.S.</i>
<i>Fernwood M.S.</i>	<i>Nancy Ryles H.S.</i>
<i>Gold Beach H.S.</i>	<i>Nyssa H.S.</i>
<i>Glencoe H.S.</i>	<i>Oregon Episcopal School</i>
<i>Grant H.S.</i>	<i>Riverside H.S.</i>
<i>Hillsboro H.S.</i>	<i>Sellwood M.S.</i>
<i>Hood River Valley H.S.</i>	<i>Wilson H.S.</i>
<i>Huntington H.S.</i>	

SPECIAL RESEARCH PROJECTS

Pacific University's Science and Technology Camp for Girls.
Pacific University, Advanced Physics – student research
Portland State University, Geology – faculty and student research projects
Portland Public Schools, Talented and Gifted Student (TAG) Program

SPECIAL GROUP TOURS

High School Chemistry Symposium, Reed College Chemistry Department
Science at Reed (admissions office program for high school juniors and seniors)

Most of the reactor tours include actual hands-on use of facility equipment to conduct experiments in basic radiation science, health physics, and nuclear physics. This increases the time and effort on the part of the facility staff but the response from participants has been extremely positive and indicates that the results are well worth the effort.

The most popular experiments for middle school students (many of whom have been participants in the Portland MESA Program discussed below) are a demonstration of the inverse square law and the absorption of radiation by different types of material. For high school classes, a typical lab experience would involve determining the background of a G-M scalar system and then determining the half-life of a radioactive material.

Along with expanding the number of experiments available to visiting schools, the program has increased the use licensed Reed College students to operate the reactor as laboratory assistants. Comments from high school teachers indicate that the interaction between college and high school students during these visits increases the interest of the high school students and increases the benefit they derive from the experience.

College classes are generally more closely tailored to the individual interests and needs of the Consortium faculty member involved. Experiments include more direct use of the reactor itself by the students, more detailed analysis of materials, and emphasize the incorporation of other classroom activities as much as possible.

The Portland MESA (Mathematics, Engineering, and Science Achievement) Program continues to use the facility for technical site visits for high school and middle school students. This program, cosponsored by the Portland Public Schools and Portland State University, targets minority and disadvantaged youth who are historically under-represented in those professions.

NSF-Sponsored Undergraduate Faculty Workshop

Work sponsored by the USDOE Reactor Use Sharing Grants to Reed Reactor Facility in past years has directly resulted in the development and successful funding of an undergraduate faculty workshop by the National Science Foundation. This workshop, Nuclear Methods in Geology, was conducted by Portland State University, in conjunction with the facility, during 1992.

This workshop brings ten faculty members from primarily undergraduate institutions to Portland for three weeks. The reactor was used for neutron activation analysis, fission-track age dating, and autoradiography. The focus of this workshop was on the use of nuclear methods within the framework of undergraduate classroom instruction, rather than the more traditional perspective of purely graduate level, research applications. Participants were assisted in the development of plans for on-going facility use.

High School Student Projects

The Reed Reactor Facility continued to be used in independent science projects initiated by students from several Oregon high schools. A student from Gold Beach High School irradiated yeast with gamma radiation wishing to produce a stronger strain. Another student from Gold Beach High School irradiated pea and corn seeds with gamma radiation to investigate the possibility of irradiating seeds to prevent decay before planting. Two projects were conducted for Riverside High School students, one of which involved the analysis of local soil, well water, river water, and plants. This project was in the top two at the Northwest Science Exposition and went on to the international competition.

Pacific University Science and Technology Camp for Girls

The Pacific University Science and Technology Camp for Girls was a four week summer camp in July 1992 for 7th and 8th grade girls. This camp was funded by the U.S. Department of Energy. The overall goal was to encourage the participants to continue in math and science. The 24 girls involved studied computer science, physics, biology, and chemistry. The physics component was taught by Dr. Juliet Brosing (a current reactor operator) and Dr. Mary Fehrs, both faculty at Pacific University. Three days of the camp were spent at the facility analyzing beach sand for heavy metals using neutron activation analysis. The students were also given an introduction to radiation safety and health physics.

