Radiation Center and TRIGA Reactor

Annual Report

July 1, 2011 — June 30, 2012

OSU
Oregon State
UNIVERSITY

Submitted by:
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To satisy the requirements of :

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B. Battelle Energy Alliance, LLC; Subcontract Award No. 00074510.

C. Oregon Department of Energy, OOE Rule No. 345-030-010.

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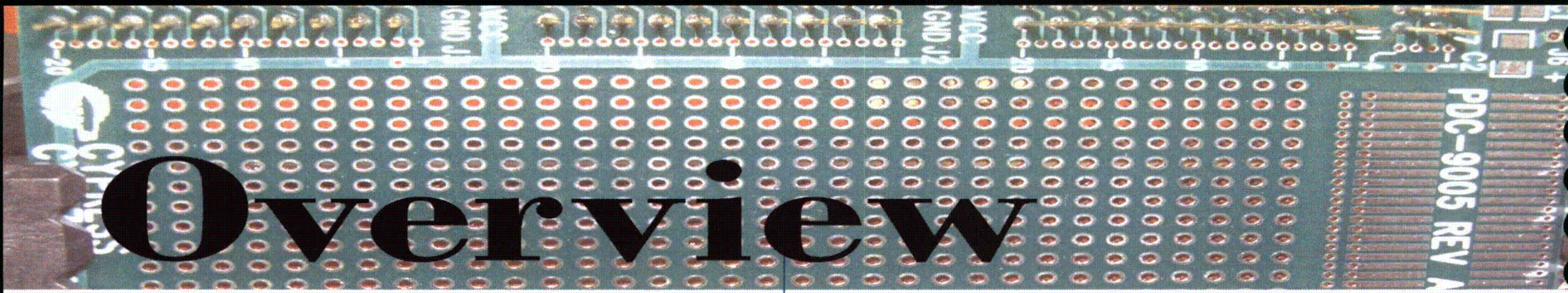


Overview

Executive Summary

The data from this reporting year shows that the use of the Radiation Center and the Oregon State TRIGA reactor (OSTR) has continued to grow in many areas.

The Radiation Center supported 58 different courses this year, mostly in the Department of Nuclear Engineering, Radiation Health Physics, Medical Physics, and Radiochemistry. About 29% of these courses involved the OSTR. The number of OSTR hours used for academic courses and training was 28, while 4,849 hours were used for research projects. Sixty-five percent of the OSTR research hours were in support of off-campus research projects, reflecting the use of the OSTR nationally and internationally. Radiation Center users published or submitted 83 articles this year, and made 83 presentations on work that involved the OSTR or Radiation Center. The number of samples irradiated in the reactor during this reporting period was 3,584. Funded OSTR use hours comprised 84% of the research use.

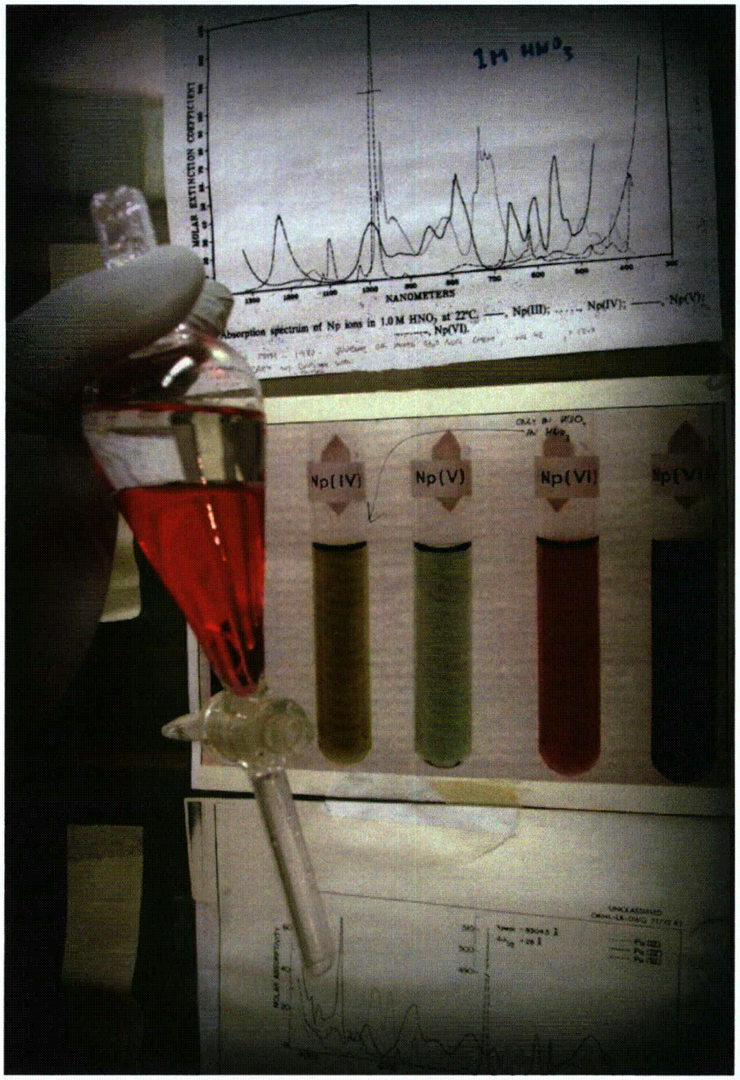
Personnel at the Radiation Center conducted 123 tours of the facility, accommodating 1,392 visitors. The visitors included elementary, middle school, high school, and college students; relatives and friends; faculty; current and prospective clients; national laboratory and industrial scientists and engineers; and state, federal and international officials. The Radiation Center is a significant positive attraction on campus because visitors leave with a good impression of the facility and of Oregon State University.

The Radiation Center projects database continues to provide a useful way of tracking the many different aspects of work at the facility. The number of projects supported this year was 205. Reactor related projects comprised 68% of all projects. The total research supported by the Radiation Center, as reported by our researchers, was $8,076,109. The actual total is likely considerably higher. This year the Radiation Center provided service to 73 different organizations/institutions, 32% of which were from other states and 23% of which were from outside the U. S. and Canada. So while the Center's primary mission is local, it is also a facility with a national and international clientele.

The Radiation Center web site provides an easy way for potential users to evaluate the Center's facilities and capabilities as well as to apply for a project and check use charges. The address is: http://radiationcenter.oregonstate.edu.

Introduction

The current annual report of the Oregon State University Radiation Center and TRIGA Reactor follows the usual format by including information relating to the entire Radiation Center rather than just the reactor. However, the information is still presented in such a manner that data on the reactor may



be examined separately, if desired. It should be noted that all annual data given in this report covers the period from July 1, 2011 through June 30, 2012. Cumulative reactor operating data in this report relates only to the LEU fueled core. This covers the period beginning July 1, 2008 to the present date. For a summary of data on the reactor's two other cores, the reader is referred to previous annual reports.

In addition to providing general information about the activities of the Radiation Center, this report is designed to meet the reporting requirements of the U. S. Nuclear Regulatory Commission, the U. S. Department of Energy, and the Oregon Department of Energy. Because of this, the report is divided into several distinct parts so that the reader may easily find the sections of interest.

Overview of the Radiation Center

The Radiation Center is a unique facility which serves the entire OSU campus, all other institutions within the Oregon University System, and many other universities and organizations throughout the nation and the world. The Center also regularly provides special services to state and federal agencies, particularly agencies dealing with law enforcement, energy, health, and environmental quality, and renders assistance to Oregon industry. In addition, the Radiation Center provides permanent office and laboratory space for the OSU Department of Nuclear Engineering and Radiation Health Physics, the OSU Institute of Nuclear Science and Engineering, and for the OSU nuclear chemistry, radiation chemistry, geochemistry and radiochemistry programs. There is no other university facility with the combined capabilities of the OSU Radiation Center in the western half of the United States.

Located in the Radiation Center are many items of specialized equipment and unique teaching and research facilities. They include a TRIGA Mark II research nuclear reactor; a ^{60}Co gamma irradiator; a large number of state-of-the art computer-based gamma radiation spectrometers and associated germanium detectors; and a variety of instruments for radiation measurements and monitoring. Specialized facilities for radiation work include teaching and research laboratories with instrumentation and related equipment for performing neutron activation analysis and radiotracer studies; laboratories for plant experiments involving radioactivity; a facility for repair and calibration of radiation protection instrumentation; and facilities for packaging radioactive materials for shipment to national and international destinations.

A major non-nuclear facility housed in the Radiation Center is the one-quarter scale thermal hydraulic advanced plant experimental (APEX) test facility for the Westinghouse AP600 and AP1000 reactor designs. The AP600 and AP1000 are next-generation nuclear reactor designs which incorporate many passive safety features as well as considerably simplified plant systems and equipment. APEX operates at pressures up to 400 psia and temperatures up to 450°F using electrical heaters instead of nuclear fuel. All major components of the AP600 and AP1000 are included in APEX and all systems are appropriately scaled to enable the experimental measurements to be used for safety evaluations and licensing of the full scale plant. This world-class facility meets exacting quality assurance criteria to provide assurance of safety as well as validity of the test results.

Also housed in the Radiation Center is the Advanced Thermal Hydraulics Research Laboratory (ATHRL), which is used for state-of-the-art two-phase flow experiments.

The Radiation Center staff regularly provides direct support and assistance to OSU teaching and research programs. Areas of expertise commonly involved in such efforts include nuclear engineering, nuclear and radiation chemistry, neutron activation analysis, radiation effects on biological systems, radiation dosimetry, environmental radioactivity, production of short-lived radioisotopes, radiation shielding, nuclear instrumentation, emergency response, transportation of radioactive materials, instrument calibration, radiation health physics, radioactive waste disposal, and other related areas.

In addition to formal academic and research support, the Center's staff provides a wide variety of other services including public tours and instructional programs, and professional consultation associated with the feasibility, design, safety, and execution of experiments using radiation and radioactive materials.

People

This section contains a listing of all people who were residents of the Radiation Center or who worked a significant amount of time at the Center during this reporting period.

It should be noted that not all of the faculty and students who used the Radiation Center for their teaching and research are listed. Summary information on the number of people involved is given in Table VI.1, while individual names and projects are listed in Table VI.2.

