UNIVERSITY OF CALIFORNIA IRVINE
NUCLEAR REACTOR FACILITY
ANNUAL OPERATING REPORT (AOR)
2022-2023

FACILITY LICENSE R-116 – DOCKET NUMBER 50-326

A. J. SHAKA | Reactor Director

GEORGE MILLER | Reactor Supervisor Emeritus

JOHN KEFFER | Reactor Supervisor and Facility Manager

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Section 1
Operations, Personnel and Reviews Summary

The UCI Reactor Facility has continued to be utilized this year for training operator license candidates, seen an increase in use for neutron activation and by campus and visiting researchers, and has supported a Fall quarter radiation chemistry laboratory course.

Personnel

Reactor Personnel this period have changed and are as follows:

Reactor Director: Professor A. J. Shaka (SRO)

Reactor Supervisor Emeritus: Professor George Miller (SRO)

Reactor Supervisor/Facility Manager: Mr. John Keffer (SRO)

Associate Reactor Supervisor and Development Engineer: vacant

Reactor Operator: Mr. Victor Klumper (RO) (continuing graduate student)

Reactor Operator: Ms. Mando Eijansantos (RO) (returning graduate student)

Campus Radiation Safety Officer (RSO): Ms. Bridgette Neri (ARSO) replaced Mr. Aldrich Rivera

Operations

The facility has maintained open status for research and instruction and normal operations throughout the past year.

Operation of this facility supported UCI and visiting research and education programs in the Department of Chemistry (CHEM) and other UCI schools and departments. Research is being conducted in application of radioisotopes as tracers and radiochemical analytical and separation techniques, including focused applications for medical isotope research, and nuclear waste separations. An assistant professor appointed in chemistry is implementing plans to use the facility for nuclear fuel related research as the overall laboratory research program gains momentum. The group's laboratory reconstruction is complete, and the research group is growing in membership.

Reactor utilization, apart from operator training and maintenance, is for analytical sample irradiation, production of isotopic tracers and medical isotopes, and neutron instrument testing. Analysis samples come from diverse origins related to forensic science, fossil fuels, geochemistry, art, and archaeological studies, chemical separations in nuclear fuel cycle experiments, chemical synthesis, industrial quality control, enzyme studies, trace element pollution studies, etc. Laboratory classes in September 2022 included work by undergraduates learning tracer and activation analysis techniques using small quantities of short-lived activated materials. The nuclear instrumentation class was not held this Spring, but a new operator class was launched.

The operator training program continued with three participants from a previous year's class and six new participants enrolled in a new Chem 100 course. The students were selected from Chemistry, Physics, and Engineering departments and are graduates and undergraduates. Lectures and Discussions were in person, instructed by Professors Shaka and Finkeldei, and Lab sessions were in-facility, led by Mr. Keffer, over the ten-week Spring quarter.

Use was made of the facility by other educational institutions, using the reactor and the gamma irradiator. The tour program of the reactor facility has resumed, attracting visitors from within the University and area schools as well as the outside professional community. In person tours were also available for potential graduate students.

Operations increased over last year, with the reactor generating 30% more energy and the facility receiving over 1000 visitors and researchers.

Criticality was achieved for 203.4 hours, an over 40% increase from the previous year, and the total energy generated was equivalent to 83.6 hours at full steady state power. 309 separate experiments were performed this year and 344 samples were irradiated, showing an increased use of the facility. The pneumatic transfer system use decreased but CT experimental N_2/air flushing was routinely performed, accounting for some associated Ar-41 release. One pulse was performed this year. A few unusual maintenance/surveillance results/activities were noted/conducted during this period and are described in Section 6.

<u>Inspections and Reviews</u>

A routine annual NRC inspection was held December 13-15th, 2022 with a focus on: (1) procedures; (2) experiments; (3) health physics; (4) design changes; (5) committees, audits, and review; and (6) transportation activities. The U.S. Nuclear Regulatory Commission (NRC) staff determined that the licensee's programs were acceptably directed toward the protection of public health and safety, and in compliance with NRC requirements. A written report was received on February 14th, 2023. No findings of significance were identified.

