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Nuclear Reactor Program

NC STATE UNIVERSITY

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25 March 2014

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

Re: Annual Report for 2013
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 25 March 2014.

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

Enclosures:
Annual Operating Report for 2013
Attachment A: PULSTAR Reactor Environmental Radiation Surveillance Report

A020
NRR

NORTH CAROLINA STATE UNIVERSITY

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 January 2013 - 31 December 2013

The following annual report for 2013 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. The reactor was shutdown for the cooling system modifications. Commissioning procedures and power ascension testing were used to confirm operation of the primary and secondary cooling systems and to assess changes made to radiation shielding prior to resuming normal operations. 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, and Research

- 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

Neutron Activation Analysis

- Crude oil
- Food samples
- Fish tissues
- Laboratory animal tissue
- Human hair, nails, and urine

- Polymers and plastics
- Sediment/soil/rocks
- Silicon crystals
- Textiles
- Water

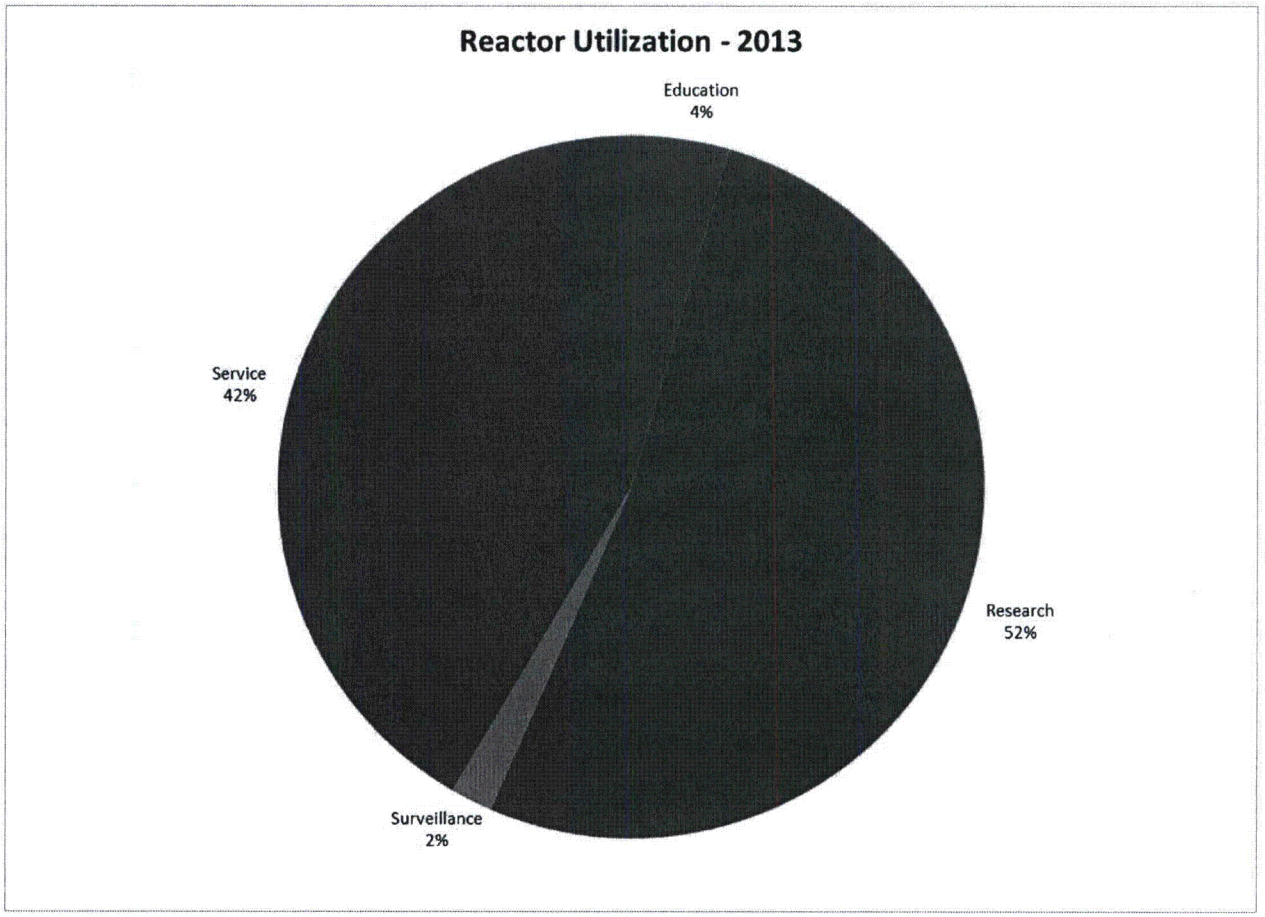

Figure 1 - Reactor Utilization by Protocol

Utilization	Hours	Percent
Education	106	5%
Research	1227	52%
Service	46	2%
Surveillance	980	42%
TOTAL	2359	100%

