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30 March 2016

Document Control Desk
US Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Re: Annual Report for 2015
License No. R-120
Docket No. 50-297

In accordance with Technical Specification 6.7.4, the annual operating report for our facility is attached.

If you have any questions regarding this correspondence or require additional information, please contact Gerald Wicks at 919-515-4601 or wicks@ncsu.edu.

I declare under penalty of perjury that the forgoing is true and correct. Executed on 30 March 2016.

Ayman I. Hawari, Ph. D.,
Director, Nuclear Reactor Program
North Carolina State University

Enclosures:
Annual Operating Report for 2015
Attachment A: PULSTAR Reactor Environmental Radiation Surveillance Report

NORTH CAROLINA STATE UNIVERSITY

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 January 2015 - 31 December 2015

The following annual report for 2015 is submitted in accordance with Section 6.7.4 of the North Carolina State University PULSTAR Reactor Technical Specifications:

6.7.4.a Brief Summary:

Reactor operations have been routine during this reporting period. The primary and secondary cooling systems were modified with new equipment. The changes made were reviewed in accordance with 10 CFR 50.59 and made using an approved design change. Details are provided in Section 6.7.4.e.

i Operating experience including a summary of experiments performed.

Reactor operations have been routine during this reporting period. The following is a brief summary of the types of experiments performed:

Teaching Laboratories, Short Courses, Research and Services:

- Core thermal power measurements
- Dynamic reactivity measurements
- Axial power and peaking factor measurements (flux mapping)
- Reactor power determination using photodiode arrays
- Neutron fluence and spectral measurements
- In-core detector certification
- Accelerated lifetime testing for nuclear detectors
- Neutron radiography
- Positron production facility
- Neutron Diffraction
- Isotope Production
- Crude oil
- Food samples
- Fish tissues
- Laboratory animal tissue
- Human hair, nails, and urine
- Polymers and plastics
- Sediment/soil/rocks
- Silicon crystals
- Textiles
- Water

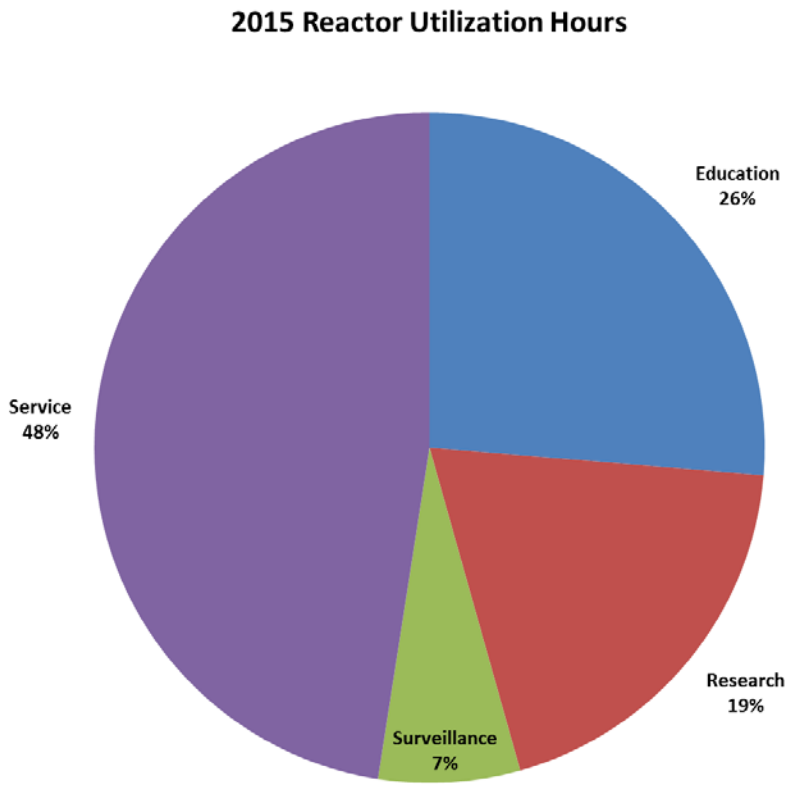

Figure 1 - Reactor Utilization by Protocol

Utilization	Hours	Percent
Education	582	26%
Research	427	19%
Surveillance	151	7%
Service	1052	48%
TOTAL	2212	100%

NOTE: Utilization hours (2212 h) exceeded critical hours (1044.88 h) since there was typically more than one user of the reactor facility at a given time.

ii Changes in Performance Characteristics Related to Reactor Safety:

None

iii Results of Surveillance, Tests, and Inspections:

The reactor surveillance program has revealed no significant or unexpected trends in reactor systems performance during this reporting period. The Reactor Safety and Audit Committee (RSAC) performed its annual audit for the facility and determined that all phases of operation and supporting documents were in compliance.

