REED COLLEGE

July 23, 2014

REACTOR FACILITY
3203 Southeast
Woodstock Boulevard
Portland, Oregon
97202-8199

telephone
503/777-7222
fax
503/777-7274
email
reactor@reed.edu
web
http://reactor.reed.edu

Deanna Henry
Oregon Office of Energy
625 Marion St. NE
Salem, OR 97301-3742

Dear Deanna,

Enclosed is Reed College Reactor's Annual Report.

Please feel free to contact me for additional information.

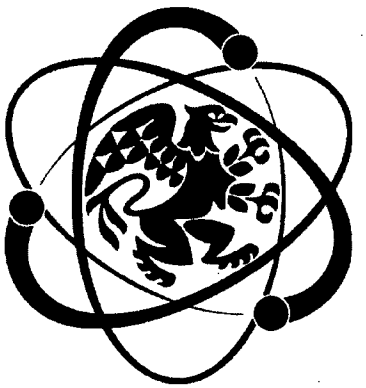
Regards,

Melinda P. Krahenbuhl
Director, Reed College Reactor

A020
NRR

REED RESEARCH REACTOR ANNUAL REPORT

July 1, 2013 -- June 30, 2014



3203 Southeast Woodstock Blvd.
Portland, Oregon 97202-8199
503-777-7222
Fax: 503-777-7274
http://reactor.reed.edu
reactor@reed.edu

TABLE OF CONTENTS

OVERVIEW

This report covers the period from July 1, 2013 to June 30, 2014, and is intended to fulfill the reporting requirements of the U.S. Nuclear Regulatory Commission License No. R-112, Docket 50-288, the U.S. Department of Energy, and the Oregon Department of Energy Rule No. 345-030-010.

We specifically wish to thank Portland General Electric and Concordia University for their financial aid.

Reed College operates a 250 kW TRIGA® Mark I reactor. The Reed College Research Reactor has been a resource for research and educational projects in the Portland area since 1968. The main uses of the Reed Research Reactor are instruction and research, especially in the field of trace-element analysis.

During the year there were 1871 visitors from schools, colleges, universities, and special groups. Specifically, 537 visitors were part of Reed College activities (prospective students, family of students, Reed classes, etc.). Forty-two members of emergency response organizations came for training. Finally, there were 15 entries by inspectors and regulators from state and federal agencies. Including tours and research conducted at the facility, the Reed Research Reactor contributed to the educational programs of 22 colleges, universities and K-12.

During the year the reactor was taken critical 462 times on 165 days. The total energy produced was approximately 33.75 megawatt-hours.

The reactor staff consists of a Director, a Reactor Operations Manager, and Reed College undergraduate students who are licensed by the Nuclear Regulatory Commission as reactor operators or senior reactor operators. During the reporting period, 12 out of 14 Reactor Operator candidates passed their NRC exams and 13 out of 14 the Senior Reactor Operator candidates passed their NRC exams.

There were no radiation exposures to individuals in excess of the limit during the year. There were no releases of liquid radioactive material from the facility and airborne releases were well within regulatory limits. There were no shipments of low-level radioactive waste from the facility.

The Nuclear Regulatory Commission conducted an inspection December 16-19 2013.

PEOPLE

Reactor Staff

Reed College eliminated the position of Assistant Director and replaced it with Reactor Operations Manager. Brian Fairchild was hired as the Reactor Operations Manager in July 2013. During the period July 1, 2013 to June 30, 2014, the staff consisted of:

Reactor Director:	Melinda Krahenbuhl	(6/11 - present)
Reactor Operations Manager:	Brian Fairchild	(7/13 – present)
Radiation Safety Officer:	Kathleen Fisher	(1/03 – present)
Operations Supervisor:	Christina Barrett	(5/13 – present)
Training Supervisor:	Molly Maguire Ilana Novakoski	(5/12 – 5/14) (5/14 – present)
Training Supervisor:	Veronica Stewart Alexandra Mariani	(5/13 – 5/14) (5/14 – present)
Requalification Supervisor:	Erin Weisenhorn Wilson Horner	(7/13 - 6/14) (6/14 - present)
Projects Supervisor	Kathryn Linthicum Hannah Choi	(5/13 - 5/14) (6/14 - present)