NOTE: Utilization hours (2359 h) exceed critical hours (1007 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 2013:	40.517 Megawatt·days
Critical hours in 2013:	1007.15 hours
Cumulative Total Energy Output Since Initial Criticality:	1545.07 Megawatt·days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

Emergency Shutdowns - NONE

Unscheduled Shutdowns – Ten

22-FEB-2013 Reactor SCRAM – Linear Level Monitor Over-Power SCRAM – The SCRAM was caused by static electrical discharge when reactor operator touched the instrumentation drawer. No over power condition existed. The reactor was cleared for restart.

09-AUG-2013 Reactor SCRAM – Low Flow SCRAM – Between 09-AUG-2013 and 04-OCT-2013 following the installation of the new nitrogen-16 delay tanks and annubar flow measuring system nine Low Flow SCRAMs occurred. This was due to entrained air in the primary piping system. As the entrained air entered the flow measuring system it would cause spikes in the measurement and trigger a false low flow reading. At no time was there a low flow condition. After each occurrence the system was vented, calibrated and the reactor was cleared for restart.

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.

785 Auxiliary Generator – The PRE-HI ENG TEMP light came on during the monthly generator check. It was determined that this was due to low coolant level. Coolant was added and the condition cleared.

786 Log N and Linear Level Monitor – The NON-OP light came on during the startup checklist. It was determined that the high voltage power supply was faulty and was replaced. The monitor was calibrated and placed back into service.

787 Auxiliary Generator – The battery for the auxiliary generator was replaced. This was a preventative maintenance activity.

788 Installation of Rosemount Annubar – The Rosemount Annubar was installed as per DC741. The primary piping was partial drained and subsequently refilled for this installation.

789 Primary Demineralizer Pump – The mechanical shaft seal was leaking and was replaced.

790 Primary and Secondary System Replacement – The primary and secondary piping was replaced as per DC744 and DC745.

791 Source Range Monitor/Fission Chamber – The source range monitor failed high, CPS $\geq 10^5$. It was determined that the failure was due to a faulty fission chamber. A new fission chamber, cables and connectors were installed. The monitor was calibrated and placed back into service.

792 RTD2 and Transmitter – RTD2 (pool temperature) and transmitter was replaced. The channel was calibrated and returned to service. This was a preventative maintenance activity.

793 Flow Channel – A Low Primary Flow SCRAM occurred during operation. It was determined that entrained was causing fluctuations in the measurement. The system was vented, calibrated and placed back into service. There was never a low flow condition.

794 Flow Channel – A Low Primary Flow SCRAM occurred during operation. It was determined that entrained was causing fluctuations in the measurement. The system was vented, calibrated and placed back into service. There was never a low flow condition.

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

Facility Changes

Design changes to the reactor facility were reviewed to determine whether or not a 10CFR50.59 evaluation was required. Based on the reviews, DC741 and DC745 required a 10CFR50.59 evaluation.

The following design changes were made:

741 Installation of Rosemount 485 Annubar pak-lok Assembly – This design change allowed for the installation of the Rosemount 485 Annubar with pak-lok assembly. This change for the characterization of the annubar system and comparison to the Flow Orifice Measuring System. It does not allow for the use of the device for reactor operation.

744 Removal and Installation of Primary and Secondary Coolant Systems – This design change detailed the process of removing the primary and secondary components that were being replaced in Design Change 745.

745 Primary and Secondary Cooling System Modifications – This design change details the replacement of the primary and secondary components in preparation for the reactor power upgrade to 2 MW.

757 Control Console Annunciator Modification – This design change allows for the installation of separate annunciators that alert the reactor operator of personnel entry into various high radiation areas located in the reactor building.

759 Waste Water Processing System – This design change allows for the installation of waste water filtration system to reduce liquid discharge volume and activity and to recycle water for re-use in the reactor pool.

761 Process Air Flow Monitoring – This design change allows for the installation air flow monitoring

devices in the effluent systems.

Document Changes

Procedure changes were reviewed to determine whether or not a 10CFR50.59 evaluation was required. Based on the reviews, none required a 10CFR50.59 evaluation.

740 Emergency Procedure 2 – Off-site Notification – Updated Attachment 2 – The State of North Carolina Authentication Code List. This was classified as a minor change.