6.7.4.b Energy Output and Critical Hours:

Total Energy Output in 2015:	38.15 Megawatt·days
Critical hours in 2015:	1044.88 hours
Cumulative Total Energy Output Since Initial Criticality:	1632.39 Megawatt·days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

Emergency Shutdowns - NONE

Unscheduled Shutdowns – Two

16-FEB-2015 Flapper NOT Closed SCRAM. Immediately following the SCRAM, it was verified that the Flapper was actually closed. SCRAM was caused by the secondary pump discharge check valve S6 not closing properly. The valve was removed and inspected. Debris, from the initial construction of the system, had accumulated in the hinge mechanism of the valve. The mechanism was thoroughly cleaned and its operation was notably improved. A temporary corrective action was to add the valve cleaning as a maintenance item and to place it on the maintenance schedule. It is being evaluated if the valve can be removed permanently to prevent this from occurring in the future.

29-APR-2015 Linear Level Over-Power SCRAM. While performing a routine increase from intermediate power to full power a Linear Level Over-Power SCRAM occurred at approximately 250 kW. During this event all TRIP STATUS lights activated and the RANGE display LED panel went blank. System was power-cycled and a complete calibration per surveillance procedure and factory manual was performed. For more information refer to maintenance item 809 listed in Section 6.7.4.d of this report.

6.7.4.d Corrective and Preventative Maintenance:

Preventative maintenance, tests and calibrations are scheduled, performed and tracked utilizing the PULSTAR Surveillance File System. Each major component of the Reactor Safety System defined in Section 3.3, and all surveillance required by Section 4 of the Technical Specifications are monitored by this file system to ensure that maintenance and calibrations are performed in a timely manner. All historical data relating to those components, in addition to many other sub-systems, are maintained in these files.

803 PS-1-03-6 – Reactor Power Recorder – Replacement of Reactor Power Recorder as per design change 774. Surveillance procedure PS-1-03-6 *Reactor Power Recorder* was performed satisfactorily following the replacement.

804 PS-8-03-1 – Neutron Imaging Facility – The Neutron Imaging Facility beam shutter was not opening and closing smoothly. Upon inspection two of the roller bearings were found to be walking out of the roller housings. The bearings were pressed back into place and tack welded. Surveillance procedure PS-8-03-1 *Neutron Imaging Facility Periodic Inspection* was performed satisfactorily following the replacement.

805 PS-5-02-1A – Main Exhaust Fan Motor Starter – During the startup checklist evacuation test, the main exhaust damper did not indicate closed and the Main Ventilation start pushbutton indicated on and would not turn off. Upon inspection, a plastic clip on the Main Exhaust motor starter for the auxiliary contact block was broken causing the auxiliary contact to not close properly. The auxiliary contact block was moved to the opposite unused side of the motor starter. A new motor starter unit

was ordered and the item was placed on the maintenance schedule for replacement when it is received from the distributor. The evacuation test was completed satisfactorily.

806 PS-6-12-6 – Stack Sample Pump – Stack Sample Pump Low flow alarm occurred. Upon inspection, the pump was operating but generating air flow below the set-point. The vanes were found to be worn and were replaced. Following replacement of the vanes, the unit was returned to service.

807 PS-8-03-1 – Neutron Imaging Facility – The Neutron Imaging Facility beam shutter was not opening and closing smoothly. Upon inspection one roller bearing was found to be walking inwards in one of the rollers. This is the opposite direction that the bearing was moving in Maintenance Log 804. All four roller assemblies were replaced with new assemblies. Surveillance procedure PS-8-03-1 *Neutron Imaging Facility Periodic Inspection* was performed satisfactorily following the replacement.

809 PS-1-03-4A – Linear Level Monitor – While increasing power from 200 kW a Linear Level Over-Power SCRAM occurred at approximately 250 kW. It was noted that the RANGE display was blank, all trip status lights were indicating on and that the power recorder was displaying "+Over". At no time was there ever an over-power condition. The reactor was secured and a calibration was performed satisfactorily. The signal from the Linear Level Monitor was recorded overnight. The condition that caused the SCRAM to occur could not be repeated or recreated.

810 PS-1-05-1 – Safety Level Monitor/Detector – During the reactor startup checklist, the Safety Level Monitor went downscale low when placed into auto-ranging mode. Upon inspection the signal cable at the connection to the detector was degraded from radiation. Both the high voltage and signal cables were replaced. A channel calibration was performed satisfactorily following the replacement.

811 PS-3-02-5A – Cooling Tower – Periodic cooling tower cleaning by outside contractor. Cooling tower strainer basket cleaned.

812 PS-5-02-1A – Main Exhaust Fan Motor Starter – During the startup checklist evacuation test, the main exhaust damper did not indicate closed and the Main Ventilation start pushbutton indicated on and would not turn off. The motor starter was replaced. The evacuation test was completed satisfactorily.