In April 2023, the required annual Reactor Operations Committee meeting was held remotely via Zoom and Google drive. No significant issues were discussed.

An Emergency/Security exercise was conducted on site in June 2023. On and off campus emergency response personnel were involved in the tabletop TTX event and participants toured the reactor facility. In preparation for this event several Zoom planning meetings were held in 2023. A full follow-up after action report was prepared and issued by UCI Emergency Service personnel.

Inspections/audits continue to be conducted quarterly by the Radiation Safety staff of EH&S at UCI. These have identified that surveillance frequency schedules have been properly maintained, and results continue to show absence of significant levels of contamination or personnel exposure.

Section 2

Data Tabulations for the Period July 1st, 2022 to June 30th, 2023

TABLE I – General Information

Experiment Approvals on file (active)	3
Experiments performed (including repeats)	309
Samples irradiated	344
Energy generated this period (Megawatt hours)	20.91
Total, 69 element core	127.00
>74 element core	1739.75
Total energy generated since initial criticality (Megawatt hours)	1866.76
Pulse operation this period	1
Total reactor pulses to 6/30/2023	1115
Hours critical this period	203.4
Total hours critical to date	11204.3
Inadvertent scrams or unplanned shutdowns or events at power	19
Non-research personnel visits to reactor – logged and PRM issued (incl. tours)	693
Maximum dosimeter recorded for visits - all less than 1 mrem (non-researchers)	0.1
Visiting researchers (Temporary PRM, incl. repeats)	311
Maximum exposure recorded at one visit (mrem, Temp PRM, researcher)	1.1
Staff and researchers badged with Thermoluminescent Dosimeters (TLD)	9
Students and assistant, or operators training – (TLD badged)	25
Exposures reported for radiochemistry class (2022-23), deep mrem ave.	5
Isotope Shipments off campus this period	3

TABLE II – Reactor Core Status 2023-06-30 (Core Configuration last Changed 2018-01-18)		
Fuel elements in core (including 2 fuel followers)		84
Fuel elements in storage (reactor tank - used)		23
Fuel elements unused (4 instrumented elements + 1 element + 1 FFCR)		6
Graphite reflector elements in core		32
Graphite reflector elements in reactor tank storage		2
Water filled fuel element positions		4
Experimental facilities in core positions		5
Non-fueled control rods		2
Total core positions accounted for		127
Core excess, cold, no xenon (as of 6/30/2023)		$2.61
Control Rod Worths (Calibrated 02/03/2023)	REG	$2.77
	SHIM	$3.22
	ATR	$1.74
	FTR	$0.64
	Total	$8.37
Maximum possible pulse insertion (calculated)		$2.38
Maximum peak power recorded (8/30/2022), $1.78 insertion		280MW
Maximum peak temperature recorded in pulse (B-ring, 8/30/2022), $1.78 insertion		309 °C

Section 3

Inadvertent Scrams, Unplanned Shutdowns, Events at Power

TABLE III – Scrams, Unplanned Shutdowns, Events at Power			
2022-07-20		<1.5W	WRM period scram on startup air firing of transient rods
2022-07-26		<1.5W	WRM period scram on startup air firing of transient rods
2022-08-11		<1.5W	WRM period scram on startup air firing of transient rods
2022-08-30		5W	Pulse of $1.78 peak power indication low/bad display of 025 MW. Suspect instrument problem with capacitors requiring further troubleshooting repair. 10s/2s energy integral also low/suspect. Fuel temperature in line with historical values.
2023-10-06		1.5W	WRM period scram circuit noise when depressing REG drive UP button.
2023-10-19		<1.5W	WRM period scram on key switch key insert.
2023-12-05		250kW	Manual scram on 10% power drop from experiment failure in CT. Characterization of the failure, and the sample and TRIGA tube materials used, resulted in the development of different double encapsulation materials and the implementation of temperature monitoring/cooling for future similar experiments.
2023-01-10		1.5W	Source Interlock Rod Block
2023-01-10		1.5W	Source Interlock Rod Block
2023-01-10		1.5W	Source Interlock Rod Block
2023-03-13		1kW	FTR UP Light Problematic
2023-03-14		1kW	FTR UP Light Problematic
2023-03-20		100kW	CAM High, post manual SCRAM, after operation at 100kW. Beta NCPM from entrained contamination in CT flushed out during experiment cooling. CT was subsequently cleaned of particulates.
2023-04-04		90kW	FTR UP Light Problematic
2023-04-12		250kW	PRM DMC-3000 dropped in reactor pool by Visiting Researcher
2023-04-14		250kW	WRLM scram, WRM (erratic, circuit noise)
2023-04-18		<1.5W	WRM period scram (erratic, circuit noise)
2023-04-20		<1.5W	WRM period scram (erratic, circuit noise)
2023-06-07		<1.5W	WRM period scram (erratic, circuit noise)