Radiation Center Staff

Steve Reese, Director

Dina Pope, Office Manager

Shaun Bromagem, Business Manager

Kimberly Reese, Receptionist

S. Todd Keller, Reactor Administrator

Gary Wachs, Reactor Supervisor, Senior Reactor Operator

Robert Schickler, Senior Reactor Operator

Wade Marcum, Reactor Operator

Scott Menn, Senior Health Physicist

Jim Darrough, Health Physicist

Leah Minc, Neutron Activation Analysis Manager

Steve Smith, Scientific Instrument Technician, Senior Reactor Operator

Erin Cimbri, Custodian

Ryne Burgess, Health Physics Monitor (Student)

Kyle Combs, Health Physics Monitor (Student)

Joey DeShields, Health Physics Monitor (Student)

Reactor Operations Committee

Andrew Klein, Chair
OSU Nuclear Engineering and Radiation Health Physics

Rainier Farmer
OSU Radiation Safety

Abi Tavakoli Farsoni
OSU Nuclear Engineering and Radiation Health Physics

Michael Hartman
University of Michigan

Todd Keller
OSU Radiation Center

Scott Menn
OSU Radiation Center

Steve Reese *(not voting)*
OSU Radiation Center

Gary Wachs *(not voting)*
OSU Radiation Center

Bill Warnes
OSU Mechanical Engineering

Professional and Research Faculty

Binney, Stephen E.
Director Emeritus, Radiation Center, Professor Emeritus, Nuclear Engineering and Radiation Health Physics

Daniels, Malcolm
Professor Emeritus, Chemistry

****Hamby, David***
Professor, Nuclear Engineering and Radiation Health Physics

Hart, Lucas P.
Faculty Research Associate, Chemistry

****Higginbotham, Jack F.***
Director, Oregon Space Grant, Professor, Nuclear Engineering and Radiation Health Physics

****Higley, Kathryn A.***
Department Head, Nuclear Engineering and Radiation Health Physics

Johnson, Arthur G.
Director Emeritus, Radiation Center, Professor Emeritus, Nuclear Engineering and Radiation Health Physics

****Keller, S. Todd***
Reactor Administrator, Radiation Center

Klein, Andrew C.
Professor, Nuclear Engineering and Radiation Health Physics

****Krane, Kenneth S.***
Professor Emeritus, Physics

****Loveland, Walter D.***
Professor, Chemistry

****Menn, Scott A.***
Senior Health Physicist, Radiation Center

****Minc, Leah***
Assistant Professor, Anthropology

****Palmer, Todd S.***
Professor, Nuclear Engineering and Radiation Health Physics

****Paulenova, Alena***
Associate Professor, Senior Research, Radiation Center

Pope, Dina
Office Manager, Radiation Center

****Reese, Steven R.***
Director, Radiation Center

Reyes, Jr., José N.
Professor, Nuclear Engineering and Radiation Health Physics, ATHRL Principal Investigator

Ringle, John C.
Professor Emeritus, Nuclear Engineering and Radiation Health Physics

Robinson, Alan H.
Department Head, Emeritus, Nuclear Engineering and Radiation Health Physics

****Schmitt, Roman A.***
Professor Emeritus, Chemistry

Krystina Tack
Medical Physics Program Director

****Wachs, Gary***
Reactor Supervisor, Radiation Center

Woods, Brian
Associate Professor, Nuclear Engineering and Radiation Health Physics

Wu, Qiao
Professor, Nuclear Engineer and Radiation Health Physics

**OSTR users for research and/or teaching*

Facilities

Research Reactor

The Oregon State University TRIGA Reactor (OSTR) is a water-cooled, swimming pool type research reactor which uses uranium/zirconium hydride fuel elements in a circular grid array. The reactor core is surrounded by a ring of graphite which serves to reflect neutrons back into the core. The core is situated near the bottom of a 22-foot deep water-filled tank, and the tank is surrounded by a concrete bioshield which acts as a radiation shield and structural support. The reactor is licensed by the U.S. Nuclear Regulatory Commission to operate at a maximum steady state power of 1.1 MW and can also be pulsed up to a peak power of about 2500 MW.

The OSTR has a number of different irradiation facilities including a pneumatic transfer tube, a rotating rack, a thermal column, four beam ports, five sample holding (dummy) fuel elements for special in-core irradiations, an in-core irradiation tube, and a cadmium-lined in-core irradiation tube for experiments requiring a high energy neutron flux.

The **pneumatic transfer facility** enables samples to be inserted and removed from the core in four to five seconds. Consequently this facility is normally used for neutron activation analysis involving short-lived radionuclides. On the other hand, the **rotating rack** is used for much longer irradiation of samples (e.g., hours). The rack consists of a circular array of 40 tubular positions, each of which can hold two sample tubes. Rotation of the rack ensures that each sample will receive an identical irradiation.

The reactor's **thermal column** consists of a large stack of graphite blocks which slows down neutrons from the reactor core in order to increase thermal neutron activation of samples. Over 99% of the neutrons in the thermal column are thermal neutrons. Graphite blocks are removed from the thermal column to enable samples to be positioned inside for irradiation.

The **beam ports** are tubular penetrations in the reactor's main concrete shield which enable neutron and gamma radiation to stream from the core when a beam port's shield plugs are removed. The neutron radiography facility utilized the tangential beam port (beam port #3) to produce ASTM E545 category I radiography capability. The other beam ports are available for a variety of experiments.

If samples to be irradiated require a large neutron fluence, especially from higher energy neutrons, they may be inserted into a dummy fuel element. This device will then be placed into one of the core's inner grid positions which would normally be occupied by a fuel element. Similarly samples can be placed in the **in-core irradiation tube (ICIT)** which can be inserted in the same core location.

The **cadmium-lined in-core irradiation tube (CLICIT)** enables samples to be irradiated in a high flux region near the center of the core. The cadmium lining in the facility eliminates thermal neutrons and thus permits sample exposure to higher energy neutrons only. The cadmium-lined end of this air-filled aluminum irradiation tube is inserted into an inner grid position of the reactor core which would normally be occupied by a fuel element. It is the same as the ICIT except for the presence of the cadmium lining.

The two main uses of the OSTR are instruction and research.

Instruction

Instructional use of the reactor is twofold. First, it is used significantly for classes in Nuclear Engineering, Radiation Health Physics, and Chemistry at both the graduate and undergraduate levels to demonstrate numerous principles which have been presented in the classroom. Basic neutron behavior is the same in small reactors as it is in large power reactors, and many demonstrations and instructional experiments can be performed using the OSTR which cannot be carried out with a commercial power reactor. Shorter-term demonstration experiments are also performed for many undergraduate students in Physics, Chemistry, and Biology classes, as well as for visitors from other universities and colleges, from high schools, and from public groups.

The second instructional application of the OSTR involves educating reactor operators, operations managers, and health physicists. The OSTR is in a unique position to provide such education since curricula must include hands-on experience at an operating reactor and in associated laboratories. The many types of educational programs that the Radiation Center provides are more fully described in Part VI of this report.

During this reporting period the OSTR accommodated a number of different OSU academic classes and other academic programs. In addition, portions of classes from other Oregon universities were also supported by the OSTR.

Research

The OSTR is a unique and valuable tool for a wide variety of research applications and serves as an excellent source of neutrons and/or gamma radiation. The most commonly used experimental technique requiring reactor use is instrumental neutron activation analysis (INAA). This is a particularly sensitive method of elemental analysis which is described in more detail in Part VI.

The OSTR's irradiation facilities provide a wide range of neutron flux levels and neutron flux qualities which are sufficient to meet the needs of most researchers. This is true not only for INAA, but also for other experimental purposes such as the $^{39}Ar/^{40}Ar$ ratio and fission track methods of age dating samples.

Analytical Equipment

The Radiation Center has a large variety of radiation detection instrumentation. This equipment is upgraded as necessary, especially the gamma ray spectrometers with their associated computers and germanium detectors. Additional equipment for classroom use and an extensive inventory of portable radiation detection instrumentation are also available.

Radiation Center nuclear instrumentation receives intensive use in both teaching and research applications. In addition, service projects also use these systems and the combined use often results in 24-hour per day schedules for many of the analytical instruments. Use of Radiation Center equipment extends beyond that located at the Center and instrumentation may be made available on a loan basis to OSU researchers in other departments.

Radioisotope Irradiation Sources

The Radiation Center is equipped with a 1,644 curie (as of 7/27/01) Gammacell 220 ^{60}Co irradiator which is capable of delivering high doses of gamma radiation over a range of dose rates to a variety of materials.

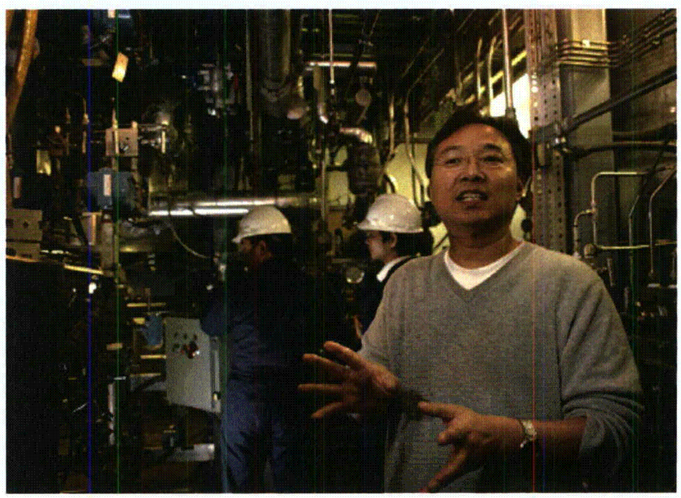
Typically, the irradiator is used by researchers wishing to perform mutation and other biological effects studies; studies in the area of radiation chemistry; dosimeter testing; sterilization of food materials, soils, sediments, biological specimen, and other media; gamma radiation damage studies; and other such applications. In addition to the ^{60}Co irradiator, the Center is also equipped with a variety of smaller ^{60}Co, ^{137}Cs, ^{226}Ra, plutonium-beryllium, and other isotopic sealed sources of various radioactivity levels which are available for use as irradiation sources.

During this reporting period there was a diverse group of projects using the ^{60}Co irradiator. These projects included the irradiation of a variety of biological materials including different types of seeds.

In addition, the irradiator was used for sterilization of several media and the evaluation of the radiation effects on different materials. Table III.1 provides use data for the Gammacell 220 irradiator.

Laboratories and Classrooms

The Radiation Center is equipped with a number of different radioactive material laboratories designed to accommodate research projects and classes offered by various OSU academic departments or off-campus groups.



Instructional facilities available at the Center include a laboratory especially equipped for teaching radiochemistry and a nuclear instrumentation teaching laboratory equipped with modular sets of counting equipment which can be configured to accommodate a variety of experiments involving the measurement of many types of radiation. The Center also has two student computer rooms.

In addition to these dedicated instructional facilities, many other research laboratories and pieces of specialized equipment are regularly used for teaching. In particular, classes are routinely given access to gamma spectrometry equipment located in Center laboratories. A number of classes also regularly use the OSTR and the Reactor Bay as an integral part of their instructional coursework.

There are two classrooms in the Radiation Center which are capable of holding about 35 and 18 students. In addition, there are two smaller conference rooms and a library suitable for graduate classes and thesis examinations. As a service to the student body, the Radiation Center also provides an office area for the student chapters of the American Nuclear Society and the Health Physics Society.

This reporting period saw continued high utilization of the Radiation Center's thermal hydraulics laboratory. This laboratory is being used by Nuclear Engineering faculty members to accommodate a one-quarter scale model of the Palisades Nuclear Power reactor. The multi-million dollar advanced plant experimental (APEX) facility was fully utilized by the U. S. Nuclear Regulatory Commission to provide licensing data and to test safety systems in "beyond design basis" accidents. The fully scaled, integral model APEX facility uses electrical heating elements to simulate the fuel elements, operates at 450°F and 400 psia, and responds at twice real time. It is the only facility of its type in the world and is owned by the U. S. Department of Energy and operated by OSU. In addition, a new building, Advanced Thermal Hydraulics Research Laboratory (ATHRL) was constructed next to the Reactor Building in 1998.

All of the laboratories and classrooms are used extensively during the academic year. A listing of courses accommodated at the Radiation Center during this reporting period along with their enrollments is given in Table III.2.

Instrument Repair & Calibration Facility

The Radiation Center has a facility for the repair and calibration of essentially all types of radiation monitoring instrumentation. This includes instruments for the detection and measurement of alpha, beta, gamma, and neutron radiation. It encompasses both high range instruments for measuring intense radiation fields and low range instruments used to measure environmental levels of radioactivity.

The Center's instrument repair and calibration facility is used regularly throughout the year and is absolutely essential to the continued operation of the many different programs carried out at the Center. In addition, the absence of any comparable facility in the state has led to a greatly expanded instrument calibration program for the Center, including calibration of essentially all radiation detection instruments used by state and federal agencies in the state of Oregon. This includes instruments used on the OSU campus and all other institutions in the Oregon University System, plus instruments from the Oregon Health Division's Radiation Protection Services, the Oregon Department of Energy, the Oregon Public Utilities Commission, the Oregon Health Sciences University, the Army Corps of Engineers, and the U. S. Environmental Protection Agency.