813 PS-5-06-1 – Reactor Building Differential Pressure – Bay to Atmosphere dP gauge was indicating low differential pressure. Upon inspection it was found that the atmospheric pressure sensing line was obstructed. The line was replaced and differential pressure indication returned to normal.

814 PS-1-14-6 – Secondary Coolant System Check Valve – Check valve S6 was closing hard causing vibration in the secondary piping. The valve was removed and cleaned. After reinstallation, the performance of the valve was greatly improved.

815 PS-3-02-5A – Cooling Tower Fan – During daily inspections, the welds for the cooling tower fan motor mounting bracket were found to be cracked causing the fan to wobble during operation. Mounting bracket was repaired and cooling tower was returned to service.

816 PS-5-06-1 – Reactor Building Differential Pressure – Bay to Atmosphere dP gauge was indicating low differential pressure. Upon inspection it was found that a small piece of debris was blocking the newly installed line as detailed in Maintenance Log 813. The line was removed and the hole drilled out and the line was reinserted. Differential pressure indication returned to normal.

817 PS-1-14-6 – Secondary Coolant System Check Valve – Check valve S6 was closing hard causing vibration in the secondary piping. The valve was removed and cleaned and the spring tension of the valve was adjusted. After reinstallation, the performance of the valve was greatly improved. Design

Change 805 – Removal of Secondary Check Valve was approved in January 2016. The design change will be implemented if the valve poses further difficulty.

818 PS-5-01-1A – Main Ventilation/Confinement System – During the startup checklist evacuation test, Confinement Fan No. 1 failed to start. Confinement Fan No. 2 started following the 55 second delay as required. Upon inspection it was found the auxiliary contact for the Main Supply Fan would not change state. The auxiliary contact was replaced. The evacuation test was completed satisfactorily.

6.7.4.e Changes in Facility, Procedures, Tests, and Experiments:

Facility Changes

Design changes to the reactor facility are reviewed to determine whether or not a 10 CFR 50.59 evaluation was required. There were no design changes in 2015.

Document Changes

Procedure changes were reviewed to determine whether or not a 10 CFR 50.59 evaluation was required. Based on the screening reviews none required a full 10 CFR 50.59 evaluation.

In anticipation of the upcoming license renewal in 2017, a procedure review process commenced in 2015. All procedures are being evaluated, revised, reaffirmed, or retired. This process is scheduled to be completed prior to the license renewal submittal in 2017.

779 Security Plan – The Physical Security Plan was revised. It was determined that the changes did not decrease the effectiveness of the plan. The changes were implemented and the NRC was informed.

780 PS-3-01-4 – Calorimetric Power Calibration – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

782 Special Procedure 2.7 – Unplanned Event Notification and Reporting – Added guidance for unplanned planned events associated with experimental facilities.

783 PS-1-10 – Temperature Channel Calibration – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

784 PS-4-07 – Fuel Inspection – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

785 PS-1-11-1 – Temperature Monitoring Channel Check – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

786 PS-5-06-1(2) – Magnehelic Gauge Calibration – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

787 PS-5-08-1 – Dampers, Gaskets, and Seals Inspection – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

788 PS-4-01(02)(03)(04)-2(3) – Control Rod Inspection – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

789 PS-4-01(02)(03)(04)-2(3) – Control Rod Calibration – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures. Incorporated Special Procedure SP3.5 *Gang Rod Worth Curve Verification* into this procedure.

790 PS-2-03 – Flow Channel Calibration – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures. Added instructions on how to bring the manometer on service.

791 PS-4-06-2 – Flow Monitoring Channel Check – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures. Added instructions to bring the manometer on

service.

792 PS-8-02-1 – Excess Reactivity and Shutdown Margin Calculation – Procedure reaffirmation and reformat with minor changes due to periodic review of procedures.

793 NRP-OP-411 – Deuterium System Procedures – Updated procedure to include instructions for the following components: Palladium Filter, Para-Ortho Converter and a Solid Diagnostics System for characterizing the deuterium crystal.

794 NRP-OP-101 – Reactor Startup and Shutdown – Added instructions to verify that the ventilation system is in the required mode of operation while performing fueled experiments as directed by Technical Specification 3.8.

795 NRP-OP-104 – Reactor Experiments – Added verification that the limitations for performing fueled experiments as directed by Technical Specification 3.8 are satisfied.

796 PS-8-04-1 – Reactivity Coefficients – New surveillance procedure for measuring the reactivity coefficients for any core configuration. This procedure is based on the startup test procedures for previous cores.

798 PS-4-07-2 – Reactor Fuel Burnup – New surveillance procedure for determining and tracking fuel burnup as required by Technical Specification 5.1.b.