Senior Reactor Operators (SRO)			
Hannah Allen	Josh Hepworth	Melinda Krahenbuhl	Rachael Otto
Christina Barrett	Wilson Horner	Simran Mahtani	Erin Sheffels
Lily Ben-Avi	Austin Humphrey	Charlie McIntyre	Nathan Showell
Hannah Choi	Kathryn Linthicum	Ilana Novakoski	Veronica Stewert
Michael Conner	Trevor Lohrey	Evan Peairs	Reilly Villanueva
Daniel Dashevsky	Jake Luton	Alexandra Mariani	Erin Weisenhorn
Brian Fairchild	Isaac Khader	Huy Nguyen	Andrew Warren
Reactor Operators (RO)			
Sarah Black	Hunter Gill	Stephan Okar	Nicole Scherm
Andrew Blount	Vincent Griffith	Jossef Osborn	Natalie Stone
Madeline Brandt	Alexander Harris	Alexander Pan	Riley Thornton
Audrey Dannar	Jowie Koh	Edgar Perez	Timothy Tyree
Kevin Freymiller	Malcolm McCarthy	Helana Pedrotti	Michaela Voorhees
Elisabeth Grace	Jared Milfred	Grace Poetzinger	

The list of operators includes everyone who held a license at any time during the reporting period. Reactor Operators who upgrade their licenses to Senior Reactor Operators during the reporting period are listed under Senior Reactor Operators. For the 2013-2014 year there are 51 licensed operators at Reed College, 23 women and 28 men.

Reactor Operations Committee (ROC)

For the 2013 – 2014, the membership of the Reactor Operation committee is shown below.

Reactor Operations Committee

Wayne Lei - *(Director of Research and Development, Portland General Electric)*
Norm Dyer *(OAR Services)*
Johnny Powell *(Physics Faculty, Reed College)*
Robert McCollough *(Neighborhood Association)*
Kathleen Fisher *(Director, Reed Environmental Health and Safety)*
Lucas Illing – Chair *(Physics Faculty, Reed College)*
Steve Reese *(Radiation Center Director, Oregon State University)*
Nigel Nicholson *(Dean of the Faculty, Reed College)*
Melinda Krahenbuhl *(Director, RRR)*
Brian Fairchild *(Reactor Operations Manager, RRR)*
Christina Barrett *(Supervisor, RRR)*

FACILITIES

Reactor Facility

In addition to the reactor, Reed College has a radiochemistry lab. The equipment available at the reactor facility includes high purity germanium gamma spectrometers, a whole body counter, ion chambers, beta counters, Geiger Muller tubes, neutron detectors, alpha detectors, and thermo luminescent dosimeter readers. These instruments are used for experiments and training in nuclear science and radiation detection. Two exit monitors are in the control room. A liquid scintillation detector serves both the reactor and broad scope license users. The reactor facility has several systems for performing irradiations, described below.

Rotating Specimen Rack Facility

The rotating specimen rack is located in a well on top of the graphite reflector surrounding the core. The rack consists of a circular array of 40 tubular receptacles, each of which can accommodate two irradiation tubes. Vials holding up to 17 ml (four drams) are used in this system. Samples are loaded in the specimen rack prior to the start-up of the reactor. The rack automatically rotates during irradiation to ensure each sample receives the same neutron flux. Typically, researchers use the rotating rack when long irradiation times (generally greater than five minutes) are required. The approximate thermal neutron flux in a rotating rack position at full power is 1.7×10^{12} n/cm^{2}s with a cadmium ratio of 6. The specimen rack can be used for gamma irradiations (approximately 8 Rad/min) when the reactor is shutdown.

