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Department of Chemistry

1102 Natural Sciences II
University of California, Irvine
Irvine, CA 92697-2025

Wednesday, September 25, 2019

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

SUBJECT: University of California – Irvine, Docket Number 50-326, License Number R-116, Annual Report Submittal in Accordance with Technical Specification 6.7.1

Dear Sir or Madam:

By way of this letter, the University of California, Irvine is submitting the annual operating report as required by Technical Specification 6.7.1 of license number R-116, covering the period of July 1st, 2018 through June 30th, 2019.

If you have any questions regarding this matter, please contact Jonathan Wallick at (949) 824-6082.

Sincerely,

Dr. Rachel Martin
Reactor Director

Enclosure: UC Irvine Annual NRC Report 2018-2019.pdf

CC with Enclosure:

- James Bullock, Dean of School of Physical Sciences, University of California, Irvine
- Johnny Eads, Inspector, U. S. Nuclear Regulatory Commission
- Linh Tran, Project Manager, U. S. Nuclear Regulatory Commission
- George Miller, Chemistry Department, Associate Reactor Supervisor, University of California, Irvine
- Jonathan Wallick, Chemistry Department, Reactor Supervisor, University of California, Irvine
- Reactor Operations Committee Members, University of California, Irvine
- American Nuclear Insurance, 95 Glastonbury Blvd., Glastonbury CT 06033, Policy NF-176

2018 - 2019

UC Irvine
Nuclear Reactor Facility
Annual Report

FACILITY LICENSE R-116 – DOCKET NUMBER 50-326

JONATHAN WALLICK | Associate Reactor Supervisor

Table of Contents

Section 1
Operations Summary

Operation of this facility supports UCI research and education programs in the Department of Chemistry (CHEM) and the Department of Chemical Engineering and Material Science (ChEMS). Research is being conducted in application of radioisotopes as tracers and radiochemical analytical and separation techniques including applications to nuclear waste separations.

Reactor utilization, apart from operator training and maintenance, is for analytical sample irradiation, production of isotopic tracers, 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. The reactor is also used in class work by undergraduates learning tracer and activation analysis techniques using small quantities of short-lived activated materials. Enrollment in the Fall Quarter 2018 laboratory course in Radioisotope Techniques using the facility was 23 students with 2 graduate teaching assistants, who also learned these techniques.

Support for UCI faculty and students includes grants from NRC and DOE (NEUP and NSSC), and partnerships with national laboratories (PNNL, LLNL, LANL, and INL).

Use is also made of the facility by other educational institutions, both for research and for visits/tours. A modest Nuclear Science Outreach program (NSOP) using UCI students to present talks and a laboratory to middle and high school classes has been continued. This program has also involved tours, class demonstrations, and analyses of samples submitted by faculty.

Operations have dropped somewhat steeply as the primary on campus user and associated group has effectively shut down. Criticality was achieved for 171.03 hours, down significantly from the previous year, and the total energy generated was equivalent to 88.49 hours at full steady state power. 89 separate experiments were performed and 1653 samples were irradiated, showing the decreased throughput for the facility. Three moderate level mixed isotope shipments were made, all Yellow II category, totaling 3.82 GBq of activity. Twenty-one pulses were performed this year, all without incident, with the highest pulse on record at the facility of 1.21 GW. One 10 CFR 50.59 change has been initiated and completed during the course of the last year. Again, with an aging facility such as this, a few unusual maintenance/surveillance results/activities were noted/conducted during this period: replacement of a contaminated in core terminus, and a complete tear apart and rebuild of the ATR drive to fix long standing issues. One new experiment was approved and its associated experimental facility installed in the reactor pool.

No routine NRC inspection has taken place yet owing to problems with scheduling the regulatory side, but is expected to be scheduled and completed soon. In 2018-2019, a Reactor Operations Committee meeting was held on January 29th, 2019 in accordance with Technical Specification requirements.

No follow-ups or incidents have been forthcoming regarding security or emergency response. One emergency drill / exercise has been held this past year involving the UCI EH&S

radiological personnel, Orange County Fire Authority, UCI Police Department, Orange County Health Care Agency, California National Guard Hazmat team, and reactor staff and faculty. The exercise was held on November 21st, 2018, to large success, involving all agencies previously named, running tabletop exercises with the entire group. A larger drill run by the federal government, Silent Thunder, is set to be conducted early 2020.

Inspections/audits continue to be conducted quarterly by the Radiation Protection staff of EH&S at UCI. These have identified that frequency schedules have been properly maintained, and results continue to show absence of significant levels of contamination or personnel exposure. One incident did occur this past year, but was properly documented and corrective actions taken. Our radiation safety division has been in a state of flux for the past three years, mainly due to funding issues that are partially resolved.