Pacific University Modern Physics Lab

In fall of 1992 the Modern Physics Lab at Pacific University spent three lab sessions (4-5 hours per week for three weeks) at the reactor. The ten students did several labs including: basic health physics, Compton scattering, subcritical multiplication, and determination of delayed neutron lifetimes. This lab is taught alternate years at Pacific. This lab will be taught again in Fall 1994 (with approximately ten students) and will use the facility for at least three weeks.

Sabbatical Research

Dr. Juliet Brosing spent her sabbatical year (1993-94) at the Reed Reactor. She was hired part time as Assistant Director to assist first Michael Pollock and then Stephen Frantz in running the reactor program. In addition she is doing research to characterize the neutron energy spectrum in the reactor, using foil activation techniques. This research will continue next year, with at least one undergraduate student from Pacific participating in this research program.

Reed Classes, Theses, and Faculty Research

The Reed College Reactor Facility was used in four Reed College Classes and two senior theses.

- The Chemistry 110 class conducted a lab using neutron activation analysis to analyze for copper and potassium in a compound synthesized earlier in the course, and the determination of the amount of various metals in breakfast cereals.
- Chemistry 315 students evaluated the presence of impurities in aluminum foil.
- An art class irradiated small paintings and performed autoradiography of the painting.
- A physics class incorporated a lab to measure the energy of gamma radiation resulting from Compton scattering in aluminum. The radiation source for this lab (Au-198) was manufactured as needed in the reactor.
- Josh Filner ('94) used the reactor in an attempt to develop an analytical technique for lithium and other metals in solid solutions, in conjunction with his work on intercalation chemistry.
- Zack Nobel ('94) used the reactor to dope high purity silicon with phosphorous, by transforming some of the silicon with neutrons.

Industrial and Commercial Applications

The Reed Reactor Facility is available for use by industrial or commercial concerns whenever it does not conflict with our educational goals. As in past years, the primary operations involve neutron activation analysis of materials or environmental samples. Arrangements may be made either on a time lease basis or the industry may contract for sample analysis.

REACTOR OPERATIONS AND MAINTENANCE

Operations

During the three year period, 211 reactor start-up checklists were completed with a total of 476 times critical. A reactor start-up is conducted on each day of reactor operation; each "time critical" represents one reactor operation. The total energy production amounted to 30.90 MWh. Operations by month and the average for each year appear in Figures 3-5. Note that there was no operation from December 1991 to March 1992 due to recovery from a fuel leak, discussed below.

Figure 3 - Days of Operation

Figure 4 - Times Critical

Figure 5 - Energy Production

Fuel Leaks

The only fuel leaks in the reactor's history occurred during the reporting period: one in November 1991 and one in January 1994. Some fission product gasses were detected but no personnel exposure limits or release limits were exceeded. Repeated attempts to recreate the leak or identify the leaking element were unsuccessful. After thorough discussion with the regulating agencies, normal operations have resumed.

On November 23, 1991 the reactor experienced its first fuel leak. The reactor was at full power with pool water temperature at 95.7°F when the Gaseous Stack Monitor (GSM) unexpectedly alarmed. The operator promptly scrammed the reactor. The operators declared the situation an Unusual Event, and initiated emergency procedures, including the notification of other senior staff and the NRC. Air samples showed evidence of Rb-88, a decay product of fission fragment Kr-88, and the water samples contained the gaseous fission products Kr-85m, Kr-88, and Xe-135.

On November 24, a team arrived from NRC Region V to provide assistance and conduct a facility inspection. Their report offered constructive criticism, but found no violations of regulations. On November 25, the NRC issued a Confirmatory Action Letter requiring Reed to develop a plan to locate the fuel cladding failure, and to submit the plan to the NRC for approval before implementing it. Reed was also forbidden from manipulating the reactor controls until the cause of the radioactivity release was understood, communicated to the NRC, and NRC approval granted.