Test and Experiments

781 Testing of the UCN Facility with Flammable Gases – Testing of the various systems and components of the Ultracold Neutron Facility outside of the biological shield with methane and deuterium in cryogenic conditions. The testing is performed well away from the reactor core and ultra-cold neutrons will not be generated during this testing phase.

797 Protocol for Solid Fueled Experiments – The purpose of the protocol is to provide the requirements for conducting research and testing of fissionable material in solid physical form in approved experimental facilities at the NCSU PULSTAR Nuclear Reactor. All License, Technical Specifications, Final Safety Analysis Report requirements and conditions are satisfied by this University Protocol.

Other Changes

770 License and Technical Specification Amendment – This license and technical specification amendment would permit the use of 4% and/or 6% U-235 fuel in the reactor core. This amendment request was approved by the appropriate campus committees in 2014 and was submitted to the Nuclear Regulatory Commission in 2015.

6.7.4.f Radioactive Effluent:

Liquid Waste (summarized by quarters)

i. Radioactivity Released During the Reporting Period:

Releases to the sanitary sewer are given below:

Period	(1)	(2)	(3)	(4)[1]	(5)
2015	Number of Batches	Total μCi	Total Volume Liters	Diluent Liters	Tritium μCi
01 JAN – 31 MAR	2	110	6.66E3	5.91E4	104
01 APR – 30 JUN	5	300	1.66E4	7.52E4	290
01 JUL – 30 SEP	5	309	1.67E4	1.27E4	306

01 OCT – 31 DEC	2	183	6.61E3	1.44E3	182
2015	882 μCi of tritium was released during this year.				
2015	902 μCi of total activity was released during this year.				
[1]Based on gross beta activity only. Tritium did not require further dilution.					

ii. Identification of Fission and Activation Products:

The gross beta-gamma activity of the batches in (i) above were less than 2×10^{-5} μCi/ml. Isotopic analyses of these batches indicated low levels of typical corrosion and activation products. No fission products were detected.

iii. Disposition of Liquid Effluent not Releasable to Sanitary Sewer System:

All liquid effluent met the requirements of 10 CFR 20 for release to the sanitary sewer.

Gaseous Waste (summarized monthly)

i. Radioactivity Discharged During the Reporting Period (in Curies) for:

(1) Gases:

Year	Month	Total Time Hours	Curies
2015	JANUARY	744	0.439
	FEBRUARY	672	0.242
	MARCH	744	0.371
	APRIL	720	0.224
	MAY	744	0.147
	JUNE	720	0.509
	JULY	744	0.359
	AUGUST	744	0.232
	SEPTEMBER	720	0.179
	OCTOBER	744	0.371
	NOVEMBER	720	0.190
	DECEMBER	744	0.0763
	TOTAL	8760	3.34

(2) Particulates with a half-life of greater than eight days:

Particulate filters from the Stack Particulate Monitoring Channel were analyzed upon removal. There was no particulate activity with a half-life greater than 8 days indicated on any filter during this reporting period.

ii. Gases and Particulates Discharged During the Reporting Period:

(1) Gases:

Total activity of argon-41 released was 3.34 curies in 2015.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack in 2015 was 1.6×10^{-8} µCi/ml. Dose calculations for the year were performed using methods given in the Final Safety Analysis Report. Dose calculations gave results less than the 10 CFR 20 constraint level of 10 mrem. These results are consistent with environmental monitoring data given in Attachment A.

(2) Particulates:

Refer to gaseous waste i.(2) above. Low levels of naturally occurring radioactivity were detected.

Solid Waste from Reactor

i. Total Volume of Solid Waste Packaged

Total volume of solid waste was 61 ft^3.

ii. Total Activity Involved

Total activity for solid waste was 0.78 mCi.

iii. Dates of shipments and disposal

Two transfers to the university broad scope radioactive materials license were made in 2015. The University Environmental Health and Safety Center arranges disposal of hazardous wastes.

6.7.4.g Personnel Radiation Exposure Report:

Twenty-eight individuals were monitored for external radiation dose during the reporting period. Internal dose monitoring was not required for any individual. Collective deep dose-equivalent for 1 Jan 2015 to 31 Dec 2015 was 1.883 person-rem. Individual deep dose-equivalent ranged from 0.001 rem to 0.457 rem with a median of 0.052 rem and average of 0.067 rem.

6.7.4.h Summary of Radiation and Contamination Surveys Within the Facility:

Radiation and contamination surveys performed within the facility indicated that:

- Radiation in the majority of areas was 5 mrem/h or less.
- Radiation in the remaining areas was higher due to reactor operations.
- Contamination in most areas was not detectable. When contamination was detected, the area or item was confined or decontaminated.