Three new operator trainees underwent training this year, with one taking the NRC examination on June 5th, 2019, resulting in his licensure as a reactor operator. As of June 30th 2019, 5 senior operators and 2 reactor operators were licensed. One SRO and three ROs are currently inactive. Beginning next quarter, a voluntary, formal operator training program is being started for UCI undergraduate and graduate students in the interest of promoting the training thrust of the reactor program.

Section 2
Data Tabulations for the Period July 1st, 2018 to June 30th, 2019

TABLE I – General Information	
Experiment Approvals on file	7
Experiments performed (including repeats)	89
Samples irradiated	1653
Energy generated this period (Megawatt hours)	22.12
Total, 69 element core = 127.00	127.00
>74 element core = 1682.25	1682.25
Total energy generated since initial criticality (Megawatt hours)	1809.25
Pulse operation this period	21
Total reactor pulses to 6/30/2017	1058
Hours critical this period	171.03
Total hours critical to date	10672.86
Inadvertent scrams or unplanned shutdowns or events at power	2
Visitors to reactor - as individuals or in tour groups	899
Maximum dosimeter recorded for visitors - all less than (mrem)	0.3
Visiting researchers (Temporary Self Indicating Dosimeters)	31
Maximum exposure recorded at one visit (mrem)	4.2
Visiting researchers (Thermoluminescent Dosimeters)	10
Students and teaching assistants in class, badged	25
Exposures reported for class (range: 0-0 mrem) average	0
Isotope Shipments this Period (Mixed Activation Products = 0.103 Ci total)	3

TABLE II – Reactor Core Status 2019-06-30 (Core Configuration Changed as of 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 6/30/2019)		$2.91
Control Rod Worths (Calibrated 01/18/2019)	REG	$3.02
	SHIM	$3.56
	ATR	$1.83
	FTR	$0.67
	Total	$9.08
Maximum possible pulse insertion (calculated)		$2.54
Maximum peak power recorded		1210 MW
Maximum peak temperature recorded in pulse (B-ring)		373.7 °C

Section 3
Inadvertent Scrams, Unplanned Shutdowns, Events at Power

TABLE III – Scrams, Unplanned Shutdowns, Events at Power			
Date	Time	Power	Type and Cause
2018-11-20	1024	250 kW	Linear scram. The linear power monitor initiated a scram while establishing stable reactor power at 250 kW. At approximately 106% of the 250 kW range, the linear power monitor initiated a scram. All control rods dropped and the reactor was put into a safe condition. Troubleshooting was performed and root cause of the failure was determined to be a stuck button, the REG UP button, and operator error in the individual not responding quickly enough to correct the condition. The event was not found to be reproducible, though the operator was cautioned to be more aware of such events and immediately depress the DOWN buttons for both SHIM and REG in such an event. Restart was authorized by the Reactor Supervisor.
2019-03-08	0743	750 mW	Period scram. A period scram occurred during a routine start up to 1.5 W. All control rods dropped and the reactor was put into a safe condition. The root cause of the failure was operator error, in that the operator was not conscious enough of the period being established during the startup. The operator was counselled to be more attentive to reactor period during start up. Restart was authorized by the SRO.

Section 4
Maintenance and Surveillance and Other Incidents

The following non-routine maintenance/surveillance activities were carried out during this period. Any reactor operation related items have been included above and are not repeated here.

TABLE IV – Maintenance, Surveillance, and Other Incidents		
Date	Time	Title and Description
2018-07-19	1400	Drywell Installation. A new irradiation facility for the exposure of larger experimental packages, specifically electronic dosimetry, was installed in the reactor pool. The installation was completed without incident and found to be completely leak tight on inspection. This facility was installed in support of experiment series 08 for the testing of battlefield dosimetry packages. The drywell is mobile in the pool, with the use of the installed crane, moving from a storage location opposite the core in the pool, to varying distances from the core depending on the desired exposure.
2018-08-01	1230	DNS Unlined Terminus Replacement. After replacement of the cadmium lined delayed neutron system in-core terminus, the primary experimenter utilizing that system had a fresh fabrication made due to concerns of internal contamination. The previous terminus was removed and stored in the pool for decay while the new terminus was installed without issue. Core excess measurements revealed no difference.
2018-11-19	1905	ATR Rebuild. After years of incidents regarding difficult motion and seizing of the Adjustable Transient Rod drive, a final incident occurred necessitating a complete teardown, cleaning, inspection, and rebuild of the drive. The drive was disconnected from the rod, which was left in its core position, and the work was performed in a prepared area away from the bridge and pool. Over the course of ten hours, all portions of the drive were disassembled, cleaned, lubricated as necessary, and reassembled, including: the externally threaded cylinder, worm drive, ring gear, ball nut, and all bearings. The root cause of the slow driving motion was found to be seizure of the ball nut on the externally threaded cylinder due to the accumulation of dirt, dust, and aged lubricants. All 242 balls in the bull nut were removed, cleaned, lubricated, and properly reloaded. The refreshed drive was reinstalled and connected to the rod. Drive travel was verified to be optimal at 38 seconds and drop testing was completed satisfactorily. Reactor operation was again permitted.