Library

The Radiation Center has a library containing a significant collections of texts, research reports, and videotapes relating to nuclear science, nuclear engineering, and radiation protection.

The Radiation Center is also a regular recipient of a great variety of publications from commercial publishers in the nuclear field, from many of the professional nuclear societies, from the U. S. Department of Energy, the U. S. Nuclear Regulatory Commission, and other federal agencies. Therefore, the Center library maintains a current collection of leading nuclear research and regulatory documentation. In addition, the Center has a collection of a number of nuclear power reactor Safety Analysis Reports and Environmental Reports specifically prepared by utilities for their facilities.

The Center maintains an up-to-date set of reports from such organizations as the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurements, and the International Commission on Radiological Units. Sets of the current U.S. Code of Federal Regulations for the U.S. Nuclear Regulatory Commission, the U.S. Department of Transportation, and other appropriate federal agencies, plus regulations of various state regulatory agencies are also available at the Center.

The Radiation Center videotape library has over one hundred tapes on nuclear engineering, radiation protection, and radiological emergency response topics. In addition, the Radiation Center uses videotapes for most of the technical orientations which are required for personnel working with radiation and radioactive materials. These tapes reproduced, recorded, and edited by Radiation Center staff, using the Center's videotape equipment and the facilities of the OSU Communication Media Center.

The Radiation Center library is used mainly to provide reference material on an as-needed basis. It receives extensive use during the academic year. In addition, the orientation videotapes are used intensively during the beginning of each term and periodically thereafter.

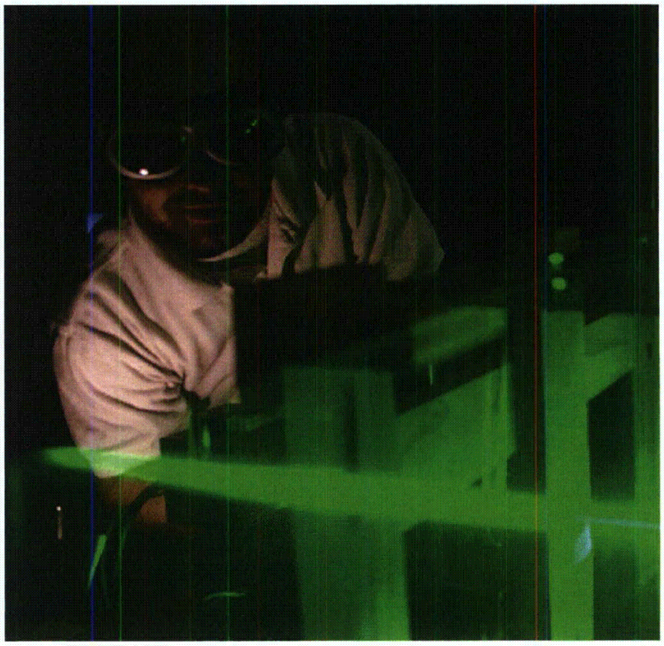


Table III.1
Gammacell 220 ^{60}Co Irradiator Use

Purpose of Irradiation	Samples	Dose Range (rads)	Number of Irradiations	Use Time (hours)
Sterilization	wood, honey, pig skin	$2.5x10^6$ to $2.5x10^6$	13	1377
Material Evaluation	silicon polymers, polymers, chemicals, electronic components	$3.0x10^5$ to $1.0x10^7$	25	662
Botanical Studies	wood, wheat pollen, potatoes, pollen, carnation leaves	$5.0x10^2$ to $2.5x10^6$	22	183
Biological Studies	mice	$5.0x10^2$ to $1.0x10^3$	11	0
Totals			71	2222

Table III.2

Student Enrollment in Courses Which are Taught or Partially Taught at the Radiation Center

Course #	CREDIT	COURSE TITLE	Number of Students			
			Summer 2011	Fall 2011	Winter 2012	Spring 2012
NE/ RHP 114*	2	Introduction to Nuclear Engineering and Radiation Health Physics		58		
NE/ RHP 115	2	Introduction to Nuclear Engineering and Radiation Health Physics			58	
NE/ RHP 116**	2	Introduction to Nuclear Engineering and Radiation Health Physics				56
NE/ RHP 234	4	Nuclear and Radiation Physics I		66		
NE/ RHP 235	4	Nuclear and Radiation Physics II			64	
NE/ RHP 236*	4	Nuclear Radiation Detection & Instrumentation				50
NE 311	4	Intro to Thermal Fluids	6	32	5	
NE 312	4	Thermodynamics			27	14
NE 319	3	Societal Aspects of Nuclear technology			68	
NE 331	4	Intro to Fluid Mechanics			27	10
NE 332	4	Heat Transfer	10	5		31
NE/RHP 333	3	Mathematical methods for NE/RHP			35	
NE/RHP/MP 401/501/601	1-16	Research	5	24	19	19
NE/RHP/MP 405/505/605	1-16	Reading and Conference		2		
NE/RHP/MP 406/506/606	1-16	Projects			1	1
NE/RHP/MP 407/507/607	1	Nuclear Engineering Seminar		96	57	91
NE/ RHP/MP 410/510/610	1-12	Internship		1		
NE/ RHP 415/515	2	Nuclear Rules and Regulations		72		
NE 451/551	4	Neutronic Analysis		35		
NE 452/552	4	Neutronic Analysis			31	
NE 455/555**	3	Reactor Operator Training I				23
NE 457/557**	3	Neuclear Reactor Lab				27
NE 467/567	4	Nuclear Reactor Thermal Hydraulics		31		
NE 667	4	Nuclear Reactor Thermal Hydraulics				
NE/RHP 435/535	3	External Dosimetry & Radiation Shielding				72
NE 474/574	4	Nuclear System Design I			44	
NE/RHP 475/575	4	Nuclear System Design II				37

Table III.2 (continued)

Student Enrollment in Courses Which are Taught or Partially Taught at the Radiation Center

Course #	CREDIT	COURSE TITLE	Number of Students			
			Summer 2010	Fall 2010	Winter 2011	Spring 2011
NE?RHP 479*	1-4	Individual Design Project				
NE/RHP 481*	4	Radiation Protection		55		
NE/RHP 582*	4	Applied Radiation Safety			17	
RHP 483/583	4	Radiation Biology			39	
RHP 488/588*	3	Radioecology		36		
NE/RHP 590	4	Internal Dosimetry			14	
NE/RHP/MP 503/603*	1	Thesis	28	39	41	48
NE/ RHP 516*	4	Radiochemistry	15			13
NE 526	3	Numerical Methods for Engineering Analysis				
NE/RHP/MP 531	3	Nuclear Physics for Engineers and Scientists		21		
NE/RHP/MP 536*	3	Advanced Radiation Detection & Measurement			21	
NE/RHP 537	3	Digital Spectrometer Design				
MP 541	3	Diagnostic Imaging Physics				
NE 550	3	Nuclear Medicine				
NE 553*	3	Advanced Nuclear Reactor Physics				16
NE 568	3	Nuclear Reactor Safety				
Course From Other OSU Departments						
CH 123*	5	General Chemistry				545
CH 222*	5	General Chemistry (Science Majors)			527	
CH 225H*	5	Honors General Chemistry			40	
CH 462*	3	Experimental Chemistry II Laboratory			12	
GEO 330*	3	Environmental Conservation			**28**	

ST *Special Topics*
* *OSTR used occasionally for demonstration and/or experiments*
** *OSTR used heavily*

Reactor

Operating Status

During the operating period between July 1, 2011 and June 30, 2012, the reactor produced 1418 MWH of thermal power during its 1510 critical hours.

Experiments Performed

During the current reporting period there were nine approved reactor experiments available for use in reactor-related programs. They are:

- A-1 Normal TRIGA Operation (No Sample Irradiation).
- B-3 Irradiation of Materials in the Standard OSTR Irradiation Facilities.
- B-11 Irradiation of Materials Involving Specific Quantities of Uranium and Thorium in the Standard OSTR Irradiation Facilities.
- B-12 Exploratory Experiments.
- B-23 Studies Using TRIGA Thermal Column.
- B-29 Reactivity Worth of Fuel.
- B-31 TRIGA Flux Mapping.
- B-33 Irradiation of Combustible Liquids in Rotating Rack.
- B-34 Irradiation of enriched uranium in the Neutron Radiography Facility.
- B-35 Irradiation of enriched uranium in the PGNAA Facility.

Of these available experiments, four were used during the reporting period. Table IV.4 provides information related to the frequency of use and the general purpose of their use.

Inactive Experiments

Presently 33 experiments are in the inactive file. This consists of experiments which have been performed in the past and may be reactivated. Many of these experiments are now performed under the more general experiments listed in the previous section. The following list identifies these inactive experiments.

- A-2 Measurement of Reactor Power Level via Mn Activation.
- A-3 Measurement of Cd Ratios for Mn, In, and Au in Rotating Rack.
- A-4 Neutron Flux Measurements in TRIGA.
- A-5 Copper Wire Irradiation.
- A-6 In-core Irradiation of LiF Crystals.
- A-7 Investigation of TRIGA's Reactor Bath Water Temperature Coefficient and High Power Level Power Fluctuation.
- B-1 Activation Analysis of Stone Meteorites, Other Meteorites, and Terrestrial Rocks.
- B-2 Measurements of Cd Ratios of Mn, In, and Au in Thermal Column.
- B-4 Flux Mapping.
- B-5 In-core Irradiation of Foils for Neutron Spectral Measurements.
- B-6 Measurements of Neutron Spectra in External Irradiation Facilities.
- B-7 Measurements of Gamma Doses in External Irradiation Facilities.
- B-8 Isotope Production.
- B-9 Neutron Radiography.
- B-10 Neutron Diffraction.
- B-13 This experiment number was changed to A-7.
- B-14 Detection of Chemically Bound Neutrons.
- B-15 This experiment number was changed to C-1.

B-16 Production and Preparation of ^{18}F.

B-17 Fission Fragment Gamma Ray Angular Correlations.

B-18 A Study of Delayed Status (n, γ) Produced Nuclei.

B-19 Instrument Timing via Light Triggering.

B-20 Sinusoidal Pile Oscillator.

B-21 Beam Port #3 Neutron Radiography Facility.

B-22 Water Flow Measurements Through TRIGA Core.

B-24 General Neutron Radiography.

B-25 Neutron Flux Monitors.

B-26 Fast Neutron Spectrum Generator.

B-27 Neutron Flux Determination Adjacent to the OSTR Core.

B-28 Gamma Scan of Sodium (TED) Capsule.

B-30 NAA of Jet, Diesel, and Furnace Fuels.

B-32 Argon Production Facility

C-1 PuO_2 Transient Experiment.

Unplanned Shutdowns

There were four unplanned reactor shutdowns during the current reporting period. Table IV.5 details these events.

Changes Pursuant to10 CFR 50-59

One safety evaluation was performed in support of the reactor this year. It was:

11-01, Changes to Reactor Experiment B-35, Irradiation of Enriched Uranium in the Prompt Gamma Neutron Activation Analysis Facility

Description

The use of the PGNAA irradiation facility was expanded to include the installation of a pneumatic transfer system. This change takes into account the experience gained concerning assumed limits due to fission gas buildup and venting requirements.

One new safety evaluation screen was performed in support of the reactor this year. It was:

11-05, Installation of a Pneumatic Transfer System in the PGNAA Instrument

Description

This screen allows the installation of a fast pneumatic transfer system within the main PGNAA irradiation chamber to allow rapid measurement of short lived fission fragments outside the irradiation chamber where background levels are low.