Pneumatic Transfer System

The pneumatic transfer system ("rabbit") consists of an irradiation chamber in the outer F-ring of the core and its associated blower and piping. This allows samples to be transferred in and out of the reactor core very rapidly while the reactor is at power.

Routine use of the pneumatic transfer system involves placing samples into vials, which in turn are placed in special capsules known as "rabbits." The capsule is loaded into the system in the laboratory next to the reactor and is then transferred pneumatically into the core-irradiation position. At the end of a predetermined time the sample is transferred back to the receiving terminal, where it is removed for measurement. The transfer time from the core to the terminal is about seven seconds, making this method of irradiating samples particularly useful for experiments involving radioisotopes with short half-lives. The flux in the core terminal is approximately 5×10^{12} n/cm^{2}s when the reactor is at full power.

In-Core Facilities

The central thimble is a water-filled irradiation chamber about 3 cm in diameter. It provides the highest available neutron flux, about 1×10^{13} n/cm^{2}s. Special sample holders are used in the central thimble to provide maximum flexibility in experiment design.

A fuel replacement source holder assembly can also be used as an irradiation facility. The chamber fits into a fuel-element position within the core itself. It holds only one specially positioned irradiation container 7.5 cm in length and 2.5 cm in diameter.

Foil-insertion holes, 0.8 cm in diameter, are drilled at various positions through the grid plates. These holes allow inserting special holders containing flux wires into the core, to obtain neutron flux maps of the core.

In-Pool Facilities

Near core, in-pool irradiation facilities can be arranged for larger samples. Neutron fluxes will be lower than in the rotary specimen rack and will depend on the sample location.

An iridium gamma irradiator is also in the reactor pool for gamma only irradiations.

Beam Facilities

The central thimble can be evacuated with gas, producing a vertical neutron beam. This beam can be used to generate directional neutron flux, or for limited irradiations above the tank. Prompt gamma analysis and neutron radiography can be done. The flux above the beam exit is approximately $1x10^6$ n/cm^{2}s when the reactor is at full power.

REGULATORY EVENTS

The Nuclear Regulatory Commission conducted an inspection during December 16-19, 2013. A Notice of Violation was issued Jan. 14, 2014. A reply was sent to the NRC on January 30, 2014. Corrective actions have been implemented.

AUDITS AND INSPECTIONS

Two audits were completed during this period. Wayne Lei (ROC committee member) completed an internal audit on May 13, 2014. Sandra Warren (General Manager, Aerotest) conducted an external audit on April 30, 2014. Recommendations are currently being evaluated.

USERS

Reactor Operations Seminar

The Reed Research Reactor conducts an annual seminar series. This non-credit course serves as an introduction to nuclear reactor theory, health physics, and reactor operation. Some of the students continue with in-depth reactor operator training and subsequently apply for a Reactor Operator (RO) license. If successful, the individual may be hired to operate the reactor. In addition, existing ROs may take the NRC Senior Reactor Operator (SRO) exam to upgrade their licenses.

During the reporting period, 14 out of 16 RO candidates and 15 out of 17 SRO candidates passed their NRC exams.

Figure 1 is a graph of the pass rate for RO and SRO since 2000.