After consulting with facilities that had experienced similar fuel leaks, the Reed staff developed a "sniffing" apparatus to search for radioactive fission products in the reactor pool water. The water sniffer was based on recommendations from General Atomic and recent experiences at the University of Utah. With the reactor at a constant power, water from the top of the core was collected by a funnel and drawn through Tygon tubing by a varistaltic pump. After passing through 100 feet of tubing coiled up inside of a lead cage as a delay line, to allow short lived nuclides such as N-16 and O-19 to decay, the tube was wrapped around a HPGe detector attached to a multichannel analyzer. The exhaust was then returned to the bottom of the reactor pool.

On April 10, 1992, NRC concurrence with the recovery plan was received, and NRC representatives flew to the Reed campus to observe the operations. As per the plan, the reactor was

brought up in power in slow steps, beginning at 5 watts, then proceeding to 100 w; 1,000 w; 10,000 w; 100,000 w; and ultimately 240,000 watts. At each step, the reactor was held at a steady power level for at least an hour while the detectors described above were used to search for signs of fission products. The sniffing apparatus was easily able to detect trace amounts of Na-24 and Fe-59 in the water, activation product from the aluminum and steel clad fuel elements, but there were no signs of fission product activity on any of the detectors, including the facility monitors which had responded during the Unusual Event. After several hours of continuous operation at full power (240 kW) yielded no signs of fission product activity whatsoever, it became apparent that the leak was not recurring.

In recognition of the fact that a repeat of the fuel leak incident would not pose any radiological hazard to the staff or to the public, the NRC permitted Reed to resume normal operations. As part of the recovery plan, Reed revised its Emergency Plan so that its Emergency Action Levels were more consistent with standard regulatory practice. The threshold for reporting events had been too low previously, causing unnecessary concern when the event was declared. Reed also agreed to maintain the fuel leak detection equipment and procedures, so that if the leak were to repeat, it could be dealt with quickly.

The second leak occurred on January 20, 1994. The reactor was at full power, operating under normal conditions for senior thesis projects. At about 2:38 p.m., the reactor operator noticed that the failsafe light on the Air Particulate Monitor (APM) flickered and then went out. While examining the APM chart recorder (which indicated a rise in activity), the CAM failsafe went out indicating radioactivity in the reactor bay air. The reactor was immediately scrammed and the filter paper was collected and analyzed. Isotopes of Rb-89 and Cs-138 were identified, the only source of which is the fission of U-235. Effluent calculations were immediately performed.

The reactions of the students and operators were appropriate, calm, and expedient. Because the reactor was shut down immediately, the radiation levels in the bay remained very low, so low that none of the monitors reached alarm levels, isolation was not tripped, and within a half hour the failsafe light was back on. Calculated concentrations at the site boundary indicated a maximum gaseous activity of 3.7×10^{-10} mCi/ml (Unusual Event level 4.5×10^{-7} mCi/ml) with a particulate activity of 1.0×10^{-12} mCi/ml (Unusual Event level 1×10^{-9} mCi/ml). This did not qualify in any category of emergency under either our Emergency Plan or federal or state guidelines.

Testing began January 22, 1994. The previously designed sniffer apparatus was set up, consisting of tubing attached to a funnel which could be placed over a section of the reactor core. The water in the tubing was analyzed by both a NaI detector and a Ge detector before returning to the bottom of the tank. As outlined in the approved procedure the entire core was "sniffed" at 0 power, 100 w, 1000 w, 10,000 w, 100,000 w and 240,000 w (full power). On January 24, testing was resumed. The core was "sniffed" at 0 power, then at full power for two more hours. During testing, wipe tests were taken of surfaces in the reactor bay. A separate air sampler equipped with charcoal cartridge (loaned by the Oregon State Health Division) for the detection of any possible iodine isotopes was operating in the reactor bay at the level of the employee breathing zone.

No additional release of fission products was detected (as indicated by the lack of short half-life fission products) in either the sniffer or in the air samplers. The leak did not recur. Despite numerous and careful attempts, no further evidence of the location of the fuel leak has yet been gathered. No activities above background were detected in any of the air filter or wipe test samples.

The facility completed the leak testing without locating a leaking assembly, therefore the reactor has returned to normal operations. Other TRIGA facilities reported similar situations in the past. The facility will maintain the procedure and sniffing equipment for future use.