Section 5
Facility Changes and Special Experiments Approved

One 10 CFR 50.59 change has been initiated and completed during the course of the last year.

The single screening form was completed to facilitate the experiment review, approval, and installation of the aluminum drywell noted earlier in section 4.

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 ($CaSO_4$-Dy) hanging directly in the exhaust at the point of 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 consistently at 20-25 mrem per year below background level, 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 - 07/01/2018 - 06/30/2019:	
A. Minutes of Operation (minutes):	393.3
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:	28.32
Release from pool surface – 07/01/2018 – 06/30/2019:	
F. Total Hours of Operation at Full Power (EFPH):	88.49
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:	63.72
Total Emissions from PT and Pool (µCi): E + J:	92.04
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	**1.46 E-10**

Since 2.0 E-09 µCi/mL provides an annual exposure for constant immersion of 10 mrem, this corresponds to < 1.0 mrem potential additional radiation exposure to an individual standing in and breathing in the effluent stack for the entire year.

Additional note: Exhaust is diluted by a factor of 100 before release and the mixed 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 and purchased materials (exclusively ^{14}C and ^{3}H).

Solid, Dry Waste:

One transfers of two 2 cubic foot containers of dry waste were disposed during this period (07/01/2018 through 06/30/2019), estimated at a total quantity in 4 cu ft of 2.0 microcuries of mixed activation products (measured as ^{60}Co equivalent at time of transfer).

Liquid Waste:

One transfer two 1 gallon containers of liquid waste were disposed during this period, estimated at a total quantity in 2 gallons of 29.5 microcuries of mixed activation products (measured as ^{3}H equivalent at the time of transfer).

Section 7
Environmental Surveillance

Calcium Sulfate/Dysprosium thermo luminescent dosimeters are in place at 12 locations around the UCI Campus for environmental monitoring purposes. These are provided by Mirion Technologies, Irvine, California (formerly Global Dosimetry Systems). 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 lock-boxes (except for locations 10 and 12). The table below lists the locations.

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
4. Reactor Facility Main Air Exhaust
5. Rowland Hall, First Floor Hallway Over Reactor Facility
6. McGaugh Hall Top Floor
7. Langson Library Top Floor
8. Reines Hall Top Floor
9. Reactor Facility Emergency Exhaust Duct
10. On-campus Housing
11. Rowland Hall Building Fume Hood Exhaust Duct
12. Engineering Tower Room 521

Table VII – Environmental Dosimetry Data Average Total Exposures in mrem (Including Control Background)							
Location	Quarter				Annual	Prior Year	Above Control
	2018 Q2	2018 Q3	2018 Q4	2019 Q1			
1. S. Facility Perimeter	29	29	24	23	105	118	+4
2. W. Facility Perimeter	27	27	27	28	109	132	+8
3. N. Facility Perimeter	32	28	29	31	120	130	+19
4. Facility Main Air Exhaust	22	20	20	19	81	82	-20
5. Hallway Over Facility	24	23	23	22	92	90	-9
6. McGaugh Hall Top Floor	25	23	22	23	93	96	-8
7. Langson Library Top Floor	31	26	29	29	115	118	+14
8. Reines Hall Top Floor	25	24	23	23	95	98	-6
9. Facility Emer. Exhaust	22	21	19	20	82	83	-19
10. On-Campus Housing	23	21	22	21	87	89	-14
11 Facility Fume Hood Exh.	22	20	19	19	80	82	-21
12 Engineering Tower 521	23	21	21	21	86	85	-15
Background Control	26	25	25	25	101	100	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 trend continuing for six years now.
- Location 1 near the facility's gamma irradiator, which has been in greater use this reporting period, as well as a lead cave which continues to store a high activity load.
- Location 2 is on the other side of a location in the reactor facility temporarily used for source storage.
- Location 3 is located on the other side of a concrete wall from the ion exchange resin tanks and a source storage lead cave, both of which have moderate levels of activity. This location is also now home to a newly constructed radiation use laboratory, which may be contributing to the increased dose readings.