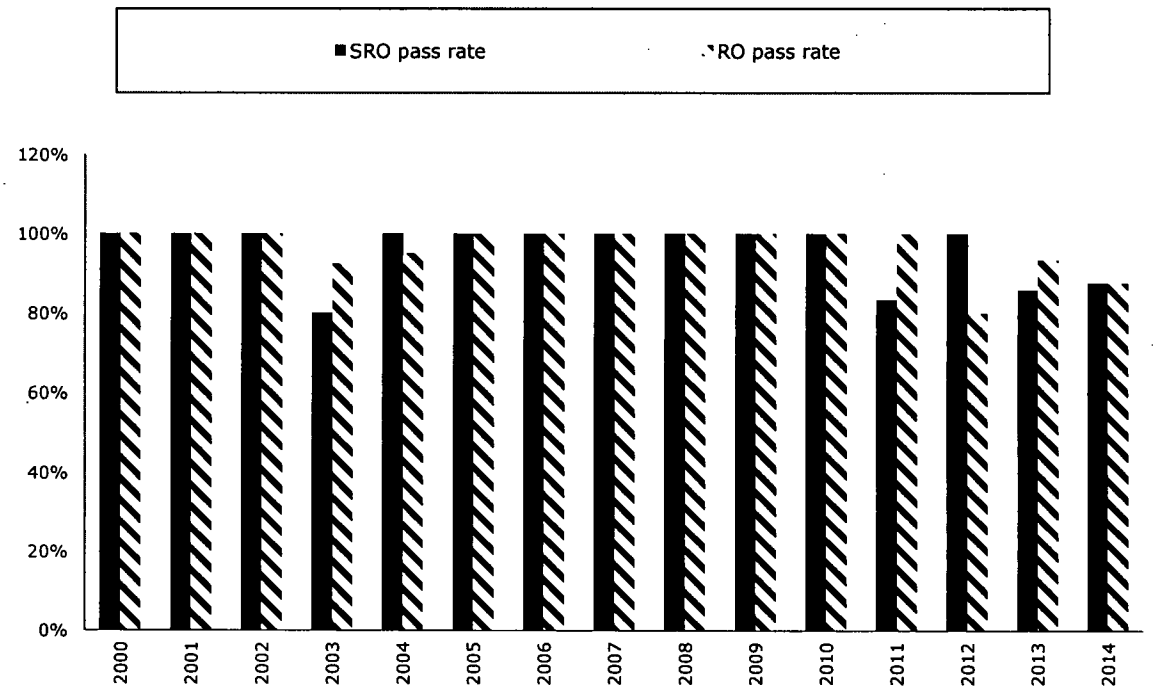


Figure 1 Reed Research Reactor License Exam Results

Outside Users

During the year there were 1871 visitors from schools, colleges, universities, and special groups. Additionally, there were 537 visitors as part of Reed College activities (prospective students, family of students, Reed classes, etc.). Forty-two members of

emergency response organizations came for training. Finally, there were 15 entries by inspectors and regulators from state and federal agencies.

The following institutions have participated in facility tours, experiments, and research projects in the reporting period.

Colleges and Universities

Concordia University
Oregon Health Science University
Oregon Institute of Technology
Oregon State University
Pacific University
Portland State University
Portland Community College (Rock Creek, Sylvania)

High Schools /Middle Schools/Elementary Schools

Lent Elementary
Lewis Elementary
Portland Public School
Waldorf Elementary
Cascade Heights Public Charter School
Catlin Gabel
Canby High School
Corbett High School
Cleveland High School
Columbia River High School
Rex Putnam High School
Meek High School
Oak Hills School
Waldorf High School
Roosevelt High School

Special Groups

Uniquely Portland
TAG
Boy Scouts (67, 611)
On Semiconductor
RSO class
Saturday Academy
ASE STEM Camp
Latin Forum
Portland PDX Hazardous Waste Team
Science Outreach

Figure 2 is a graph showing the history of visiting groups.