746 Commissioning Procedure (CP) 1.0 – Cooling System Task List – This new procedure detailed the task required to commence reactor operations following the completion of Design Change 745.

747 Commissioning Procedure (CP) 2.0 – Primary System – This new procedure detailed the steps required to refill and test the primary system following the completion of Design Change 745.

748 Commissioning Procedure (CP) 3.0 – Secondary System – This new procedure detailed the steps required to refill and test the secondary system following the completion of Design Change 745.

749 Temperature Channel Calibration – PS-1-10:S1 – Revised the procedure to incorporate changes to the temperature measuring channel following the completion of Design Change 745.

750 Flow Channel Calibration – PS-2-03:S1 – Revised the procedure to incorporate changes to the flow measuring channel following the completion of Design Change 745.

751 Flow Monitoring Channel Check Calibration – PS-4-06-1:S1 – Revised the procedure to incorporate changes to the primary system that affected how the channel check was performed following the completion of Design Change 745.

752 NRP-OP-101 – Reactor Startup and Shutdown – Revised the procedure to incorporate changes following the completion of Design Change 745.

753 NRP-OP-103 – Reactor Operation – Revised the procedure to incorporate changes following the completion of Design Change 745.

754 NRP-OP-105 – Response to SCRAMS, Alarms and Abnormal Conditions – Revised the procedure to incorporate changes following the completion of Design Change 745.

755 NRP-OP-201 – Primary Demineralizer – Revised the procedure to incorporate changes following the completion of Design Change 745.

756 Commissioning Procedure (CP) 4.0 – Reactor Cooling Control System Test – This new procedure detailed the steps required to test the performance of the primary and secondary system following the completion of Design Change 745.

758 NRP-OP-105 – Response to SCRAMS, Alarms and Abnormal Conditions – Revised the procedure to include operator instructions for high radiation area entry alarms following the completion of Design Change 757.

760 PS 6-16-2:W/M/A – Processing, Sampling, Analyses, and Assessment of Liquid Effluent – Added waste water processing and clarified water assessment for TSS and TDS and solubility.

762 PS 6-20-1:A1 – Dwyer Air Velocity Transmitter Calibration, Operation, and Maintenance – New procedure for the calibration operation and maintenance of the Dwyer 641 Air Velocity Transmitter.

763 HP5 – Access Control and Training – New procedure to establish requirements for personnel access to the facility.

764 HP1 – Radiation Protection Program – Revised the procedure to remove information that was included in HP5.

Test and Experiments

There were no new experiments or changes to existing experiments.

Other Changes

There were no other changes.

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)
	Number of Batches	Total μCi	Total Volume Liters	Diluent Liters	Tritium μCi
01 JAN – 31 MAR 13	2	114	6.84E3	8.17E4	105
01 APR – 30 JUN 13	3	377	1.02 E4	6.09E4	370
01 JUL – 30 SEP 13	3	217	1.02E4	8.46E2	216
01 OCT – 31 DEC 13	2	130	6.703E3	3.43E4	126
2013	817 μCi of tritium was released during this year.				
2013	838 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 10CFR20 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
2013	JANUARY	744	1.713
	FEBRUARY	672	1.384
	MARCH	744	1.764
	APRIL	720	0

MAY	744	0
JUNE	720	0
JULY	744	0
AUGUST	744	1.736
SEPTEMBER	720	2.271
OCTOBER	744	1.669
NOVEMBER	720	1.032
DECEMBER	744	1.150
TOTAL	8784	12.717

(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 16.699 curies in 2013.

The yearly average concentration of Argon-41 released from the PULSTAR reactor facility exhaust stack in 2013 was 8.7×10^{-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 78 ft3.

57 ft^3 of dry uncompacted waste

21 ft^3 of ion exchange resins

ii. Total Activity Involved

Total activity for solid waste was 3.9 mCi.

1.5 mCi of dry uncompacted waste

2.4 mCi of ion exchange resins

iii. Dates of shipments and disposal

A total of three transfers to the university broad scope radioactive materials license were made in 2013. The University Environmental Health and Safety Center arranges disposal of hazardous wastes.