Exposure estimated to a single individual in an uncontrolled area at this facility is minimal. With the exception of three locations near 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 three is in an adjacent radiation use laboratory. The rooms overhead (location 5) are casually occupied by very few individuals (one or two at the most) in the space above the reactor core. 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 with very minimal levels (within statistical error of zero) of potential (full 24/7 occupancy) public exposure over normal background levels.

Section 8
Radiation Exposure to Personnel

UCI issued TLD badges to students or researchers regularly utilizing radiation. Finger dosimetry (TLD) rings are also issued to all personnel, as there is a strong likelihood of regularly handling radioactive sources. TLDs are read quarterly by Mirion Technologies, and results are presented in Table VIII. Data are for 4 quarters of operations since April 1, 2018. Reporting categories are deep, eye, shallow, and neutron. Other individuals visiting or casually working in the facility were issued Dosimans or Dosicards for which results are shown in Table IX. 38 persons were issued TLD badges on a continual basis; 38 were also issued with finger TLDs. 23 students in a radioisotope techniques class were TLD badged. The two teaching assistants for the course were also given dosimetry. Reported exposures for the Radioisotopes Techniques class dropped to expected levels once again during this period, likely due to proper storage of dosimetry and sources by teaching assistants, contrary to last year, averaging 0.0 mrem each person for the quarter.

Table IX also lists all visiting individuals that were issued with Dosimans or Dosicards that record in units of 0.1 mrem. In the course of a few hours, a worker can accumulate 0.2 mrem. A tour visitor usually accumulates 0.0 or 0.1 mrem during a 45 minute visit to the facility. Any reading above 0.2 mrem is tabulated separately.

TABLE VIII
Personnel Exposure (mrem) 2018-04-01 to 2019-03-30

Group	Individuals	Whole Body				Ring
		Deep	Eye	Shallow	Neutron	Shallow
A	8	14	15	23	0	7183
B	6	4	4	13	0	0
C	24	5	7	7	0	0
D	25	0	0	0	0	0
Total	**63**	**23**	**26**	**43**	**0**	**7183**

TABLE IX
Non-Zero Data from EPDs for Workers and Visitors

Group	Persons	Avg. Admissions (per person)	Total Dose (mrem)
A	31	4	17.3
C	76	1	0.7
E	823	1	0.4
Total	**930**	**1037**	**18.4**

Group A: Activation Personnel: individuals doing extensive or casual activation analysis and radiochemical work at the facility. Most of the exposure is a result of Cl-38 or Al-28 radioactivity production.

Group B: Workers: individuals receiving exposure as a result of shipping isotopes, and/or calibration activities in the facility.

Group C: Inactive / Other: individuals who did enter but not carry out radiation related activities during this period, therefore any exposure reported is an indication of range of general background/precision where the badges are stored when not in use.
Group D: Class Students: reported for students and teaching assistants in Radioisotope Techniques class Sep-Dec 2018. Note badges kept 24/7 in laboratory room. All also ran samples by NAA as well as worked with sealed sources.
Group E: Tourists: issuing one dosimeter each for groups of up to 10, and 10 randomly for larger groups. No readings > 0.2 mrem were recorded.

Personnel exposures continue to be very low at this facility in keeping with ALARA efforts, with only one notable event this period: the reactor engineer / chief activation analyst handling an over-activated gold foil. The event was suitably documented and a dose estimate of 6420 mrem to the right hand of the individual was determined and adjusted in his record. Corrective actions and a proper path forward with appropriate extra precautions were implemented for all future work with such materials.

Section 9
Closing Remarks

Overall, the facility has seen a decline in usage and income, but measures are being taken 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. Radiation exposure to personnel also remains low, attributing most dose absorbed to the primary activation analyst of the facility. Several projects are set to establish a stronger reactor program overall:

- a new training program for reactor operator candidates is launching in September of 2019, the first for-credit program ever on the campus;
- a new commercial activation analysis service was launched in March of 2019 and is functioning well with several improvements for automation and analysis underway;
- to improve research, a faculty outreach and education program is being developed and work is currently underway on neutronic and thermal-hydraulic studies of the reactor for a license amendment request in the coming year for an increase of steady-state power levels to at least 1 MW, in order to improve the sensitivity of NAA conducted at the facility as well as expand capabilities to appeal to a broader user base;
- a second full time person has also been funded by the university to improve the ability of the reactor staff to maintain and improve the facility and associated program, and a new professor in radiochemistry was hired in July of 2019;
- and a new professional master's program is being developed for nuclear professionals in a variety of environments.

While this has always been a rather small scale operation, the need for a broader and more appealing program was made evident by the sudden departure of the core user of the facility, and the financial and utilization impacts that brought. The campus, School of Physical Sciences, and Chemistry department are deeply thanked and commended for their commitment to improving this resource that would otherwise remain underutilized, obscured, and eventually quietly disappear.