Section 4
Non-Routine Maintenance and Surveillance and Other Incidents

The following non-routine maintenance/surveillance activities were carried out during this period. As noted earlier, routine surveillance and operations were established as of the start of this review period.

TABLE IV – Maintenance, Surveillance, and Other Incidents

2022-11-06		CAM (Continuous Air Monitor) pump flow low, call-out after hours RSE responded. Backup pump installed, original pump serviced, re-built and RTS.
2023-03-28		CT (Central Thimble) irradiation facility cleaned of accumulated particulates using in line vacuum filter and subsequent Swiffer ream cleaning.
2023-04-12		DMC 3000 personal digital dosimeter dropped in pool to bottom at side of reactor reflector next to pool liner wall. Retrieved via extension pole net, desiccant dried, and ready to RTS following calibration check.
2023-06-26		Purification slow leak (<1 liter/week) at particulate filter to ion exchange bed riser fittings retaped and reassembled. Periodic particulate filter replacement performed.

Section 5
Facility Changes and Special Experiments Approved

Four (4) 10 CFR 50.59 change screenings were initiated and completed during the year:

2022-01	9/15/2022	Replace Horizon 1.0 Area Radiation Monitor (ARM) system with Horizon 2.1 ARM system.
2022-02	11/18/2022	Install Yokogawa digital recorder in parallel with existing Westronics paper recorder.
2023-01	2/24/2023	Experiment 5 addendum, Ac-225 production
2023-02	6/16/2023	SOP for Exp 5 Ac-225 sample cooling

No new experiments involving the reactor were approved or performed during the year.

Section 6

Radioactive Effluent Release

(a) Gases

The major direct release to the environs is Argon-41 produced during normal operations. Very small amounts of other gases may be released from irradiated materials in experiments.

Releases are computed based on original measurements at point of origin within the facility and taking only dilution into account. Since much of the release is from operation of the pneumatic transfer system for samples, this is a conservative estimate in that assumption is made that all use of the PT is at full steady state power level (250 kW) when, in fact, considerable use is with the reactor at a lower power level. In view of the small numbers involved, and the fact that an integrated dose check is provided by an environmental dosimeter hanging on the side of the exhausts at the point of entry to the fan creating the stack discharge, it is considered unnecessary to provide further checks of these estimates. The dosimeter data confirm that an individual standing directly in the exhaust flow for one year would receive an additional submersion dose from the exhaust less than the reliability limit of the dosimeters, or less than 20 mrem per year. The dosimeter data are presented separately in section 7. Over the years that data have been collected, the accumulated exposure at the exhaust locations have been lower than for "control" points because of lower masses of concrete structures in the vicinity. In fact, the data have been consistent at about 20 mrem per year below control level, and >30 mrem below a distant check level (5^{th} floor library) so confidence of exposure less than 5 mrem over background seems plausible.