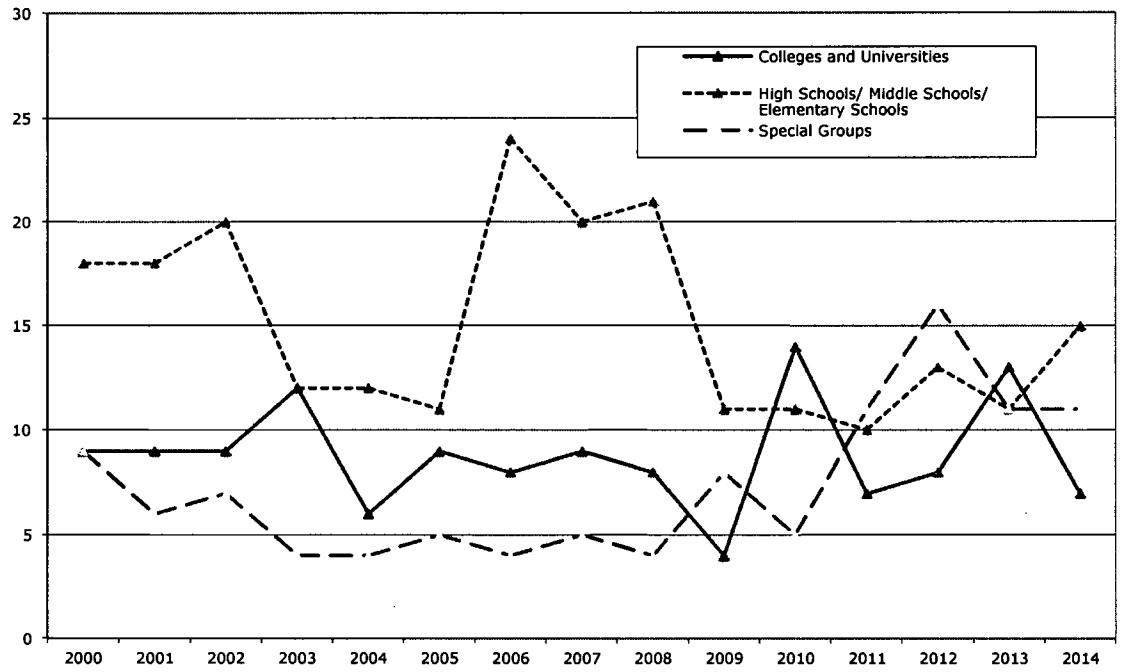


Figure 2 Visiting Groups

Many reactor tours include hands-on use of facility equipment to conduct experiments in radiation science, health physics, and nuclear physics. A typical lab involves determining the background of a Geiger Muller scaler system and then determining the half-life of a sample of radioactive material. 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.

Several special programs for gifted children use the reactor for projects. These are designed to enrich their educational program and prepare them for college. Some of the groups who use the reactor target minority and disadvantaged youth who are historically under-represented in science professions. Additionally several Boy Scouts of America troops have visited the facility to complete the Nuclear Science merit badge.

High School Student Project

The Reed Research Reactor continues to be used in independent science projects initiated by students from several Oregon and Washington State high schools.

Concordia University

The reactor provides training and experiments involving radiation, radioactive material, and trace element analysis for Concordia University classes.

Scaler Kits

Through the generosity of Portland General Electric, the reactor lends out kits containing a Geiger counter, a scaler, and some small exempt sources to local high schools.

Reed Classes

- Chemistry 101 students explored the properties of alpha, beta and gamma irradiation.
- Chemistry 311 Extent of Chemical Reaction using potassium as the tracer
- Physics 332-Two groups from Advanced Laboratory II completed independent projects
    - Measurement of Cs-137 activity and characteristics using two different approaches
    - Measurement of flux, Cd ratio and flux profile of the rotary specimen rack
- Biology 356 Genetics and Gene Regulation – Two students evaluated the relationship between double strand breaks in DNA and neutron/gamma dose.
- Biology 351 Developmental Biology followed by Biology 481 Independent project – "*Ionizing Radiation Damage and Repair in Zebrafish Throughout Early Embryogenesis*" Christina Barrett and Ivy Hellickson

Industrial and Commercial Applications

The Reed Research Reactor is available for industrial or commercial concerns when it does not conflict with our educational goals. As in the past, the primary operations involved neutron activation analysis of materials or environmental samples. The facility also provides radiation protection training to interested parties and schools in the area.