Surveillance and Maintenance

Non-Routine Maintenance

October 2011

- Reconstructed the drain basin for Beam Port #1 to include a catch tray and easy drain system.

November 2011

- Replaced failing fission chamber detector due to cable insulation breakdown.

December 2011

- Completed painting of reactor pedestal and NRF structure.
- Rebuilt the Transient rod drive assembly with new bearings and air seals.
- Inspected the Transient rod to determine if possible catastrophic failure was likely to occur due to TRTR report.

February 2012

- Replaced rabbit system blower with similar new, and rebuilt the two original motors.
- Replaced #5 local ARM detector due to failure.
- Rebuilt the cooling tower chemical injection pump.

Reactor

March 2012

- Replace reactor stack guide wires using SS wire due to one broken and the other three rusty.
- Added a new HOBBs meter to monitor run hours on the new rabbit blowers to more closely control brush replacement needs.

April 2012

- Installed a rented charcoal filter and resin bed in the Heat Exchanger room to provide high quality makeup water during weekly drain and refill of reactor tank.

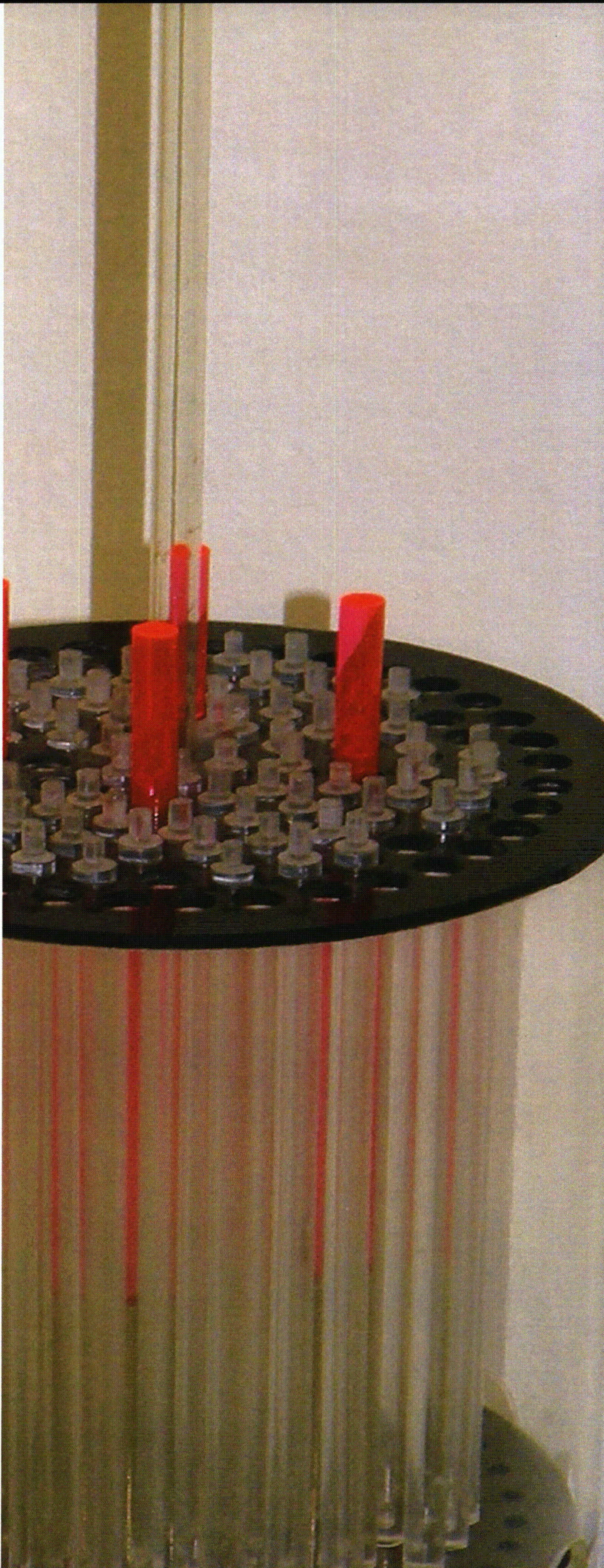


Table IV.1
Present OSTR Operating Statistics

Operational Data For LEU Core	Annual Values (2011/2012)	Cumulative Values
MWH of energy produced	1418	4676
MWD of energy produced	59	194.8
Grams ^{235}U used	81	269
Number of fuel elements added to (+) or removed(-) from the core	0	90
Number of pulses	39	134
Hours reactor critical	1510	5096
Hours at full power (1 MW)	1415	4655
Number of startup and shutdown checks	250	688
Number of irradiation requests processed	338	805
Number of samples irradiated	1352	3660

Table IV.2
OSTR Use Time in Terms of Specific Use Categories

OSTR Use Category	Annual Values (hours)	Cumulative Values (hours)
Teaching (departmental and others)	28	13,559.5
OSU Research	1,716	15,994
Off Campus research	3,133	37,275
Demonstrations	5	25
Reactor preclude time	789	30,197
Facility time	1	7,197
Total Reactor Use Time	5,672	104,481.5

Table IV.3
OSTR Multiple Use Time

Number of Users	Annual Values (hours)	Cumulative Values (hours)
Two	187	8,174
Three	452	3,984
Four	452	2,110
Five	180	640
Six	42	140
Seven	14	37
Total Multiple Use Time	1,327	15,085

Table IV.4
Use of OSTR Reactor Experiments

Experiment Number	Research	Teaching	Other	Total
A-1	9	0	0	9
B-3	286	20	0	306
B-35	1	0	0	1
B-31	22	0	0	22
Total	318	20	0	338

Table IV.5
Unplanned Reactor Shutdowns and Scrams

Type of Event	Number of Occurrences	Cause of Event
Percent Power Channel	2	Air voids in core during power calibration
Percent Power Chennel	1	Excessive operator rod withdrawal rate
Console Voltage Interruption	1	Vacuum inadvertently plugged into inverter circuit (D-106)

Figure IV.1
Monthly Surveillance and Maintenance (Sample Form)

OSTROP 13, Rev. LEU-1 Surveillance & Maintenance for the Month of ______________________

	SURVEILLANCE & MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]	LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED *	DATE COMPLETED	REMARKS & INITIALS
1	REACTOR TANK HIGH AND LOW WATER LEVEL ALARMS	MAXIMUM MOVEMENT ± 3 INCHES	UP:________INCHES DN:________INCHES ANN:____________				
2	BULK WATER TEMPERATURE ALARM CHECK	FUNCTIONAL					
3	CHANNEL TEST OF REACTOR TOP CAM AND STACK CAM	3600±100 cpm	Rx Top_______ Stack _______	—	—	—	—
4.A	MEASUREMENT OF REACTOR PRIMARY WATER CONDUCTIVITY	<5 μmho\cm					
4.B	PRIMARY WATER Ph MEASUREMENT	MIN: 5 MAX: 8.5					
5	BULK SHIELD TANK WATER Ph MEASUREMENT	MIN: 5 MAX: 8.5					
6	CHANGE LAZY SUSAN FILTER	FILTER CHANGED					
7	REACTOR TOP CAM OIL LEVEL CHECK	OSTROP 13.10	NEED OIL?______				
8	PROPANE TANK LIQUID LEVEL CHECK	> 50%					
9	PRIMARY PUMP BEARINGS OIL LEVEL CHECK	OSTROP 13.13	NEED OIL?______				
10	WATER MONITOR CHECK						

* Date not to be exceeded is only applicable to shaded items. It is equal to the time completed last month plus six weeks.

Figure IV.2
Quarterly Surveillance and Maintenance (Sample Form)

OSTROP 14, Rev. LEU-1 — Surveillance & Maintenance for the 1st / 2nd / 3rd / 4th Quarter of 20____

	SURVEILLANCE & MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]	LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED*	DATE COMPLETED	REMARKS & INITIALS
1	REACTOR OPERATION COMMITTEE (ROC) AUDIT	QUARTERLY					
2	QUARTERLY ROC MEETING	QUARTERLY					
3	NOT CURRENTLY USED	N/A					N/A
4	ERP INSPECTIONS	QUARTERLY					
5	NOT CURRENTLY USED	N/A					N/A
6	ROTATING RACK CHECK FOR UNKNOWN SAMPLES	EMPTY					
7	WATER MONITOR ALARM CHECK	FUNCTIONAL					
8	STACK MONITOR CHECKS (OIL DRIVE MOTORS, H.V. READINGS)	MOTORS OILED					
		PART: 1150 V ± 50	_____V				
		GAS: 900 V ± 50	_____V				
9	CHECK FILTER TAPE SPEED ON STACK MONITOR	1"/HR ± 0.2					
10	INCORPORATE 50.59 & ROCAS INTO DOCUMENTATION	QUARTERLY					
11	STACK MONITOR ALARM CIRCUIT CHECKS	ALARM ON CONTACT					

Figure IV.2 (continued)
Quarterly Surveillance and Maintenance (Sample Form)

OSTROP 14, Rev. LEU-1 — Surveillance & Maintenance for the 1st / 2nd / 3rd / 4th Quarter of 20____

	SURVEILLANCE & MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]	LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED*	DATE COMPLETED	REMARKS & INITIALS
12	ARM SYSTEM ALARM CHECKS	FUNCTIONAL					

CHAN	1	2	3S	3E	4	5	7	8	9	10	11	12	13	14
AUD														
LIGHT														
PANEL														
ANN														

		LIMITS	a) TIME	b) OPERATING EXERCISE			
13	OPERATOR LOG	a) ≥4 hours: at console (RO) or as Rx. Sup. (SRO) b) Complete Operating Exercise					

* Date not be exceeded only applies to shaded items. It is equal to the date completed last quarter plus four months.

Figure IV.3

Semi-Annual Surveillance and Maintenance (Sample Form)

OSTROP 15, Rev. LEU-1 — Surveillance & Maintenance for the 1st / 2nd Half of 20______

		SURVEILLANCE & MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]	LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED*	DATE COMPLETED	REMARKS & INITIALS
1	FUNCTIONAL CHECKS OF REACTOR INTERLOCKS	NEUTRON SOURCE COUNT RATE INTERLOCK	NO WITHDRAW					
			≥5 cps					
		TRANSIENT ROD AIR INTERLOCK	NO PULSE					
		PULSE PROHIBIT ABOVE 1 kW	≥1 kW					
		TWO ROD WITHDRAWAL PROHIBIT	1 only					
		PULSE MODE ROD MOVEMENT INTERLOCK	NO MOVEMENT					
		MAXIMUM PULSE REACTIVITY INSERTION LIMIT	≤ $2.50					
		PULSE INTERLOCK ON RANGE SWITCH	NO PULSE					
2	SAFETY CIRCUIT TEST	PERIOD SCRAM	≥3 sec					
3	NOT CURENTLY USED							
4	TEST PULSE	PULSE # ________ $________ ________ MW ________ °C	≤20% CHANGE	PULSE # ______ $______ ______ MW ______ °C				
5	NOT CURRENTLY USED							N/A
6	NOT CURRENTLY USED							N/A
7	NOT CURRENTLY USED							N/A

*Date not to be exceeded is only applicable to shaded items. It is equal to the date last time plus 7 1/2 months.