Release estimates based on operational parameters are as follows:

TABLE V – Radioactive Effluent Release Estimates	
Operation of pneumatic transfer system - 07/01/2022 - 06/30/2023:	
A. Minutes of Operation (minutes):	2002
B. Release Rate Assumed (µCi/mL):	6.0 E-08
C. Flow Rate of Exhaust Air (mL/min):	1.2 E+08
D. Dilution Factor (unitless):	0.01
E. PT System Release Computed (µCi): A*B*C*D = E:	144.14
Release from pool surface – 07/01/2021 – 06/30/2022:	
F. Total Hours of Operation at Full Power (EFPH):	83.62
G. Release Rate Assumed (µCi/mL):	1.0 E-08
H. Flow Rate of Exhaust Air (mL/min):	1.2 E+08
I. Dilution Factor (unitless):	0.01
J. Pool Surface Release Computed (µCi): F*G*H*I*60 = J:	60.21
Total Emissions from PT and Pool (µCi): E + J:	204.35
Total Effluent Released in One Year (mL): 525960 min / year*H*I	6.31 E+11
Average Concentration Released (µCi/mL): Total Emissions / Total Effluent	32.4 E-11

Since 2.0 E-09 µCi/mL provides an annual exposure for constant immersion of 10 mrem, this corresponds to < 2 mrem potential additional radiation exposure to an individual standing in and breathing in the effluent stack for the entire year, a zero-likelihood event. *Note*: Minutes of operation includes PT air blower minutes and CT minutes with N_2/air cooling. *Additional note*: the mixed and diluted exhaust plume is discharged to approximately 100 feet above the roof level (200 feet above surrounding ground), granting even greater dilution.

(b) Liquids and Solids

Liquid and solid wastes from utilization of by-product materials are disposed through a university contract. Waste is transferred to the custody of UCI Environmental Health and Safety (EH&S). Disposals to this custody are given below. It is important to note that activity values are estimated at the time of transfer to EH&S control. Since few shipments are being made from campus, decay to negligible levels occurs for all medium-lived radionuclides. Teaching course items (used for training in liquid scintillation counting techniques) may be a mixture of reactor generated byproducts including ^{3}H from ^{6}Li irradiation and purchased materials (exclusively ^{14}C). During this period, advantage continued to be taken of a campus program to dispose of additional legacy radioisotope materials including decayed sealed sources and measurement samples, mostly not UCI reactor related.

Production of radioactive waste materials has been minimal during this period.

Liquid Waste:

One liquid waste transfer was made this period.

1. 3 containers, 0.07 gallons, waste from sample disposal following activation analysis containing petroleum distillates Naphtha 10%, HKGO, LKGO petrol hydrocarbon distillates 20%, N Methyl Pyrrolidone NMP 30%, and H_2O 40%, with trace ^{60}Co.
2. 1 container, 1 ft^3 of waste of liquid scintillation cocktail vials in bag lined box, with trace ^{60}Co, ^{124}Sb.

Solid, Dry Waste:

One solid dry waste transfer was made this period.

1. Eleven containers of dry solids, 8 ft^3 total, with trace ^{60}Co, ^{124}Sb, ^{133}Ba, ^{65}Zn in 5ft^3 of boxed nitrile glove waste, 1 ft^3 particulate filter element, and 2 ft^3 of quart Ziploc bags of various NAA waste.

Section 7
Environmental Surveillance

Environmental dosimeters are in place at 12 locations around the UCI Campus for environmental monitoring purposes. These are provided by Mirion Technologies, Oak Ridge, TN (formerly in Irvine, CA). The environmental packs have three chips in each pack which are averaged for exposure recording. Mirion runs multiple control samples in addition to the locations listed below. All dosimeters are housed in small metal locked boxes (except for locations 10 and 12). The tables below list the locations. As work in Engineering Tower 521 had ceased, the dosimeter there was redeployed to the storage closet across the hall from the east side of the reactor facility. Other locations have been renamed to agree with the locations in the revised ventilation system provided for Rowland Hall, and a new laboratory constructed on the former loading dock adjacent to the north side of the facility.

Routine contamination surveys consisting of wipe tests and G-M surveys have shown mostly a "clean" facility with significant, removable contamination only in areas coming into direct contact with samples removed from the reactor, and on sample handling tools. Trash is surveyed before disposal and not disposed of unless found to be free of removable and fixed contamination.