REACTOR OPERATIONS

Operations

During the year the reactor was taken critical 462 times on 165 days. The total energy produced was approximately 33 megawatt-hours. Operating history by month appears in table 1. A history of the data is shown in figure 3.

Table 1 Operating History 2013-2014

	TIMES CRITICAL	DAYS OPERATED	MW-HOURS
July 2013	17	7	1.46
August 2013	17	12	1.59
September 2013	78	13	4.46
October 2013	17	12	2.68
November 2013	75	24	5.61
December 2013	33	14	2.03
January 2014	12	14	1.51
February 2014	30	14	1.78
March 2014	46	18	3.30
April 2014	62	22	4.19
May 2014	56	17	4.00
June 2014	19	8	1.15
Total	462	165	33.75

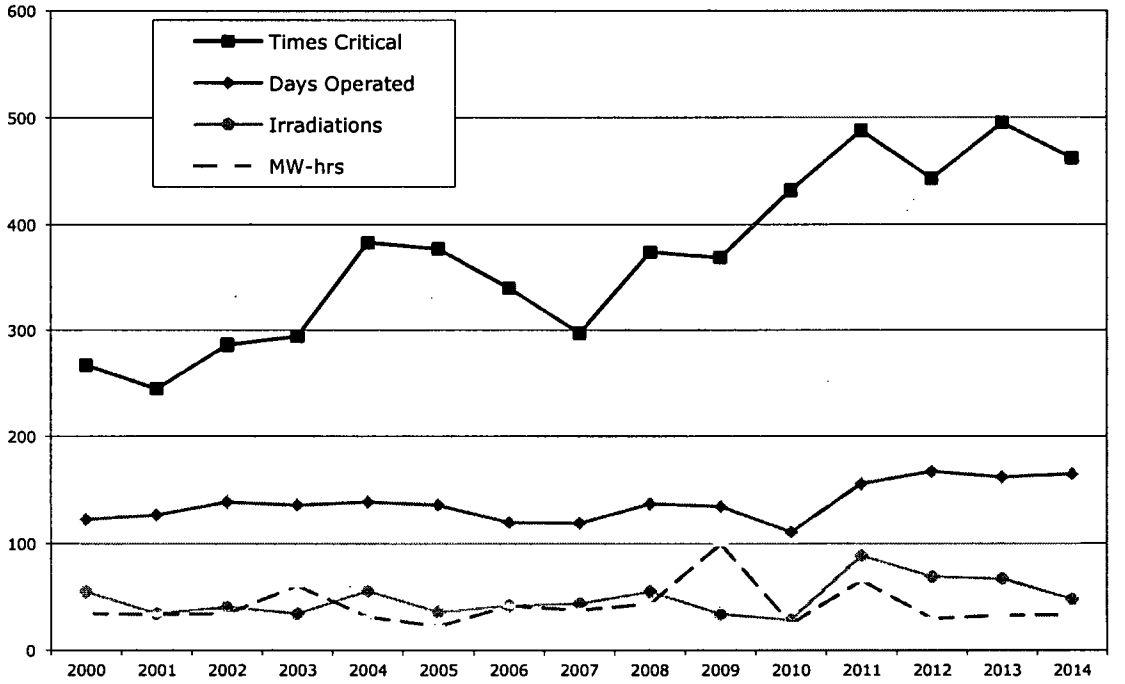


Figure 3. Operations

Unplanned Reactor Shutdowns

There were 4 inadvertent reactor shutdowns (scrams) as shown in table 2. The number of unplanned reactor shutdowns is shown in figure 4.