6.7.4.g Personnel Radiation Exposure Report:

Twenty-six 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 2013 to 31 Dec 2013 was 2.207 person-rem. Individual deep dose-equivalent ranged from 0.001 rem to 0.286 rem with a median of 0.067 rem and average of 0.085 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 50 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 2013 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 2013
[JANUARY 1, 2013 - DECEMBER 31, 2013]

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	N.E.	MONTHLY	MONTHLY	10 CFR 20
	GAMMA EMITTERS	N.E.			T.S. 6.7.4
WATER FROM REACTOR FACILITY	GROSS BETA	N.E.	PRIOR TO DISCHARGE (~ MONTHLY)	PRIOR TO DISCHARGE (~ MONTHLY)	10 CFR 20
	GROSS GAMMA	N.E.			T.S. 6.7.4
	TRITIUM	N.E.			CITY OF RALEIGH ORDINANCE
AIR PARTICLES AT 5 CAMPUS STATIONS[1]	GROSS BETA	RSD	WEEKLY	QUARTERLY	10 CFR 20
	GAMMA EMITTERS	RSD	WEEKLY	QUARTERLY	10 CFR 20
AIR DOSE AT 8 CAMPUS STATIONS[2]	TLD DOSIMETER	RSD	QUARTERLY	QUARTERLY	10 CFR 20
SURFACE WATER ROCKY BRANCH CREEK	GROSS BETA	RSD	QUARTERLY	QUARTERLY	NCSU
	GAMMA EMITTERS	RSD	QUARTERLY	QUARTERLY	NCSU
	TRITIUM	N.E.		QUARTERLY	10 CFR 20
VEGETATION NCSU CAMPUS	GROSS BETA	RSD	SEMI-ANNUALLY	EVERY OTHER YEAR	NCSU
	GAMMA	RSD			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 5 STATIONS INCLUDE:

WITHERS, DANIELS, BROUGHTON, D.H. HILL LIBRARY AND ENVIRONMENTAL HEALTH & SAFETY CENTER.

[2]THESE 8 STATIONS INCLUDE: PULSTAR REACTOR, A CONTROL STATION (EH&S) AND THE 5 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. Figures 2a through 2e show bar graphs of gross beta activity (fCi/cubic meter *vs.* sampling quarters per year). The highest gross beta activity observed was 19.0 fCi/cubic meter at the Withers Hall station during the week of 07/08/13 to 07/15/13. The annual campus average was 12.6 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 2.4 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
BROUGHTON	SOUTHWEST	125	-17
DH HILL	NORTHWEST	192	+11
DANIELS	SOUTHEAST	90	-8
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL	NORTHEAST	402	-4

[1]DIRECTION - DIRECTION FROM REACTOR STACK

[2]DISTANCE - DISTANCE FROM REACTOR STACK

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

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

PERIOD	BROUGHTON	DH HILL	DANIELS	WITHERS	EH&S
03/04 - 03/11	10.5 ± 1.0	16.6 ± 1.2	12.0 ± 1.1	8.7 ± 1.0	15.5 ± 1.1
05/28 - 06/04	8.2 ± 0.9	12.5 ±1.0	7.9 ± 0.9	11.8 ± 1.0	10.9 ± 0.8
07/08 - 07/15	12.1 ± 1.0	16.3 ± 1.1	16.3 ± 1.1	19.0 ± 1.2	9.0 ± 0.8
11/11 - 11/18	9.6 ± 1.0	15.9 ± 1.1	15.1 ± 1.1	15.0 ± 1.1	9.8 ± 0.9

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

PERIOD 2013	CO-57	CO-60	NB-95	ZR-95	RU-103	RU-106	CS-137	CE-141	CE-144
03/04- 03/11	0.21	0.35	0.29	0.47	0.27	2.37	0.26	0.38	1.22
05/28 - 06/04	0.20	0.37	0.28	0.48	0.28	2.48	0.29	0.34	1.28
07/08 - 07/15	0.18	0.35	0.31	0.54	0.33	2.51	0.29	0.43	1.40
11/11 - 11/18	0.17	0.37	0.37	0.50	0.32	2.41	0.29	0.39	1.41

NOTE: NO GAMMA ACTIVITY DUE TO ANY OF THESE RADIONUCLIDES WAS DETECTED.

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. Data given for 2013 show that no I-131 activity was detected.

TABLE 3.1 I-131 IN COW'S MILK (pCi·Liter $^{-1} \pm 2\sigma$) LLD ~ 3 pCi·Liter $^{-1}$

	PCI LITER^{-1}	
DATE	**CAMPUS CREAMERY**	**LAKE WHEELER**
NOVEMBER 2013	< 3	< 3

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) 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 2013	ON	1.5±0.5	6.3±0.8
	OFF	0.1±0.3	1.0±0.6
	GYM	0.1±0.3	1.0±0.6
SECOND QUARTER 2013	ON	- 0.1±0.2	3.8±0.7
	OFF	- 0.1±0.2	2.6±0.6
	GYM	0.0±0.2	3.1±0.7
THIRD QUARTER 2013	ON	0.4±0.3	2.7±0.6
	OFF	0.4±0.3	3.5±0.7
	GYM	0.1±0.2	3.5±0.7
[1]FOURTH QUARTER 2013	ON	0.675±0.958	1.46±0.693
	OFF	0.741±1.06	1.72±0.666
	GYM	0.246±0.758	2.02±0.704

[1]Fourth Quarter gross alpha and gross beta water results were provided by a contracted analytical lab due to lab instrumentation problems.