Figure IV.3 (continued)

Semi-Annual Surveillance and Maintenance (Sample Form)

OSTROP 15, Rev. LEU-1 — Surveillance & Maintenance for the 1st / 2nd Half of 20______

	SURVEILLANCE & MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]		LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED*	DATE COMPLETED	REMARKS & INITIALS
8	CLEANING & LUBRICATION OF TRANSIENT ROD CARRIER INTERNAL BARREL							
9	LUBRICATION OF BALL-NUT DRIVE ON TRANSIENT ROD CARRIER							
10	LUBRICATION OF THE ROTATING RACK BEARINGS		10W OIL					
11	CONSOLE CHECK LIST		OSTROP 15.XI					
12	INVERTER MAINTENANCE		See User Manual					
13	STANDARD CONTROL ROD MOTOR CHECKS		LO-17 Bodine Oil					
14	ION CHAMBER RESISTANCE MEASUREMENTS WITH MEGGAR INDUCED VOLTAGE	SAFETY CHANNEL	NONE (Info Only)					
		%POWER CHANNEL	NONE (Info Only)					
15	FISSION CHAMBER RESISTANCE CALCULATION $R = \frac{800\ V}{\Delta I}$	@ 100 V. I = ______ AMPS @ 900 V. I = ______ AMPS ΔI = ______ AMPS R = ______ Ω	NONE (Info Only)					
16	FUNCTIONAL CHECK OF HOLDUP TANK WATER LEVEL ALARMS		OSTROP 15.XVIII	HIGH ______ FULL______				
17	INSPECTION OF THE PNEUMATIC TRANSFER SYSTEM	BRUSH INSPECTION						
		SOLENOID VALVE INSPECTION	FUNCTIONAL					
		SAMPLE INSERTION TIME CHECK	≤6 SECONDS					

*Date not to be exceeded is only applicable to shaded items. It is equal to the date last time plus 7 1/2 months.

Figure IV.4
Annual Surveillance and Maintenance (Sample Form)

OSTROP 16, Rev. LEU-1 — Annual Surveillance and Maintenance for 20______

	SURVEILLANCE AND MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]		LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED*	DATE COMPLETED	REMARKS & INITIALS
1	BIENNIAL INSPECTION OF CONTROL RODS:	FFCRS	OSTROP 12.0					
		TRANS						
2	ANNUAL REPORT		NOV 1		OCT 1	NOV 1		
3	CONTROL ROD CALIBRATION:	NORMAL	OSTROP 9.0					
		CLICIT						
		ICIT/DUMMY						
4	REACTOR POWER CALIBRATION		OSTROP 8.0					
5	CALIBRATION OF REACTOR TANK WATER TEMP TEMPERATURE METERS		OSTROP 16.5					
6	CONTINUOUS AIR MONITOR CALIBRATION:	Particulate Monitor	RCHPP 18					
		Gas Monitor						
7	STACK MONITOR CALIBRATION	Particulate Monitor	RCHPP 18 & 26					
		Gas Monitor						
8	AREA RADIATION MONITOR CALIBRATION		RCHPP 18.0					
9	DECOMMISSIONING COST UPDATE		N/A	N/A		AUGUST 1		

* Date not be exceeded is only applicable to shaded items. It is equal to the date completed last year plus 15 months.
For biennial license requirements, it is equal to the date completed last time plus 2 1/2 years.

Figure IV.4 (continued)
Annual Surveillance and Maintenance (Sample Form)

OSTROP 16, Rev. LEU-1 — Annual Surveillance and Maintenance for 20______

SURVEILLANCE AND MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]			LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED*	DATE COMPLETED	REMARKS & INITIALS
10	SNM PHYSICAL INVENTORY		N/A	N/A	OCTOBER 1			
11	MATERIAL BALANCE REPORTS		N/A	N/A	NOVEMBER			
12	STANDARD CONTROL ROD DRIVE INSPECTION		OSTROP 16.13					
13	CORE EXCESS		≤$7.55	NORMAL ___ ICIT___ CLICIT ___				
14	EMERGENCY RESPONSE PLAN	CFD TRAINING						
		GOOD SAM TRAINING						
		ERP REVIEW						
		ERP DRILL						
		FIRST AID FOR:						
		FIRST AID FOR:						
		EVACUATION DRILL						
		AUTO EVAC ANNOUNCEMENT TEST						
		ERP EQUIPMENT INVENTORY						
		BIENNIAL SUPPORT AGREEMENTS						
15	PHYSICAL SECURITY PLAN	OSP/DPS TRAINING						
		PSP REVIEW						
		PSP DRILL						
		LOCK/SAFE COMBO CHANGES						
		AUTHORIZATION LIST UPDATE						
		SPOOF MEASUREMENTS						

* Date not be exceeded is only applicable to shaded items. It is equal to the date completed last year plus 15 months.
For biennial license requirements, it is equal to the date completed last time plus 2 1/2 years.

Figure IV.4 (continued)

Annual Surveillance and Maintenance (Sample Form)

OSTROP 16, Rev. LEU-1 | Annual Surveillance and Maintenance for 20______

#	SURVEILLANCE AND MAINTENANCE [SHADE INDICATES LICENSE REQUIREMENT]	LIMITS	AS FOUND	TARGET DATE	DATE NOT TO BE EXCEEDED*	DATE COMPLETED	REMARKS & INITIALS
16	KEY INVENTORY	ANNUAL					
17	CONTROL ROD WITHDRAWAL INSERTION & SCRAM TIMES						
	(TRANS / SAFE / SHIM / REG) SCRAM	≤2 sec					
	(TRANS / SAFE / SHIM / REG) W/D	<50 sec					
	(TRANS / SAFE / SHIM / REG) INSERT	≤50 sec					
18	REACTOR BAY VENTILATION SYSTEM SHUTDOWN TEST	DAMPERS CLOSE IN ≤5 SECONDS		1st Floor _____ 2nd Floor			
19	CALIBRATION OF THE FUEL ELEMENT TEMPERATURE CHANNEL	Per Checksheet					
20	FUEL ELEMENT INSPECTION FOR SELECTED ELEMENTS	≥ 20 FE's inspected No damage, deteriora.tion or swell. At least one FE from each ring inspected. 100% of irradiated FE's inspected after 5 years.					
21	REACTOR TANK AND CORE COMPONENT INSPECTION	NO WHITE SPOTS					
22	EMERGENCY LIGHT LOAD TEST	RCHPP 18.0					

#	REACTOR OPERATOR LICENSE CONDITIONS	ANNUAL REQUALIFICATION				BIENNIAL MEDICAL		EVERY 6 YEARS LICENSE		
		WRITTEN EXAM		OPERATING TEST				APPLICATION		EXPIRATION DATE
	OPERATOR NAME	DATE DUE	DATE PASSED	DATE DUE	DATE PASSED	DATE DUE	DATE COMPLETED	DUE DATE	DATE MAILED	
23										
24	NEUTRON RADIOGRAPHY FACILITY INTERLOCKS									

* Date not be exceeded is only applicable to shaded items. It is equal to the date completed last year plus 15 months.
For biennial license requirements, it is equal to the date completed last time plus 2 1/2 years.

Radiation Protection

Introduction

The purpose of the radiation protection program is to ensure the safe use of radiation and radioactive material in the Center's teaching, research, and service activities, and in a similar manner to the fulfillment of all regulatory requirements of the State of Oregon, the U.S. Nuclear Regulatory Commission, and other regulatory agencies. The comprehensive nature of the program is shown in Table V.1, which lists the program's major radiation protection requirements and the performance frequency for each item.

The radiation protection program is implemented by a staff consisting of a Senior Health Physicist, a Health Physicist, and several part-time Health Physics Monitors (see Part II). Assistance is also provided by the reactor operations group, the neutron activation analysis group, the Scientific Instrument Technician, and the Radiation Center Director.

The data contained in the following sections have been prepared to comply with the current requirements of Nuclear Regulatory Commission (NRC) Facility License No. R-106 (Docket No. 50-243) and the Technical Specifications contained in that license. The material has also been prepared in compliance with Oregon Department of Energy Rule No. 345-30-010, which requires an annual report of environmental effects due to research reactor operations.

Within the scope of Oregon State University's radiation protection program, it is standard operating policy to maintain all releases of radioactivity to the unrestricted environment and all exposures to radiation and radioactive materials at levels which are consistently "as low as reasonably achievable" (ALARA).

Environmental Releases

The annual reporting requirements in the OSTR Technical Specifications state that the licensee (OSU) shall include "a summary of the nature and amount of radioactive effluents released or discharged to the environs beyond the effective control of the licensee, as measured at, or prior to, the point of such release or discharge." The liquid and gaseous effluents released, and the solid waste generated and transferred are discussed briefly below. Data regarding these effluents are also summarized in detail in the designated tables.

Liquid Effluents Released

Liquid Effluents

Oregon State University has implemented a policy to reduce the volume of radioactive liquid effluents to an absolute minimum. For example, water used during the ion exchanger resin change is now recycled as reactor makeup water. Waste water from Radiation Center laboratories and the OSTR is collected at a holdup tank prior to release to the sanitary sewer. Liquid effluent are analyzed for radioactivity content at the time it is released to the collection point. For this reporting period, the Radiation Center and reactor made three liquid effluent releases to the sanitary sewer. All Radiation Center and reactor facility liquid effluent data pertaining to this release are contained in Table V.2.

Liquid Waste Generated and Transferred

Liquid waste generated from glassware and laboratory experiments is transferred by the campus Radiation Safety Office to its waste processing facility. The annual summary of liquid waste generated and transferred is contained in Table V.3.

Airborne Effluents Released

Airborne effluents are discussed in terms of the gaseous component and the particulate component.

Gaseous Effluents
Gaseous effluents from the reactor facility are monitored by the reactor stack effluent monitor. Monitoring is continuous, i.e., prior to, during, and after reactor operations. It is normal for the reactor facility stack effluent monitor to begin operation as one of the first systems in the morning and to cease operation as one of the last systems at the end of the day. All gaseous effluent data for this reporting period are summarized in Table V.4.

Particulate effluents from the reactor facility are also monitored by the reactor facility stack effluent monitor.

Particulate Effluents
Evaluation of the detectable particulate radioactivity in the stack effluent confirmed its origin as naturally-occurring radon daughter products, within a range of approximately $3x10^{-11}$ μCi/ml to 1×10^{-9} μCi/ml. This particulate radioactivity is predominantly ^{214}Pb and ^{214}Bi, which is not associated with reactor operations.

There was no release of particulate effluents with a half life greater than eight days and therefore the reporting of the average concentration of radioactive particulates with half lives greater than eight days is not applicable.

Solid Waste Released

Data for the radioactive material in the solid waste generated and transferred during this reporting period are summarized in Table V.5 for both the reactor facility and the Radiation Center. Solid radioactive waste is routinely transferred to OSU Radiation Safety. Until this waste is disposed of by the Radiation Safety Office, it is held along with other campus radioactive waste on the University's State of Oregon radioactive materials license.

Solid radioactive waste is disposed of by OSU Radiation Safety by transfer to the University's radioactive waste disposal vendor.

Personnel Dose

The OSTR annual reporting requirements specify that the licensee shall present a summary of the radiation exposure received by facility personnel and visitors. The summary includes all Radiation Center personnel who may have received exposure to radiation. These personnel have been categorized into six groups: facility operating personnel, key facility research personnel, facilities services maintenance personnel, students in laboratory classes, police and security personnel, and visitors.

Facility operating personnel include the reactor operations and health physics staff. The dosimeters used to monitor these individuals include quarterly TLD badges, quarterly track-etch/albedo neutron dosimeters, monthly TLD (finger) extremity dosimeters, pocket ion chambers, electronic dosimetry.

Key facility research personnel consist of Radiation Center staff, faculty, and graduate students who perform research using the reactor, reactor-activated materials, or using other research facilities present at the Center. The individual dosimetry requirements for these personnel will vary with the type of research being conducted, but will generally include a quarterly TLD film badge and TLD (finger) extremity dosimeters. If the possibility of neutron exposure exists, researchers are also monitored with a track-etch/ albedo neutron dosimeter.