Table VI - Locations for Environmental Dosimeters
1. South Reactor Facility Perimeter
2. West Reactor Facility Perimeter
3. North Reactor Facility Perimeter in adjacent lab of Atmospheric Chemistry group.
4. Rowland Hall Roof Air Exhaust Duct to Fan 1.
5. Rowland Hall, First Floor Hallway Over Reactor Facility.
6. McGaugh Hall Top (5th) Floor
7. Langson Library Top Floor
8. Reines Hall Top (5th) Floor
9. Rowland Hall Roof Air Exhaust Duct to Fan 2.
10. On-campus Faculty Housing
11. Rowland Hall Roof Air Exhaust Duct to Fan 3.
12. Reactor Storage Closet Rowland Hall East side of facility.

Table VII – Environmental Dosimetry Data
Average Total Exposures in mrem (Including Control Background)

Location	***Quarter***				***Annual***	***Prior Year***	***Above Control***
	2022 Q2	**2022 Q3**	**2022 Q4**	**2023 Q1**			
1. S. Facility Perimeter	**41**	**32**	**28**	**29**	130	111	+3
2. W. Facility Perimeter	**39**	**29**	**32**	**32**	132	112	+5
3. N. Facility Perimeter	**40**	**28**	**29**	**33**	130	112	+3
4. Facility Air Exhaust Fan 1.	**33**	**22**	**21**	**21**	97	86	-30
5. Hallway Over Facility	**33**	**23**	**24**	**27**	107	94	-20
6. McGaugh Hall Top Floor	**34**	**26**	**24**	**28**	112	96	-15
7. Langson Library Top Floor	**44**	**31**	**31**	**36**	142	125	+15
8. Reines Hall Top Floor	**38**	**27**	**26**	**30**	121	105	-6
9. Facility Air Exhaust Fan 2.	**36**	**23**	**21**	**24**	104	87	-23
10. On-Campus Housing	**34**	**23**	**22**	**26**	105	91	-22
11 Facility Air Exhaust Fan 3.	**33**	**23**	**21**	**23**	100	88	-27
12 E. Facility Closet	**37**	**26**	**24**	**28**	115	101	-12
Background Control	**43**	**27**	**26**	**31**	127	106	0

Discussion

Raw data is presented here, along with controls and prior year comparisons. Within this range, the data sets vary relatively little. Locations on walls bordering the facility, such as 1, 2, 3, are usually the highest, remote locations, such as 10, 11, and 12, are the lowest. Data for this year reflects several issues:

- Location 7 is on the top floor of a large building and may experience greater cosmic flux, as well as concrete releases. This has been a result continuing for many years.
- Location 1 near the facility's gamma irradiator, as well as a lead cave which continues to store a higher activity load.
- Location 2 is on the other side of a location in the reactor facility temporarily used for source storage.
- Location 3 is on the other side of a concrete wall from the ion exchange resin tanks which have moderate levels of activity. This location is also in a radiation use laboratory, which may be contributing to the higher dose readings but more likely due to TNORM in the concrete wall and floor.

Conclusion

Exposure estimated to a single individual in any uncontrolled area at this facility is minimal. With the exception of three locations nearest the facility, all dosimetry associated with exposures from the facility indicates lower than control levels. Locations 1 and 2 are in hallways with extremely minimal occupancy or travel, especially since security policy is to maintain permanently locked doors to the hallways on this floor level (access only with building keys), and location 3 is in an adjacent radiation use laboratory. The hallway overhead (location 5) is only casually occupied and not close to a main building entrance. The air released from the facility/building (measured by locations 4, 9, and 11) continues to give no detectable exposure above background. Over many years, the data at each specific location has shown remarkable consistency. The net conclusion is that, within precision of measurement, and compared to distant control areas (numbers 7 and 10), we are operating within statistical error of zero of potential (full 24/7 occupancy) public exposure over normal background levels.