Unplanned Reactor Shutdowns (SCRAMS)

There were 26 unplanned reactor shutdowns during the period, as shown in Table A. All were classified as inadvertent. Four occurred when switching the reactor from manual to automatic operation at high power (a problem which has occurred sporadically for many years); the rest resulted from operator or trainee error. The number of unplanned reactor shutdowns is consistent with previous operations.

TABLE A - Unplanned Reactor Shutdowns 1991-94

<u>Date</u>	<u>Type</u>	<u>Cause Of Shutdown</u>
8/31/91	Linear Power	Operator error
6/30/92	Linear Power	Operator error
7/31/92	Reactor Period	Operator error
7/31/92	Linear Power	Operator error
7/31/92	Reactor Period	Operator error
10/19/92	Linear Power	Trainee error
10/26/92	Linear Power	Operator error
12/3/92	Linear Power	Operator error
1/13/93	Reactor Period	Operator error
1/14/93	Reactor Period	Trainee error
1/14/93	Linear Power	Trainee error
1/14/93	Linear Power	Trainee error
1/15/93	Reactor Period	Operator error
1/18/93	Linear Power	Operator error
2/25/93	Reactor Period	Operator error
6/25/93	Linear Power	Automatic switch contact
7/21/93	Linear Power	Operator error
7/21/93	Linear Power	Operator error
7/22/93	Linear Power	Operator error
8/12/93	Linear Power	Automatic switch contact
8/12/93	Linear Power	Automatic switch contact
11/11/93	Linear Power	Automatic switch contact
1/13/94	Linear Power	Operator error
4/20/94	Reactor Period	Operator error
7/30/94	Linear Power	Operator error
8/23/94	Reactor Period	Operator error
8/23/94	Reactor Period	Operator error

Maintenance

Routine equipment checks are conducted by reactor staff members on a daily, weekly, bimonthly, semiannual (January and July) and annual (January) basis as required by facility procedures. Reed College maintenance personnel assist with routine preventative maintenance to auxiliary equipment. Significant maintenance operations which were not part of a regular schedule are described in Table B. Note that the facility was without a secondary cooling system from August 1991 to March 1994. This limited the length of high power operations since there was no heat removal capability other than ambient losses.

TABLE B - Significant Maintenance Operations 1991-94

<u>Date</u>	<u>Maintenance</u>
8/6/91	The secondary cooling system pump failed. A replacement pump was ordered.
8/10/91	Replaced the safety control rod drive mechanism.
8/21/91	The replacement, higher capacity secondary cooling system pump was installed. The higher pressure damaged the heat exchanger, causing it to leak.
9/6/91	Installed temporary bypass around the heat exchanger so that the primary system could be run independently (for filtration and ion exchange).
1/29/92	Refurbished the klaxon evacuation alarm.
3/25/92	Relocated the Air Particulate Monitor (APM) to the exit corridor from the reactor bay, to reduce the background radiation at the detector. The sampling locations were not changed.
4/6/92	Replaced the stack monitor pump.
7/3/92	Replaced the cadmium cell (light detector) in the percent power scram.
4/16/94	Removed, cleaned, and replaced the central thimble to dislodge a piece of lexan used in a senior thesis experiment. The lexan (a plastic spacer) degraded when the reactor was taken to full power.
3/25/94	Installed new secondary cooling system and plate-type heat exchanger. The new system uses a forced draft cooling tower rather than lake water for cooling.

RADIATION PROTECTION

Personnel Dosimetry

During the period from 7/1/91 to 6/30/94, personnel dosimeters were issued to 40 Reed students and staff and 1 contractor working at the reactor. Since dosimeters are changed on a calendar quarter schedule, this period is the closest to the reporting period. In almost all cases, individuals were issued both a ring badge for estimating hand exposure and a whole-body badge. A total of 143 person-quarters were reported.

Seven individual ring badges met or exceeded the detection limit of 30 mR/quarter as indicated on Table C. There was no exposure on the whole-body dosimetry above the detection limit.