Facilities Services maintenance personnel are normally issued a gamma sensitive electronic dosimeter as their basic monitoring device. A few Facilities Services personnel who routinely perform maintenance on mechanical or refrigeration equipment are issued a quarterly Xß(γ) TLD badge and other dosimeters as appropriate for the work being performed.

Students attending laboratory classes are issued quarterly Xß(γ) TLD badges, TLD (finger) extremity dosimeters, and track-etch/albedo or other neutron dosimeters, as appropriate.

Students or small groups of students who attend a one-time lab demonstration and do not handle radioactive materials are usually issued a gamma sensitive electronic dosimeter. These results are not included with the laboratory class students.

OSU police and security personnel are issued a quarterly Xß(γ) TLD badge to be used during their patrols of the Radiation Center and reactor facility.

Visitors, depending on the locations visited, may be issued a gamma sensitive electronic dosimeters. OSU Radiation Center policy does not normally allow people in the visitor category to become actively involved in the use or handling of radioactive materials.

An annual summary of the radiation doses received by each of the above six groups is shown in Table V.6. There were no personnel radiation exposures in excess of the limits in 10 CFR 20 or State of Oregon regulations during the reporting period.

Facility Survey Data

The OSTR Technical Specifications require an annual summary of the radiation levels and levels of contamination observed during routine surveys performed at the facility. The Center's comprehensive area radiation monitoring program encompasses the Radiation Center as well as the OSTR, and therefore monitoring results for both facilities are reported.

Area Radiation Dosimeters
Area monitoring dosimeters capable of integrating the radiation dose are located at strategic positions throughout the reactor facility and Radiation Center. All of these dosimeters contain at least a standard personnel-type beta-gamma film or TLD pack. In addition, for key locations in the reactor facility and for certain Radiation Center laboratories a CR-39 plastic track-etch neutron detector has also been included in the monitoring package.

The total dose equivalent recorded on the various reactor facility dosimeters is listed in Table V.7 and the total dose equivalent recorded on the Radiation Center area dosimeters is listed in Table V.8. Generally, the characters following the Monitor Radiation Center (MRC) designator show the room number or location.

Routine Radiation and Contamination Surveys
The Center's program for routine radiation and contamination surveys consists of daily, weekly, and monthly measurements throughout the TRIGA reactor facility and Radiation Center. The frequency of these surveys is based on the nature of the radiation work being carried out at a particular location or on other factors which indicate that surveillance over a specific area at a defined frequency is desirable.

The primary purpose of the routine radiation and contamination survey program is to assure regularly scheduled surveillance over selected work areas in the reactor facility and in the Radiation Center, in order to provide current and characteristic data on the status of radiological conditions. A second objective of the program is to assure frequent on-the-spot personal observations (along with recorded data), which will provide advance warning of needed corrections and thereby help to ensure the safe use and handling of radiation sources and radioactive materials. A third objective, which is really derived from successful execution of the first two objectives, is to gather and document information which will help to ensure that all phases of the operational and radiation protection programs are meeting the goal of keeping radiation doses to personnel and releases of radioactivity to the environment "as low as reasonably achievable" (ALARA).

The annual summary of radiation and contamination levels measured during routine facility surveys for the applicable reporting period is given in Table V.9.

Environmental Survey Data

The annual reporting requirements of the OSTR Technical Specifications include "an annual summary of environmental surveys performed outside the facility."

Gamma Radiation Monitoring

On-site Monitoring
Monitors used in the on-site gamma environmental radiation monitoring program at the Radiation Center consist of the reactor facility stack effluent monitor described in Section V and nine environmental monitoring stations.

During this reporting period, each fence environmental station utilized an LiF TLD monitoring packet supplied and processed by Mirion Technologies, Inc., Irvine, California. Each GDS packet contained three LiF TLDs and was exchanged quarterly for a total of 108 samples during the reporting period (9 stations x 3 TLDs per station x 4 quarters). The total number of GDS TLD samples for the reporting period was 108. A summary of the GDS TLD data is also shown in Table V.10.

From Table V.10 it is concluded that the doses recorded by the dosimeters on the TRIGA facility fence can be attributed to natural back-ground radiation, which is about 110 mrem per year for Oregon (Refs. 1, 2).

Off-site Monitoring
The off-site gamma environmental radiation monitoring program consists of twenty monitoring stations surrounding the Radiation Center (see Figure V.1) and six stations located within a 5 mile radius of the Radiation Center.

Each monitoring station is located about four feet above the ground (MRCTE 21 and MRCTE 22 are mounted on the roof of the EPA Laboratory and National Forage Seed Laboratory, respectively). These monitors are exchanged and processed quarterly, and the total number of TLD samples during the current one-year reporting period was 240 (20 stations x 3 chips per station per quarter x 4 quarters per year). The total number of GDS TLD samples for the reporting period was 240. A summary of GDS TLD data for the off-site monitoring stations is given in Table V.11.

After a review of the data in Table V.11, it is concluded that, like the dosimeters on the TRIGA facility fence, all of the doses recorded by the off-site dosimeters can be attributed to natural background radiation, which is about 110 mrem per year for Oregon (Refs. 1, 2).

Soil, Water, and Vegetation Surveys

The soil, water, and vegetation monitoring program consists of the collection and analysis of a limited number of samples in each category on a annual basis. The program monitors highly unlikely radioactive material releases from either the TRIGA reactor facility or the OSU Radiation Center, and also helps indicate the general trend of the radioactivity concentration in each of the various substances sampled. See Figure V.1 for the locations of the sampling stations for grass (G), soil (S), water (W) and rainwater (RW) samples. Most locations are within a 1000 foot radius of the reactor facility and the Radiation Center. In general, samples are collected over a local area having a radius of about ten feet at the positions indicated in Figure V.1.

There are a total of 22 sampling locations: four soil locations, four water locations (when water is available), and fourteen vegetation locations.

The annual concentration of total net beta radioactivity (minus tritium) for samples collected at each environmental soil, water, and vegetation sampling location (sampling station) is listed in Table V.12. Calculation of the total net beta disintegration rate incorporates subtraction of only the counting system back-ground from the gross beta counting rate, followed by application of an appropriate counting system efficiency.

The annual concentrations were calculated using sample results which exceeded the lower limit of detection (LLD), except that sample results which were less than or equal to the LLD were averaged in at the corresponding LLD concentration. Table V.13 gives the concentration and the range of values for each sample category for the current reporting period.

As used in this report, the LLD has been defined as the amount or concentration of radioactive material (in terms of μCi per unit volume or unit mass) in a representative sample, which has a 95% probability of being detected.

Identification of specific radionuclides is not routinely carried out as part of this monitoring program, but would be conducted if unusual radioactivity levels above natural background were detected. However, from Table V.12 it can be seen that the levels of radioactivity detected were consistent with naturally occurring radioactivity and comparable to values reported in previous years.

Radioactive Materials Shipments

A summary of the radioactive material shipments originating from the TRIGA reactor facility, NRC license R-106, is shown in Table V.14. A similar summary for shipments originating from the Radiation Center's State of Oregon radioactive materials license ORE 90005 is shown in Table V.15. A summary of radioactive material shipments exported under Nuclear Regulatory Commission general license 10 CFR 110.23 is shown in Table V.16.

References

1. U. S. Environmental Protection Agency, "Estimates of Ionizing Radiation Doses in the United States, 1960-2000," ORP/CSD 72-1, Office of Radiation Programs, Rockville, Maryland (1972).
2. U. S. Environmental Protection Agency, "Radiological Quality of the Environment in the United States, 1977," EPA 520/1-77-009, Office of Radiation Programs; Washington, D.C. 20460 (1977).

Table V.1

Radiation Protection Program Requirements and Frequencies

Frequency	Radiation Protection Requirement
Daily/Weekly/Monthly	Perform Routing area radiation/contamination monitoring
Monthly	Collect and analyze TRIGA primary, secondary, and make-up water. Exchange personnel dosimeters and inside area monitoring dosimeters, and review exposure reports. Inspect laboratories. Calculate previous month's gaseous effluent discharge.
As Required	Process and record solid waste and liquid effluent discharges. Prepare and record radioactive material shipments. Survey and record incoming radioactive materials receipts. Perform and record special radiation surveys. Perform thyroid and urinalysis bioassays. Conduct orientations and training. Issue radiation work permits and provide health physics coverage for maintenance operations.
Quarterly	Prepare, exchange and process environmental TLD packs. Conduct orientations for classes using radioactive materials. Collect and analyze samples from reactor stack effluent line. Exchange personnel dosimeters and inside area monitoring dosimeters, and review exposure reports.
Semi-Annual	Leak test and inventory sealed sources. Conduct floor survey of corridors and reactor bay.
Annual	Calibrate portable radiation monitoring instruments and personnel pocket ion chambers. Calibrate reactor stack effluent monitor, continuous air monitors, remote area radiation monitors, and air samplers. Measure face air velocity in laboratory hoods and exchange dust-stop filters and HEPA filters as necessary. Inventory and inspect Radiation Center emergency equipment. Conduct facility radiation survey of the ^{60}Co irradiators. Conduct personnel dosimeter training. Update decommissioning logbook. Collect and process environmental soil, water, and vegetation samples.

Table V.2

Monthly Summary of Liquid Effluent Release to the Sanitary Sewer[1]

Date of Discharge (Month and Year)	Total Quantity of Radioactivity Released (Curies)	Detectable Radionuclide in the Waste	Specific Activity For Each Detectable Radionuclide in the Waste, Where The Release Concentration Was>1 x 10^{-7} (μCi ml^{-1})	Total Quantity of Each Detectable Radionuclide Released in the Waste (Curies)	Average Concentration Of Released Radioactive Material at the Point of Release (μCi ml^{-1})	Percent of Applicable Monthly Average Concentration for Released Radioactive Material (%)[2]	Total Volume of Liquid Effluent Released Including Diluent (gal)
August 2011	7.2×10^{-2}	H-3	1.4×10^{-4}	7.2×10^{-2}	1.4×10^{-4}	1.37	138,430
October 2011	6.7×10^{-2}	H-3	2.5×10^{-4}	6.7×10^{-2}	2.5×10^{-4}	2.45	71,857
January 2012	6.0×10^{-3}	H-3	2.6×10^{-5}	6.0×10^{-3}	2.5×10^{-5}	0.26	62,082
March 2012	5.2×10^{-2}	H-3	2.8×10^{-5}	5.2×10^{-2}	2.8×10^{-5}	0.28	494,016
April 2012	5.2×10^{-2}	H-3	9.6×10^{-5}	5.2×10^{-2}	9.6×10^{-5}	0.96	142,392
June 2012	0.4	H-3, Cr-51, Co-58, Co-60	H-3, 6.0×10^{-4}	H-3, 0. 4 Cr-51, 4.3×10^{-6} Co-58, 1.1×10^{-6} Co-60, 1.0×10^{-6}	6.0×10^{-4}	H-3, 6.0 Cr-51, 0.0001 Co-58, 0.0008 Co-60, 0.0005	177,264
Annual Total for Radiation Center	6.5×10^{-1}	H-3, Cr-51, Co-58, Co-60	1.1×10^{-3}	H-3, 6.5×10^{-1}	1.14×10^{-3}	11.32	1, 086,041

(1) The OSU operational policy is to subtract only detector background from the water analysis data and not background radioactivity in the Corvallis city water.
(2) Based on values listed in 10 CFR 20, Appendix B to 20.1001 – 10.2401, Table 3, which are applicable to sewer disposal.