Section 8
Radiation Exposure to Personnel

UCI issues TLD badges to students or researchers regularly utilizing radiation within the facility. Finger dosimetry (TLD) rings were also issued to all those personnel, as there is a strong likelihood of regularly handling radioactive sources. TLDs were read quarterly by Mirion Technologies, and results are presented in Table VIII. Data are for 4 quarters of operations since April 1, 2022. Reporting categories are deep, eye, shallow, and ring shallow. Neutron dosimetry badging was discontinued owing to absence of any recorded exposure greater than zero after many years. Other individuals visiting or casually working in the facility were issued Personal Radiation Monitors (PRM) DMC 3000s (aka EPDs) for which results are shown in Table IX. 9 persons were issued TLD badges and finger TLDs on a continual basis. Researchers, operator trainees, and radiochemistry lab students have also been issued TLDs.

Table IX also lists all visiting individuals that were issued DMC 3000s (PRM) that record in units of 0.1 mrem. Over the span of a few hours, a typical worker could accumulate 0.2 mrem background. A tour visitor usually accumulates 0.0 or 0.1 mrem during a 45-minute visit to the facility.

TABLE VIII
Aggregate Personnel Exposure from TLD (mrem) 2022-04-01 to 2023-04-01

Group	Individuals	Whole Body			Ring
		Deep	Eye	Shallow	Shallow
A	4	87	93	153	297
B	3	11	13	21	0
C	2	1	2	25	0
D	25	110	134	154	-
Total	**34**	**209**	**242**	**353**	**297**

TABLE IX
Data from EPDs for Workers and Visitors*

Group	Persons Admitted*	Max Dose (mrem)	Total Dose (mrem)
A	194	1.1	11.4
B	6	0	0
C	136	0.1	0.4
D	32	0	0
E	636	0.1	1.9
Total	**1004**		**13.7**

* Multiple admissions of the same individual are separately counted. 700 separate individuals were logged in.

Group A: Activation Analysis Personnel: individuals doing extensive or casual activation analysis and radiochemical work at the facility. Most of the exposure is a result of ^{38}Cl, ^{28}Al, or ^{226}Ra radioactivity production/handling.

Group B: Workers: individuals receiving exposure from the handling isotopes for shipment, and/or sources used for calibration activities in the facility.

Group C: Inactive / Other: individuals who did enter but not directly carry out radiation related activities during this period, therefore any exposure reported is an indication of range of general background (for PRM) or background and precision where the TLDs are stored when not in use. This group includes visiting researchers admitted to review facilities for potential experiments, those bringing and taking away samples exposed in the cesium gamma irradiator in the facility and maintenance workers NOT doing work on radiation related systems all of whom are always issued EPD. [Note: Operation of the gamma irradiator is restricted to badged staff personnel].

Group D: Class Students: Radiochemistry Lab (133L) and Operator Training (199/299, 100).

Group E: Tourists: includes tour groups that entered the facility this period.

Personnel exposures continue to be very low at this facility in keeping with ALARA efforts and the low degree of operations experienced. Four individuals performed activation analysis activities this period. Handling activities of ^{38}Cl, ^{24}Na, and ^{226}Ra containing samples leads to some exposure. No radiation exposures received were greater than 25% of that allowed.

Section 9
Closing Remarks

The facility has seen an increase in the number of visitors and hours of use for instruction and research from last year. Key personnel departure and retirement are being addressed to ensure continued function. Waste generation and disposal has remained at its traditionally low values, given the low power of the reactor and the capacity for short term storage of materials. Some activated hardware from SPND testing and medical isotope development have been generated and stored for later disposal. Radiation exposure to personnel also remains low, attributing most dose absorbed per person to the activation analysis activities of the facility or to handling of calibration sources.

The increase in facility activities has been supported by increased involvement of the Reactor Director, Supervisor Emeritus, and Radiochemistry faculty. Licensed operator status and new candidate training has received increased focus.

An Assistant Professor of Chemistry, while assuming teaching roles within the radiochemistry program, is implementing a radiochemistry and nuclear fuel-oriented research program with growing research group membership and summer student participants.

It is anticipated that full operations including laboratory classes, tours and research, and selected improvements to the facility will continue in the coming year.