TABLE C - Personnel Dosimetry 1991-94

	Ring	Whole-body
Total dosimeters issued	140	141
Reports below detection limit	133	141
Details of ring dosimeters exceeding detection limit:		
	mR/qr	
Reed student	40	
Reed student	40	
Reed staff	40	
Reed student	30	
Reed student	30	
Reed student	40	
Reed staff	30	

Gaseous Releases

The only routine release of gaseous radioactivity is from Ar-41 (1.8 hour half-life) which is produced in air irradiated in the rotary specimen rack. The detected activity includes an unknown, but significant percentage of activity from N-16 (7 second half-life). The total gaseous activity, averaged over a year, is approximately 2.17×10^{-9} mCi/ml. This is well below regulatory guidelines.

Some fission product gasses were released during the fuel leaks. As reported above, calculated concentrations at the site boundary indicated a maximum gaseous activity of 3.7×10^{-10} mCi/ml with a particulate activity of 1.0×10^{-12} mCi/ml. This did not qualify in any emergency category under federal or state guidelines.

Liquid Waste Releases

No liquid radioactive waste was released from the Reed Reactor Facility during this report period.

Solid Waste Disposal

No solid radioactive waste was shipped from the Reed Reactor Facility during this report period.

Area Radiation Monitors (Dosimeters)

Radiation levels are continually monitored at four locations designed to provide an indication of the average radiation levels in the reactor bay. The locations of these dosimeters are shown on Figure 1. All are thermoluminescent dosimeters (TLDs) designed to monitor beta and gamma radiation. In addition, two locations have TLDs for neutron dose measurement.

The radiation doses measured during the period beginning July 1, 1991 and ending June 30, 1994 are shown in Table D. There are sample storage locations along the north wall: a radioactive source storage safe and a lead enclosed sample box where samples are placed immediately upon removal from the reactor. A neutron howitzer was stored along the east wall during part of this period.

Four new dosimetry locations were added in July 1994 to measure the potential dose to members of the public outside the facility. The locations are on the roof, near the new cooling tower, outside the large double doors, and near the Psychology Building windows. This dosimetry is intended to demonstrate compliance with the new federal exposure limits. Some radioactive sources were relocated inside the facility to ensure compliance (e.g., sources were moved away from the wooden double doors).

TABLE D - Area Radiation Dosimeters 1991-94
(doses in mR/calendar quarter)

Location (height above floor)	<u>B.y.</u>	<u>n</u>	<u>B.y.</u>	<u>n</u>	<u>B.y.</u>	<u>n</u>	<u>B.y.</u>	<u>n</u>
	<u>7/1/91-9/30/91</u>		<u>10/1/91-12/31/91</u>		<u>1/1/92-3/31/92</u>		<u>4/1/92-6/30/92</u>	
(A) North wall (1.5 m)	55	-	70	-	55	-	40	-
(B) North wall (2.5 m)	80	-	90	-	80	-	65	-
(C) East wall (1.7 m)	40	90	90	50	90	0	0	0
(D) South wall (1.7 m)	25	-	25	-	0	-	0	-
(E) West wall (1.0 m)	0	0	0	0	0	0	0	0
	<u>7/1/92-9/30/92</u>		<u>10/1/92-12/31/92</u>		<u>1/1/93-3/31/93</u>		<u>4/1/93-6/30/93</u>	
(A) North wall (1.5 m)	45	-	70	-	90	-	90	-
(B) North wall (2.5 m)	80	-	85	-	120	-	160	-
(C) East wall (1.7 m)	80	30	80	40	25	300	120	300
(D) South wall (1.7 m)	0	-	25	-	50	-	60	-
(E) West wall (1.0 m)	0	0	20	0	25	0	30	0
	<u>7/1/93-9/30/93</u>		<u>10/1/93-12/31/93</u>		<u>1/1/94-3/31/94</u>		<u>4/1/94-6/30/94</u>	
(A) North wall (1.5 m)	75	-	70	-	40	-	30	-
(B) North wall (2.5 m)	140	-	120	-	90	-	70	-
(C) East wall (1.7 m)	95	270	100	220	45	70	0	0
(D) South wall (1.7 m)	50	-	50	-	0	-	0	-
(E) West wall (1.0 m)	20	0	15	0	35	0	55	0

"-" means no neutron dosimeter at this location