6.7.4.i Description of Environmental Surveys Outside of the Facility:

Refer to Attachment A for results of environmental sampling and analysis.

Radiation surveys performed in unrestricted areas near the reactor facility indicated that:

- Radiation was at background levels for most areas (average background is approximately 10 µrem/h).

- Contamination was not detectable.
- Net radiation readings ranged from 0 to 30 µrem/h while the reactor was operating at power. However, radiation was at background levels in all routinely occupied spaces.
- Water samples from Rocky Branch Creek were analyzed in 2015 for tritium, gross beta activity, gross alpha activity, and gamma radiation. All sample results were consistent with background radioactivity. Environmental monitoring of Rocky Branch Creek is routinely performed in accordance with facility procedures.

ATTACHMENT A

PULSTAR REACTOR

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR CALENDAR YEAR 2015
[JANUARY 1, 2015 - DECEMBER 31, 2015]

NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY CENTER

RADIATION SAFETY DIVISION

by
Ralton J. Harris
Environmental Health Physicist

TABLE OF CONTENTS

1. INTRODUCTION

The Environmental Radiation Surveillance Program exists to provide routine measurements of the university environment surrounding the PULSTAR Reactor. The specific objectives of this program include:

- Providing information that assesses the adequacy of the protection of the university community and the public-at-large;
- Meeting requirements of regulatory agencies;
- Verifying radionuclide containment in the reactor facility;
- Meeting legal liability obligations;
- Providing public assurance and acceptance.

TABLE 1 ENVIRONMENTAL MONITORING PROGRAMS FOR THE PULSTAR REACTOR AT NORTH CAROLINA STATE UNIVERSITY

SAMPLE	ACTIVITY MEASURED	CONDUCTED BY	PREVIOUS FREQUENCY	CURRENT FREQUENCY	BASIS FOR MEASUREMENT
STACK GASES	GROSS GAMMA	N.E.	CONTINUOUS	CONTINUOUS	10 CFR 20 T.S. 6.7.4
STACK PARTICLES	GROSS BETA GAMMA EMITTERS	N.E. N.E.	MONTHLY	MONTHLY	10 CFR 20 T.S. 6.7.4
WATER FROM REACTOR FACILITY	GROSS BETA GROSS GAMMA TRITIUM	N.E. N.E. N.E.	PRIOR TO DISCHARGE (~ MONTHLY)	PRIOR TO DISCHARGE (~ MONTHLY)	10 CFR 20 T.S. 6.7.4 CITY OF RALEIGH ORDINANCE
AIR PARTICLES AT 4 CAMPUS STATIONS[1]	GROSS BETA GAMMA EMITTERS	RSD RSD	WEEKLY WEEKLY	QUARTERLY QUARTERLY	10 CFR 20 10 CFR 20
AIR DOSE AT 7 CAMPUS STATIONS[2]	TLD DOSIMETER	RSD	QUARTERLY	QUARTERLY	10 CFR 20
SURFACE WATER ROCKY BRANCH CREEK	GROSS BETA GAMMA EMITTERS TRITIUM	RSD RSD N.E.	QUARTERLY QUARTERLY	QUARTERLY QUARTERLY QUARTERLY	NCSU NCSU 10 CFR 20
VEGETATION NCSU CAMPUS	GROSS BETA GAMMA	RSD RSD	SEMI-ANNUALLY	EVERY OTHER YEAR	NCSU NCSU
MILK LOCAL DAIRY	I-131	RSD	MONTHLY	EVERY OTHER YEAR	NCSU

ABBREVIATIONS USED IN TABLE:

N.E. = NUCLEAR ENGINEERING/REACTOR FACILITY; RSD/EHSC = RADIATION SAFETY DIVISION.

[1]THESE 4 STATIONS INCLUDE:

WITHERS, DANIELS, POLK, AND ENVIRONMENTAL HEALTH & SAFETY CENTER.

[2]THESE 7 STATIONS INCLUDE: PULSTAR REACTOR, A CONTROL STATION (EH&S) AND THE 4 AIR SAMPLING STATIONS, AND NORTH HALL.

2. AIR MONITORING (TABLES 2.1, 2.2, 2.3 and 2.4)

Air monitoring is performed continually for one week during each of four (4) quarters during the year. The data in Table 2.2 are for gross beta activity levels measured during the year. The highest gross beta activity observed was 15.7 fCi/cubic meter at the Environmental Health & Safety Center station during the week of 06/12/2015 to 06/19/2015. The annual campus average value was 10.3 fCi/cubic meter.

Table 2.3 lists LLD values for several gamma emitters which would be indicative of fission product activity. No gamma activity due to any of these radionuclides was detected.

Table 2.3 lists LLD values for several gamma emitters which would be indicative of fission product activity. No gamma activity due to any of these radionuclides was detected.