Table 2 Unplanned Reactor Shutdowns

DATE	SCRAM TYPE	CAUSE OF SCRAM
July 18, 2013	Linear High Power	Overshot high power SCRAM set point
Sept. 15, 2013	Linear High Power	Overshot high power SCRAM set point
Dec. 03, 2013	Linear High Power	Reactor SCRAM due to power bump while operating
Feb. 10, 2014	Linear High Power	Overshot high power SCRAM set point

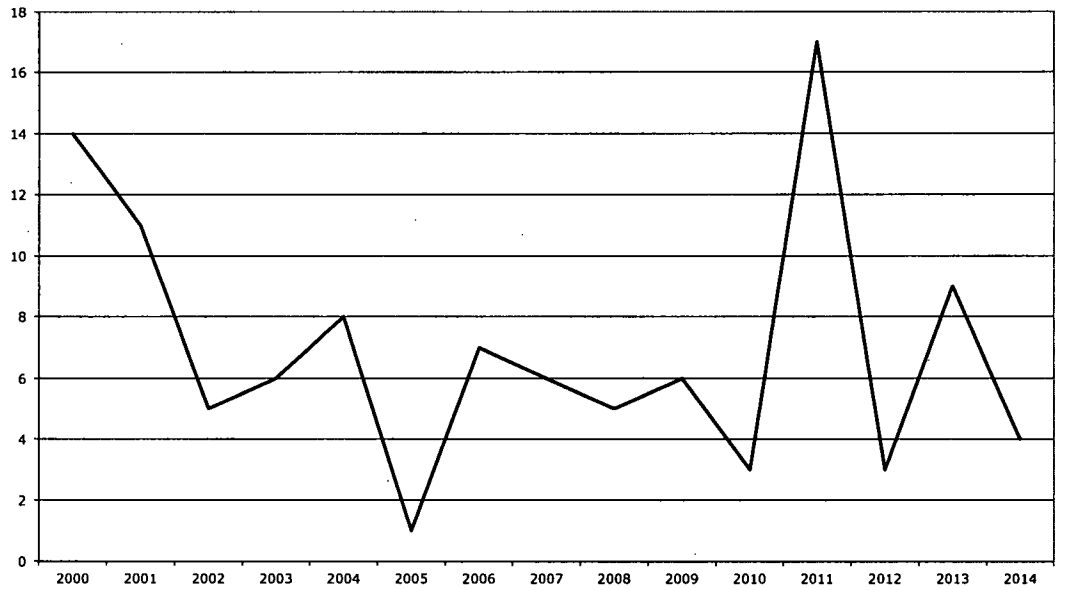


Figure 4 Unplanned Shutdowns

REACTOR MAINTENANCE

Significant Maintenance

Reactor staff performs routine equipment checks 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. The following is a list of significant maintenance preformed during this reporting period.

- Cleaned the heat exchanger
- Replaced flow meter and some piping on the primary loop.
- Installed check valve (10 CFR 50.59 Screening 12-8)
- Installed the thermocouple array
- Replaced the pH meter

Two experiments were approved by the ROC.

- Routine experiment 9 - Neutron Induced Auto radiography
- Routine experiment 10 - Radial Flux measurements

RADIATION PROTECTION

Personnel Dosimetry

Dosimeters are changed on a calendar quarter schedule. Individuals were issued beta-gamma sensitive ring badges and whole-body badges. The Director and Reactor Operations Manager were issued beta-gamma-neutron sensitive dosimetry.

During the year, no dose was recorded above the minimum for both the deep dose equivalent or shallow dose equivalent

Fixed Area Dosimetry

Radiation levels are continually monitored to provide an indication of the average radiation levels in the reactor bay and dose outside the facility. All dosimeters monitor beta and gamma radiation. Three locations also measure neutron dose.

The deep dose equivalent radiation measured by fixed dosimeters during the period July 1, 2013 to June 30, 2014 are shown in table 5. M indicated less than 1 mrem during the quarter.