Table V.3

Annual Summary of Liquid Waste Generated and Transferred

Origin of Liquid Waste	Volume of Liquid Waste Packaged[(1)] (gallons)	Detectable Radionuclides in the Waste	Total Quantity of Radioactivity in the Waste (Curies)	Dates of Waste Pickup for Transfer to the Waste Processing Facility
TRIGA Reactor Facility	15	Na-24, Cr-51, Mn-56, Co-60, Rb-89, Sb-122, Sb-124, Cs-137, H-3, Ag-110m, Sc-46, Eu152	3.44×10^{-3}	10/21/11
Radiation Center Laboratories	20.25	Pu-239, Cl-36, U-238, C-14, H-3	5.96×10^{-5}	10/21/11 2/22/12 6/10/12
TOTAL	**35.25**	**See above**	**3.50×10^{-3}**	

(1) OSTR and Radiation Center liquid waste is picked up by the Radiation Safety Office for transfer to its waste processing facility for final packaging.

Table V.4

Monthly TRIGA Reactor Gaseous Waste Discharges and Analysis

Month	Total Estimated Activity Released (Curies)	Total Estimated Quantity of Argon-41 Released[(1)] (Curies)	Estimated Atmospheric Diluted Concentration of Argon-41 at Point of Release (μCi/cc)	Fraction of the Technical Specification Annual Average Argon-41 Concentration Limit (%)
July	0.54	0.54	4.36×10^{-8}	1.09
August	0.58	0.58	4.62×10^{-8}	1.15
September	0.44	0.44	3.63×10^{-8}	0.91
October	0.53	0.53	4.22×10^{-8}	1.06
November	0.44	0.44	3.64×10^{-8}	0.91
December	0.53	0.53	4.21×10^{-8}	1.05
January	0.53	0.53	4.23×10^{-8}	1.06
February	0.56	0.56	4.78×10^{-8}	1.20
March	0.67	0.67	5.37×10^{-8}	1.34
April	0.52	0.52	4.28×10^{-8}	1.07
May	0.66	0.66	5.30×10^{-8}	1.33
June	0.51	0.51	4.18×10^{-8}	1.04
TOTAL ('10-'11)	**6.50**	**6.50**	**4.40×10^{-8}[(2)]**	**1.10[(2)]**

(1) Routine gamma spectroscopy analysis of the gaseous radioactivity in the OSTR stack discharge indicated the only detectable radionuclide was argon-41.

(2) Annual Average.

Table V.5

Annual Summary of Solid Waste Generated and Transferred

Origin of Solid Waste	Volume of Solid Waste Packaged(1) (Cubic Feet)	Detectable Radionuclides in the Waste	Total Quantity of Radioactivity in Solid Waste (Curies)	Dates of Waste Pickup for Transfer to the OSU Waste Processing Facility
TRIGA Reactor Facility	30	Mn-54, Co-58, Co-60, Zn-65, As-74, Cs-134, Eu-152, Sc-46, Fe-59, Sb-124, Se-75, Hf-181, Na-24, Hg-203, Sb-125, Cr-51, Pa-233	1.52×10^{-4}	10/21/11 2/22/12 6/10/12
Radiation Center Laboratories	63	Cl-36, U-238, Np-237, Pu-242, Eu-152, Eu-154, Pu-239, Am-241, U-235, Th-232, Tc-99, Mo-99, Co-60, Ir-192, H-3, C-14, Sr-90, Cs-137, Am-243, Pu-242, Cd-109, Hg-203, Na-22, Sn-113, Po-210, Sr-85, Nb-95, Ce-139, Y-88, Cr-51, Te-123m, Cs-134	2.35×10^{-4}	10/21/11 2/22/12 6/10/12
TOTAL	93	See Above	3.88×10^{-4}	---

(1) OSTR and Radiation Center laboratory waste is picked up by OSU Radiation Safety for transfer to its waste processing facility for final packaging.

Table V.6

Annual Summary of Personnel Radiation Doses Received

	Average Annual Dose[1]		Greatest Individual Dose[1]		Total Person-mrem For the Group[1]	
Personnel Group	**Whole Body (mrem)**	**Extremities (mrem)**	**Whole Body (mrem)**	**Extremities (mrem)**	**Whole Body (mrem)**	**Extremities (mrem)**
Facility Operating Personnel	102.43	339.57	187	1269	717	2377
Key Facility Research Personnel	2.38	16.17	31	139	31	194
Facilities Services Maintenance Personnel	<1	N/A	0.5	N/A	0.8	N/A
Laboratory Class Students	2.63	5.37	403	208	1117	573
Campus Police and Security Personnel	2.47	N/A	37	N/A	75	N/A
Visitors	<1	N/A	6.3	N/A	96.6	N/A

(1) "N/A" indicates that there was no extremity monitoring conducted or required for the group.

Table V.7

Total Dose Equivalent Recorded on Area Dosimeters Located Within the TRIGA Reactor Facility

Monitor I.D.	TRIGA Reactor Facility Location (See Figure V.1)	Total Recorded	Dose Equivalent[(1)(2)]
		Xß(γ) (mrem)	Neutron (mrem)
MRCTNE	D104: North Badge East Wall	274	ND
MRCTSE	D104: South Badge East Wall	146	ND
MRCTSW	D104: South Badge West Wall	905	ND
MRCTNW	D104: North Badge West Wall	199	ND
MRCTWN	D104: West Badge North Wall	381	ND
MRCTEN	D104: East Badge North Wall	346	ND
MRCTES	D104: East Badge South Wall	1572	ND
MRCTWS	D104: West Badge South Wall	546	ND
MRCTTOP	D104: Reactor Top Badge	710	ND
MRCTHXS	D104A: South Badge HX Room	878	ND
MRCTHXW	D104A: West Badge HX Room	657	ND
MRCD-302	D302: Reactor Control Room	447	ND
MRCD-302A	D302A: Reactor Supervisor's Office	149	N/A
MRCBP1	D104: Beam Port Number 1	319	ND
MRCBP2	D104: Beam Port Number 2	256	ND
MRCBP3	D104: Beam Port Number 3	929	ND
MRCBP4	D104: Beam Port Number 4	854	ND

(1) The total recorded dose equivalent values do not include natural background contribution and, reflect the summation of the results of four quarterly beta-gamma dosimeters or four quarterly fast neutron dosimeters for each location. A total dose equivalent of "ND" indicates that each of the dosimeters during the reporting period was less than the vendor's gamma dose reporting threshold of 10 mrem or that each of the fast neutron dosimeters was less than the vendor's threshold of 10 mrem. "N/A" indicates that there was no neutron monitor at that location.

(2) These dose equivalent values do not represent radiation exposure through an exterior wall directly into an unrestricted area.

Table V.8

Total Dose Equivalent Recorded on Area Dosimeters Located Within the Radiation Center

Monitor I.D.	Radiation Center Facility Location (See Figure V.1)	Total Recorded Dose Equivalent[(1)]	
		Xß(γ) (mrem)	Neutron (mrem)
MRCA100	A100: Receptionist's Office	31	N/A
MRCBRF	A102H: Front Personnel Dosimetry Storage Rack	63	N/A
MRCA120	A120: Stock Room	96	N/A
MRCA120A	A120A: NAA Temporary Storage	0	N/A
MRCA126	A126: Radioisotope Research Lab	236	N/A
MRCCO-60	A128: ^{60}Co Irradiator Room	625	N/A
MRCA130	A130: Shielded Exposure Room	146	N/A
MRCA132	A132: TLD Equipment Room	73	N/A
MRCA138	A138: Health Physics Laboratory	51	N/A
MRCA146	A146: Gamma Analyzer Room (Storage Cave)	112	N/A
MRCB100	B100: Gamma Analyzer Room (Storage Cave)	73	N/A
MRCB114	B114: Lab (^{226}Ra Storage Facility)	1612	ND
MRCB119-1	B119: Source Storage Room	218	N/A
MRCB119-2	B119: Source Storage Room	377	N/A
MRCB119A	B119A: Sealed Source Storage Room	2906	1303
MRCB120	B120: Instrument Calibration Facility	78	N/A
MRCB122-2	B122: Radioisotope Hood	349	N/A
MRCB122-3	B122: Radioisotope Research Laboratory	76	N/A
MRCB124-1	B124: Radioisotope Research Lab (Hood)	72	N/A
MRCB124-2	B124: Radioisotope Research Laboratory	92	N/A
MRCB124-6	B124: Radioisotope Research Laboratory	64	N/A
MRCB128	B128: Instrument Repair Shop	52	N/A
MRCB136	B136 Gamma Analyzer Room	27	N/A
MRCC100	C100: Radiation Center Director's Office	63	N/A

(1) The total recorded dose equivalent values do not include natural background contribution and, reflect the summation of the results of four quarterly beta-gamma dosimeters or four quarterly fast neutron dosimeters for each location. A total dose equivalent of "ND" indicates that each of the dosimeters during the reporting period was less than the vendor's gamma dose reporting threshold of 10 mrem or that each of the fast neutron dosimeters was less than the vendor's threshold of 10 mrem. "N/A" indicates that there was no neutron monitor at that location.

Table V.8 (continued)

Total Dose Equivalent Recorded on Area Dosimeters Located Within the Radiation Center

Monitor I.D.	Radiation Center Facility Location (See Figure V.1)	Total Recorded Dose Equivalent[(1)]	
		Xß(γ) (mrem)	Neutron (mrem)
MRCC106A	C106A: Office	62	N/A
MRCC106B	C106B: Custodian Supply Storage	45	N/A
MRCC106-H	C106H: East Loading Dock	42	N/A
MRCC118	C118: Radiochemistry Laboratory	35	N/A
MRCC120	C120: Student Counting Laboratory	26	N/A
MRCF100	F100: APEX Facility	11	N/A
MRCF102	F102: APEX Control Room	21	N/A
MRCB125N	B125: Gamma Analyzer Room (Storage Cave)	37	N/A
MRCN125S	B125: Gamma Analyzer Room	74	N/A
MRCC124	C124: Classroom	67	N/A
MRCC130	C130: Radioisotope Laboratory (Hood)	64	N/A
MRCD100	D100: Reactor Support Laboratory	90	ND
MRCD102	D102: Pneumatic Transfer Terminal Lab`	287	ND
MRCD102-H	D102H: 1st Floor Corridor at D102	113	ND
MRCD106-H	D106H: 1st Floor Corridor at D106	351	N/A
MRCD200	D200: Reactor Administrator's Office	190	ND
MRCD202	D202: Senior Health Physicist's Office	283	ND
MRCBRR	D200H: Rear Personnel Dosimetry Storage Rack	78	N/A
MRCD204	D204: Health Physicist Office	264	ND
MRCATHRL	F104: ATHRL	42	N/A
MRCD300	D300: 3rd Floor Conference Room	192	ND

(1) The total recorded dose equivalent values do not include natural background contribution and, reflect the summation of the results of four quarterly beta-gamma dosimeters or four quarterly fast neutron dosimeters for each location. A total dose equivalent of "ND" indicates that each of the dosimeters during the reporting period was less than the vendor's gamma dose reporting threshold of 10 mrem or that each of the fast neutron dosimeters was less than the vendor's threshold of 10 mrem. "N/A" indicates that there was no neutron monitor at that location.