Table 2.4 lists regulatory limits, alert levels, and average background levels for airborne radioactivity.

TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

SITE	DIRECTION[1]	DISTANCE[2] METERS	ELEVATION[3] METERS
DANIELS	SOUTHEAST	90	-8
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL	NORTHEAST	402	-4
POLK HALL	WEST	100	-7

[1]DIRECTION FROM REACTOR STACK

[2]DISTANCE FROM REACTOR STACK

[3]ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

TABLE 2.2 AIRBORNE GROSS BETA ACTIVITY ($fCi \cdot m^{-3}$ meter ± 2σ)

2015	POLK	DANIELS	WITHERS	EH&S
03/11-03/18	15.1±1.1	9.7±0.9	10.5±0.9	9.1±0.9
06/12-06/19	15.4±1.1	7.9±0.9	8.1±0.9	15.7±1.1
09/21-09/30	6.1±0.7	9.3±0.8	10.1±0.8	9.8±0.8
11/23-11/30	11.1±1.0	7.7±0.9	8.8±0.9	10.8±0.9

TABLE 2.3 AIRBORNE GAMMA ACTIVITY LLD VALUES ($fCi \cdot m^{-3}$)

PERIOD 2015	CO-57	CO-60	NB-95	ZR-95	RU-103	RU-106	CS-137	CE-141	CE-144
03/11- 03/18	0.21	0.35	0.29	0.47	0.27	2.37	0.26	0.38	1.22
06/12 - 06/19	0.20	0.37	0.28	0.48	0.28	2.48	0.29	0.34	1.28
09/21 - 09/30	0.18	0.35	0.31	0.54	0.33	2.51	0.29	0.43	1.40
11/23 - 11/30	0.17	0.37	0.37	0.50	0.32	2.41	0.29	0.39	1.41

TABLE 2.4 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY ($fCi \cdot m^{-3}$)

NUCLIDE	REGULATORY LIMIT	INVESTIGATION LEVEL	AVERAGE N.C. BACKGROUND LEVEL
GROSS BETA	1000	500	20
CS-137	2×10^5	100	2
CE-134	2×10^5	100	0
NB-95	2×10^6	100	0
ZR-95	400	100	0

THIS DATA REPRESENTS AN AVERAGE VALUE MEASURED IN NORTH CAROLINA AT VARIOUS LOCATIONS. EXCERPTED FROM *2009 ENVIRONMENTAL SURVEILLANCE REPORT* PRODUCED BY THE NC DEPARTMENT OF ENVIRONMENT & NATURAL RESOURCES DIVISION OF ENVIRONMENTAL HEALTH RADIATION PROTECTION SECTION.

3. **MILK** (TABLE 3.1)

Milk samples are collected every other year from the Campus Creamery and the Lake Wheeler Road Dairy as processed milk and raw milk and analyzed for I-131. No I-131 was detected in these samples.

TABLE 3.1 I-131 IN COW'S MILK ($pCi \cdot Liter^{-1} \pm 2\sigma$) LLD ~ 2 $pCi \cdot Liter^{-1}$

	$pCi \cdot Liter^{-1}$	
DATE	**CAMPUS CREAMERY**	**LAKE WHEELER**
2015	0.1±0.4	0.0±0.4

4. SURFACE WATER (TABLES 4.1 AND 4.2)

Table 4.1 gives the gross alpha and beta activities for water from Rocky Branch at points where it enters (ON), behind Carmichael Gymnasium (GYM) and exits (OFF) the campus. The LLD value for gross alpha and beta activities is ~ 0.4 pCi Liter-1. For gross alpha activity the Investigation Level is 5 pCi Liter-1 and the Regulatory Limit is 15 pCi Liter-1. For gross beta activity the Investigation Level is 12.5 pCi Liter-1 and the Regulatory Limit is 50 pCi Liter-1. Gamma analysis of all samples was also performed. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 4.2 were detected.

TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER (pCi·Liter $^{-1}$ ± 2σ)
LLD_α ~ 0.4 pCi·Liter^{-1} LLD_β ~ 0.4 pCi·Liter $^{-1}$

		pCi Liter $^{-1}$	
DATE	**LOCATION**	**GROSS ALPHA**	**GROSS BETA**
FIRST QUARTER 2015	ON	-0.05±0.1	2.5±0.6
	OFF	0.2±0.2	2.7±0.6
	GYM	0.2±0.2	2.3±0.6
SECOND QUARTER 2015	ON	0.1±0.2	3.1±0.6
	OFF	0.0±0.1	2.8±0.6
	GYM	0.2±0.2	3.4±0.6
THIRD QUARTER 2015	ON	0.2±0.2	3.6±0.7
	OFF	0.0±0.2	2.3±0.6
	GYM	0. 0±0.2	2.0±0.6
[1]FOURTH QUARTER 2015	ON	0.03±0.1	3.9±0.7
	OFF	0.0±0.2	3.2±0.6
	GYM	0.05±0.1	3.9±0.6