Table 5 Area Radiation Dosimeters
(doses are in mrem per calendar quarter)

LOCATION	HEIGHT (M)	RADIATION DETECTED	JUL 1 – SEP 30	OCT 1 - DEC 31	JAN 1 - MAR 31	APR 1 - JUN 30	TOTAL
Reactor East Wall	1.5	β, γ	10	6	2	2	20
Reactor North Wall	1.6	β, γ	4	2	0	6	12
Reactor West Wall	1.0	β, γ, n	23	29	34	17	103
Reactor South Wall	1.6	β, γ, n	5	11	4	5	25
Reactor North Wall	2.3	β, γ	4	8	3	2	17
Control Room	1.5	β, γ	3	4	2	3	12
Outside North	2.8	β, γ	0	5	0	M	5
Outside Roof	0.4	β, γ, n	M	M	M	M	M
Outside East	1.5	β, γ	M	M	M	M	M
Outside South	0.4	β, γ	M	M	M	M	M
Counting Room	1.5	β, γ	M	M	M	M	M

Gaseous Releases

The only routine release of gaseous radioactivity is from ^{41}Ar (1.83-hour half-life) and ^{16}N (7.13-second half-life). These come from activation of pool water and air in the pool water and in the irradiation facilities. For the reporting period, the average gaseous activity at the site boundary was 3.69 x 10^{-10} μCi/ml, which would deliver a dose to a member of the public of approximately 1.85 mrem, well below regulatory guidelines and constraints. Figure 5 shows the gaseous releases for each year.

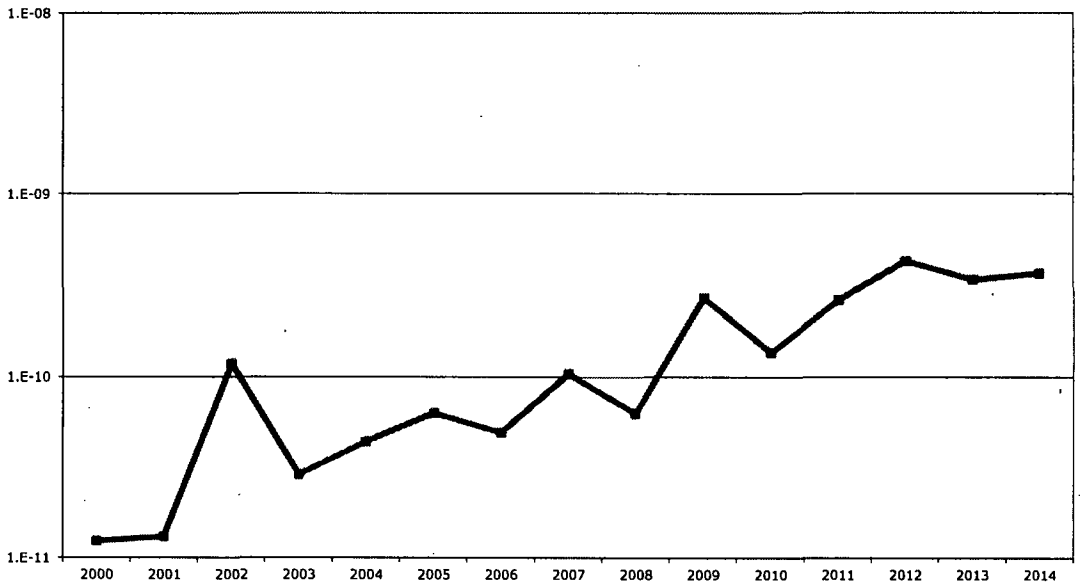


Figure 5 Gaseous Releases Activity (μCi/ml) at Site Boundary

Liquid Waste Releases

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

Solid Waste Disposal

There were no shipments of low-level radioactive waste from the facility during this reporting period.

Environmental Sampling

Soil samples taken from the area surrounding the facility showed no activity above background. Water from the facility's secondary cooling system and the nearby canyon were sampled for activation products and tritium, but showed no activity above normal background.