Table V.9

Annual Summary of Radiation and Contamination Levels Observed Within the Reactor Facility and Radiation Center During Routine Radiation Surveys

Accessible Location (See Figure V.1)	Whole Body Radiation Levels (mrem/hr)		Contamination Levels[1] (dpm/cm^2)	
	Average	Maximum	Average	Maximum
TRIGA Reactor Facility:				
Reactor Top (D104)	1.64	90	<500	25,870
Reactor 2nd Deck Area (D104)	6.56	46	<500	926
Reactor Bay SW (D104)	<1	50	<500	<500
Reactor Bay NW (D104)	<1	9	<500	3,269
Reactor Bay NE (D104)	<1	18	<500	2,608
Reactor Bay SE (D104)	<1	7	<500	5,179
Class Experiments (D104, D302)	<1	<1	<500	<500
Demineralizer Tank & Make Up Water System (D104A)	<1	28	<500	1,300
Particulate Filter--Outside Shielding (D104A)	<1	6	<500	3,036
Radiation Center:				
NAA Counting Rooms (A146, B100)	<1	2.7	<500	<500
Health Physics Laboratory (A138)	<1	1.7	<500	<500
^{60}Co Irradiator Room and Calibration Rooms (A128, B120, A130)	<1	31	<500	<500
Radiation Research Labs (A126, A136) (B108, B114, B122, B124, C126, C130, C132A)	<1	12	<500	652
Radioactive Source Storage (B119, B119A, A120A, A132A)	<1	25	<500	<500
Student Chemistry Laboratory (C118)	<1	<1	<500	<500
Student Counting Laboratory (C120)	<1	<1	<500	<500
Operations Counting Room (B136, B125)	<1	1.2	<500	<500
Pneumatic Transfer Laboratory (D102)	<1	10	<500	11,800
RX support Room (D100)	<1	<1	<500	<500

(1) <500 dpm/100 cm2 = Less than the lower limit of detection for the portable survey instrument used.

Table V.10

Total Dose Equivalent at the TRIGA Reactor Facility Fence

Fence Environmental Monitoring Station (See Figure V.1)	Total Recorded Dose Equivalent (Including Background) Based on Mirion TLDs[1,2] (mrem)
MRCFE-1	87 ± 4
MRCFE-2	83 ± 5
MRCFE-3	77 ± 7
MRCFE-4	85 ± 4
MRCFE-5	91 ± 8
MRCFE-6	83 ± 6
MRCFE-7	84 ± 5
MRCFE-8	80 ± 5
MRCFE-9	80 ± 4

(1) Average Corvallis area natural background using Mirion TLDs totals 75 ± 11 mrem for the same period.

(2) ± values represent the standard deviation of the total value at the 95% confidence level.

Table V.11

Total Dose Equivalent at the Off-Site Gamma Radiation Monitoring Stations

Off-Site Radiation Monitoring Station (See Figure V.1)	Total Recorded Dose Equivalent (Including Background) Based on Mirion TLDs[1,2] (mrem)
MRCTE-2	82 ± 5
MRCTE-3	54 ± 5
MRCTE-4	81 ± 6
MRCTE-5	87 ± 6
MRCTE-6	82 ± 9
MRCTE-7	81 ± 5
MRCTE-8	94 ± 5
MRCTE-9	85 ± 6
MRCTE-10	76 ± 5
MRCTE-12	89 ± 7
MRCTE-13	55 ± 6
MRCTE-14	83 ± 3
MRCTE-15	76 ± 6
MRCTE-16	85 ± 5
MRCTE-17	82 ± 5
MRCTE-18	79 ± 6
MRCTE-19	86 ± 5
MRCTE-20	79 ± 4
MRCTE-21	74 ± 9
MRCTE-22	77 ± 5

(1) Average Corvallis area natural background using Mirion TLDs totals 75 ± 11 mrem for the same period.
(2) ± values represent the standard deviation of the total value at the 95% confidence level.

Table V.12

Annual Average Concentration of the Total Net Beta Radioactivity (minus ^3H) for Environmental Soil, Water, and Vegetation Samples

Sample Location (See Fig. V.1)	Sample Type	Annual Average Concentration Of the Total Net Beta (Minus ^3H) Radioactivity(1)	Reporting Units
1-W	Water	$7.29x10^{-6}$ (2)	$\mu Ci\ ml^{-1}$
4-W	Water	$7.29x10^{-6}$ (2)	$\mu Ci\ ml^{-1}$
11-W	Water	$7.29x10^{-6}$ (2)	$\mu Ci\ ml^{-1}$
19-RW	Water	$7.29x10^{-6}$ (2)	$\mu Ci\ ml^{-1}$
3-S	Soil	$2.36x10^{-5}$ (2) $\pm 5.25x10^{-6}$	$\mu Ci\ g^{-1}$ of dry soil
5-S	Soil	$1.22x10^{-5} \pm 4.07x10^{-6}$	$\mu Ci\ g^{-1}$ of dry soil
20-S	Soil	$1.66x10^{-5}$ (2) $\pm 4.63x10^{-6}$	$\mu Ci\ g^{-1}$ of dry soil
21-S	Soil	$8.37x10^{-6}$ (2)	$\mu Ci\ g^{-1}$ of dry soil
2-G	Grass	$4.20x10^{-4} \pm 4.61x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
6-G	Grass	$2.29x10^{-4} \pm 2.42x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
7-G	Grass	$2.93x10^{-4} \pm 3.34x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
8-G	Grass	$3.46x10^{-4} \pm 2.92x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
9-G	Grass	$3.64x10^{-4} \pm 3.00x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
10-G	Grass	$2.88x10^{-4} \pm 2.35x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
12-G	Grass	$3.27x10^{-4} \pm 2.04x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
13-G	Grass	$2.90x10^{-4} \pm 2.33x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
14-G	Grass	$1.55x10^{-4} \pm 2.15x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
15-G	Grass	$2.09x10^{-4} \pm 2.38x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
16-G	Grass	$1.31x10^{-4} \pm 1.75x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
17-G	Grass	$2.57x10^{-4} \pm 2.35x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
18-G	Grass	$2.18x10^{-4} \pm 2.60x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash
22-G	Grass	$1.10x10^{-4} \pm 2.70x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash

(1) ± values represent the standard deviation of the value at the 95% confidence level.
(2) Less than lower limit of detection value shown.

Table V.13

Beta-Gamma Concentration and Range of LLD Values for Soil, Water, and Vegetation Samples

Sample Type	Average Value	Range of Values	Reporting Units
Soil	$9.17x10^{-6}$	$8.37x10^{-6}$ to $1.03x10^{-5}$	$\mu Ci\ g^{-1}$ of dry soil
Water	$7.29x10^{-6}$ (1)	$7.29x10^{-6}$ (1)	$\mu Ci\ ml^{-1}$
Vegetation	$4.03x10^{-5}$	$2.37x10^{-5}$ to $7.22x10^{-5}$	$\mu Ci\ g^{-1}$ of dry ash

(1) Less than lower limit of detection value shown.

Table V.14

Annual Summary of Radioactive Material Shipments Originating From the TRIGA Reactor Facility's NRC License R-106

Shipped To	Total Activity (TBq)	Number of Shipments				
		Exempt	Limited Quantity	Yellow II	Yellow III	Total
Berkeley Geochronology Center Berkeley, CA USA	1.58×10^{-6}	5	2	0	0	7
C.O.R.D. University of Wisconsin-Madison Madison, WI USA	5.17×10^{-6}	0	0	0	16	16
Cal State Fullerton Fullerton, CA USA	6.33×10^{-9}	1	0	0	0	1
California Institue of Technology Pasadena, CA USA	5.84×10^{-7}	0	0	1	0	1
Lehigh University Bethlehem, PA USA	1.20×10^{-7}	2	0	0	0	2
Materion Coperation Elmore, OH USA	3.73×10^{-2}	0	0	0	4	4
Materion Natural Resources Delta, UT USA	1.08×10^{-1}	0	0	0	22	22
Occidental College Los Angeles, CA USA	3.87×10^{-9}	1	0	0	0	1
Oregon State University Corvallis, OR USA	5.60×10^{-6}	1	0	2	0	3
Plattsburgh State University Plattsburgh, NY USA	1.17×10^{-8}	2	0	0	0	2
Stanford University Stanford, CA, USA	1.01×10^{-8}	1	0	0	0	1
Syracuse University Syracuse, NY USA	4.81×10^{-7}	3	1	0	0	4
Union College Schenectady, NY USA	8.48×10^{-9}	2	0	0	0	2
University of Arizona Tucson, AZ USA	8.16×10^{-4}	7	0	2	0	9
University of California at Berkeley Berkeley, CA USA	3.19×10^{-6}	0	0	2	0	2
University of California at Santa Barbara Santa Barbara, CA USA	3.49×10^{-7}	1	1	0	0	2
University of Florida Gainesville, FL USA	9.10×10^{-8}	3	0	0	0	3
University of Michigan Ann Arbor, MI USA	4.41×10^{-8}	1	0	0	0	1
University of Minnesota Minneapolis, MN USA	5.00×10^{-8}	1	0	0	0	1
University of Wisconsin-Madison Madison, WI USA	1.14×10^{-5}	0	0	3	0	3
Totals	**1.46×10^{-1}**	**31**	**4**	**11**	**26**	**72**

Table V.15

Annual Summary of Radioactive Material Shipments Originating From the Radiation Center's State of Oregon License ORE 90005

Shipped To	Total Activity (TBq)	Number of Shipments			
		Exempt	Limited Quantity	White I	Total
Argonne National Lab Argonne, IL USA	8.01×10^{-12}	1	0	0	1
Lawrence Berkeley National Laboratory Berkeley, CA USA	2.05×10^{-9}	1	0	0	1
Los Alamos National Lab Los Alamos, NM USA	6.14×10^{-6}	5	3	3	11
Pacific Northwest National Lab Richland, WA USA	6.50×10^{-11}	1	0	0	1
Totals	**6.14×10^{-6}**	**8**	**3**	**3**	**14**

Table V.16

Annual Summary of Radioactive Material Shipments Exported Under NRC General License 10 CFR 110.23

Shipped To	Total Activity (TBq)	Number of Shipments			
		Exempt	Limited Quantity	Yellow II	Total
Glasgow University Glasgow SCOTLAND	$2.49 x 10^{-8}$	1	0	0	1
Institute of Geology, China Earthquake Admin Beijing PR CHINA	$3.12 x 10^{-9}$	1	0	0	1
Lanzhou University Lanzhou, Gansu CHINA	$1.04 x 10^{-8}$	1	0	0	1
Lund University Lund, SWEDEN	$3.17 x 10^{-7}$	3	0	0	3
Polish Academy of Sciences Krakow, POLAND	$2.92 x 10^{-8}$	2	0	0	2
QUAD-Lab, Roskilde University Roskilde, DENMARK	$2.57 x 10^{-8}$	2	0	0	2
Scottish Universities Research & Reactor Centre East Kilbride, SCOTLAND	$2.13 x 10^{-6}$	1	4	0	5
Universitat Gottingen Gottingen, GERMANY	$2.46 x 10^{-8}$	2	0	0	2
Universitat Potsdam Postdam, GERMANY	$5.37 x 10^{-9}$	1	0	0	1
Universite Paris-Sud Paris, FRANCE	$4.77 x 10^{-6}$	0	0	2	2
University of Geneva Geneva, SWITZERLAND	$2.74 x 10^{-7}$	6	1	0	7
University of Melbourne Parkville, Victoria AUSTRALIA	$9.23 x 10^{-7}$	0	0	2	2
University of Milano-Bicocca Milano, ITALY	$1.27 x 10^{-9}$	1	0	0	1
University of Padova Padova, ITALY	$6.50 x 10^{-9}$	2	0	0	2
University of Queensland Brisbane, Queensland AUSTRALIA	$2.31 x 10^{-6}$	0	0	1	1
University of Rennes Rennes, FRANCE	$3.67 x 10^{-8}$	1	0	0	1
University of Zurich Zurich, SWITZERLAND	$1.18 x 10^{-8}$	3	0	0	3
Victoria University of Wellington Wellington, NEW ZELAND	1.29x10-8	2	0	0	2
Totals	**$1.08 x 10^{-5}$**	**29**	**5**	**5**	**39**

Figure V.1

Monitoring Stations for the OSU TRIGA Reactor