TABLE 4.2 LLD VALUES FOR GAMMA EMITTERS IN SURFACE WATER	
NUCLIDE	**LLD (pCi·Liter^{-1})**
Co-60	0.4
Zn-65	0.7
Cs-137	0.3
Cs-134	0.4
Sr-85	0.4
Ru-103	0.3
Ru-106	3.0
Nb-95	0.4
Zr-95	0.5

5. VEGETATION (TABLE 5.1 & 5.2)

Tables 5.1 gives gross beta activities for grass samples collected on the NCSU Campus. Table 5.2 lists LLD values for several gamma emitters. None of these gamma emitters were detected. The vegetation sampling is performed every other year.

TABLE 5.1 GROSS BETA ACTIVITY IN CAMPUS VEGETATION *LLD – 0.5 pCi·g^{-1}

DATE	SAMPLE LOCATION	(pCi·g^{-1} ± 2σ)
2015	NORTH CAMPUS	5.5±0.4
2015	SOUTH CAMPUS	3.8±0.3
2015	EAST CAMPUS	6.6±0.4
2015	WEST CAMPUS	4.2±0.3

TABLE 5.2 LLD VALUES FOR GAMMA EMITTERS IN VEGETATION

NUCLIDE	LLD (pCi·gram^{-1})
Co-60	0.01
Zn-65	0.02
Cs-137	0.01
Cs-134	0.01
Sr-85	0.01
Ru-103	0.01
Nb-95	0.01
Zr-95	0.02

6. OPTICALLY STIMULATED DOSIMETERS (TABLE 6.1)

Dosimeter analysis is contracted to Landauer, Inc. for determination of ambient radiation exposures. Exposures are integrated over a three-month period at each of the six air monitor stations listed in Table 2.1 and at the PULSTAR Reactor facility. A control dosimeter is located in the Environmental Health & Safety Center. Table 6.1 gives the dose equivalent data for these eight (8) locations.

The dose equivalents are reported as millirem per quarter year. Readings which fall below the dosimeters' minimum measurable quantities (i.e., 1 millirem for gamma radiations and 10 millirem for beta radiation) are reported by the contract vendor with the designation "M". The observed readings are typically within the expected range for natural background radiation levels.

TABLE 6.1 ENVIRONMENTAL DOSIMETER DOSES – millirem per quarter

DATE	CONTROL	POLK	WITHERS	DANIELS	EH&S	NORTH	PULSTAR
2015							
01/01 – 03/31	31	M,M	M,M	13,24	2	3	24
04/01 – 06/30	27	M,1	4,1	12,31	4	5	24
07/01 – 09/30	30	M,M	M,M	19,17	3	3	21
10/01 – 12/31	31	1,1	M,M	25,37	5	6	24

All values are reported as Deep Dose Equivalent (DDE).

"Control" is the control dose used by the vendor company for evaluation of the dosimeter.

"M" is the designation used by the vendor company to report dose equivalents below the minimum measurable quantity which is 1 millirem for gamma radiation and 10 millirem for beta radiation.

Dual dose entries indicate two (2) independent dosimeters assigned at the indicated station.

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory (ERSL) in the Radiation Safety Division has analyzed samples provided by the U.S. DOE Mixed-Analyte Performance Evaluation Program (MAPEP Test Session 31) Radiological and Environmental Sciences Laboratory (RESL) during this reporting period. The objective of this program is to provide laboratories performing environmental radiation measurements with unknowns to test their analytical techniques.

The MAPEP value listed in the Tables 7.1 (a-e) to which the ERSL results are compared is the mean of replicate determinations for each nuclide. The MAPEP uncertainty is the standard error of the mean.

For each reported radiological analyte, the laboratory result and the reference value may be used to calculate a relative bias:

$$\%\text{Bias} = \frac{(100)(\text{Laboratory Result} - \text{RESL Reference Value})}{\text{RESL Reference Value}}$$

The relative bias will place the laboratory result in one of three categories:

Acceptable	Bias $\leq$ 20%
Acceptable with Warning	20% < Bias $\leq$ 30%
Not Acceptable	Bias > 30%

TABLE 7.1a GROSS ALPHA & BETA ACTIVITY AIR FILTER - INTERCOMPARISON STUDY
01 August 2015

NCSU - ENVIRONMENTAL LABORATORY RESULTS				
RADIONUCLIDE	**REPORTED VALUE**	**REPORTED ERROR**	**MAPEP VALUE**	**ACCEPTANCE RANGE**
GROSS ALPHA	0.84	0.04	0.90	0.27 – 1.53
GROSS BETA	1.40	0.06	1.56	0.78 – 2.34

THE SAMPLE CONSISTS OF ONE 50 MM DIAMETER SIMULATED FILTER SPIKED WITH A MATRIX-FREE SOLUTION CONTAINING A SINGLE ALPHA AND A SINGLE BETA EMITTING NUCLIDE. THE REPORTED VALUES AND THE KNOWN VALUES ARE GIVEN IN BQ/FILTER.

TABLE 7.1b MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 August 2015

NCSU - ENVIRONMENTAL LABORATORY RESULTS				
RADIONUCLIDE	**[1]REPORTED VALUE**	**[1]REPORTED ERROR**	**MAPEP VALUE**	**ACCEPTANCE RANGE**
Co60	1.63	0.04	1.71	1.20 – 2.22
Cs137	1.79	0.06	1.96	1.37 – 2.55
Cs134	2.43	0.04	2.45	1.72 – 2.19
Co57	2.69	0.04	2.74	1.00 – 1.86
Mn54	2.11	0.03	2.11	1.48 – 2.74
Zn65	1.36	0.04	1.32	0.92 – 1.72

THE SAMPLE CONSISTS OF ONE 50 MM DIAMETER GLASS FIBER FILTER WHICH HAS BEEN SPIKED WITH A SOLUTION AND DRIED. THE REPORTED VALUES AND THE KNOWN VALUES ARE GIVEN IN BQ/FILTER.

TABLE 7.1c MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 August 2015

NCSU - ENVIRONMENTAL LABORATORY RESULTS				
RADIONUCLIDE	**REPORTED VALUE**	**REPORTED ERROR**	**MAPEP VALUE**	**ACCEPTANCE RANGE**
Co60	19.61	0.64	17.1	12.0 – 22.2
Cs137	0.96	1.00	------	False + Test
Cs134	23.14	0.81	23.1	16.2 – 30.0
Co57	20.03	0.59	20.8	14.6 – 27.0
Mn54	18.25	0.48	15.6	10.9 – 20.3
Zn65	15.49	0.70	13.9	9.7 – 18.1

THE SAMPLE CONSISTS OF A SPIKED ALIQUOT OF ACIDIFIED WATER (~5 % HNO_3). THE REPORTED VALUES AND THE KNOWN VALUES ARE GIVEN IN BQ/LITER.

NOTE: THE ENTRY "------" INDICATES NO ANALYTE WAS PRESENT FOR PURPOSES OF CONDUCTING A FALSE POSITIVE (+) TEST.

TABLE 7.1d GROSS ALPHA AND BETA WATER SAMPLE - INTERCOMPARISON STUDY
01 August 2015

NCSU - ENVIRONMENTAL LABORATORY RESULTS				
RADIONUCLIDE	**REPORTED VALUE**	**REPORTED ERROR**	**MAPEP VALUE**	**ACCEPTANCE RANGE**
Gross Alpha	0.57	0.18	0.429	0.129 – 0.729
Gross Beta	3.23	0.28	3.52	1.76 – 5.28

THE SAMPLE CONSISTS OF A 5% HNO_3 MATRIX FREE SOLUTION. THE REPORTED VALUES AND THE KNOWN VALUES ARE GIVEN IN BQ/LITER.

TABLE 7.1e MULTINUCLIDE VEGETATION SAMPLE - INTERCOMPARISON STUDY
01 August 2015

NCSU - ENVIRONMENTAL LABORATORY RESULTS

RADIONUCLIDE	REPORTED VALUE	REPORTED ERROR	MAPEP VALUE	ACCEPTANCE RANGE
Co60	5.39	0.20	4.56	3.19 – 5.93
Cs137	0.26	0.30	------	False + Test
Cs134	6.67	0.20	5.80	4.06 – 7.54
Co57	7.51	0.21	6.62	4.63 – 8.61
Mn54	11.22	0.22	7.68	5.38 – 9.98
Zn65	6.94	0.20	5.46	3.82 – 7.10

THE SAMPLE CONSISTS OF A SPIKED SAMPLE OF VEGETATION. THE REPORTED VALUES AND THE KNOWN VALUES ARE GIVEN IN BQ/SAMPLE.

NOTE: THE ENTRY "------" INDICATES NO ANALYTE WAS PRESENT FOR PURPOSES OF CONDUCTING A FALSE POSITIVE (+) TEST.

8. CONCLUSIONS

The data obtained during this period do not show any fission product activities. The observed environmental radioactivity is due primarily to radon progeny, primordial radionuclides (e.g. K-40) and those radionuclides which originate in the upper atmosphere as the result of cosmic ray interactions. These facts justify the conclusion that the PULSTAR Reactor facility continues to operate safely and does not release fission product materials into the environment.