TABLE 4.2 LLD VALUES FOR GAMMA EMITTERS IN SURFACE WATER	
NUCLIDE	**LLD ($pCi \cdot Liter^{-1}$)**
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. The vegetation sampling is performed every other year. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 5.2 were detected.

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

DATE	SAMPLE LOCATION	(pCi·g^{-1} ± 2σ)
08/02/2013	NORTH CAMPUS	11.5±0.8
08/02/2013	SOUTH CAMPUS	12.9±0.8
08/02/2013	EAST CAMPUS	13.7±0.9
08/02/2013	WEST CAMPUS	12.9±0.8

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 gamma 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.

Historically, dosimeter readings for D.H. Hill Library monitoring station have often been higher than those for the other campus stations due to its location inside a concrete penthouse. Pursuant to a recommendation made in the NCSU PULSTAR 2001 Annual Self-Assessment, two additional TLDs were included at the D.H. Hill Library station to supplement the existing dosimeter. These higher readings have been due to natural radioactivity as confirmed by both gross beta and gamma isotopic analyses of air particulates. This dosimeter station will be moved to another outside location beginning with the 2nd Quarter of 2014. Only one (1) dosimeter will be deployed at the new location.

TABLE 6.1 ENVIRONMENTAL DOSIMETER DOSES								
DATE	**WITHERS**	**DANIELS**	**BROUGHTON**	**DH HILL**	**EH&S**	**PULSTAR**	**NORTH**	**CONTROL**
2013								
01/01 – 03/31	M	M	M	52,42,47	M	30	M	43
05/10 – 06/30[2]	1	1	1	3	M	14[1]	1	25
07/01 – 09/30	1	7	7	21,24,20	2	23[3]	8	30
10/01 – 12/31	M	M	M	27,19,27	M	25	1	35

[1]CONTROL DOSE WAS 30 mrem FOR PULSTAR DOSIMETER.

[2]2ND QUARTER DOSIMETERS WERE NOT PROVIDED BY THE VENDOR COMPANY UNTIL MAY 10, 2013.

[3]CONTROL DOSE WAS 42 mrem FOR PULSTAR DOSIMETER.

ENTRIES FOR DH HILL ARE FOR THREE INDEPENDENT DOSIMETER READINGS FOR THAT STATION FOR 1ST, 3RD, AND 4TH QUARTERS.

CONTROL ENTRIES ARE FOR BACKGROUND DOSIMETER READINGS (SEE NOTES 1 AND 3 FOR EXCEPTIONS TO CONTROL DOSE USED).

THE DESIGNATION "M" IS USED BY THE CONTRACT VENDOR FOR REPORTING DOSE EQUIVALENTS BELOW THE MINIMUM MEASURABLE QUANTITY WHICH IS 1 MILLIREM FOR GAMMA RADIATION AND 10 MILLIREM FOR BETA RADIATION.

ALL REPORTED VALUES AR DEEP DDE.

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 28) 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 ≤ 20%
Acceptable with Warning	20% < Bias ≤ 30%
Not Acceptable	Bias > 30%

TABLE 7.1a GROSS ALPHA & BETA ACTIVITY AIR FILTER - INTERCOMPARISON STUDY
01 February 2013

NCSU - ENVIRONMENTAL LABORATORY RESULTS

RADIONUCLIDE	REPORTED VALUE	REPORTED ERROR	MAPEP VALUE	ACCEPTANCE RANGE
GROSS ALPHA	1.43	0.11	1.20	0.36 – 2.04
GROSS BETA	0.98	0.04	0.85	0.43 – 1.28

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 February 2013

NCSU - ENVIRONMENTAL LABORATORY RESULTS

RADIONUCLIDE	[1]REPORTED VALUE	[1]REPORTED ERROR	MAPEP VALUE	ACCEPTANCE RANGE
Co60	0.06	0.12	------	False + Test
Cs137	2.40	0.16	2.60	1.82 – 2.38
Cs134	0.12[1]	0.05	1.78	1.25 – 2.31
Co57	2.11	0.12	2.36	1.65 – 3.07
Mn54	4.31	0.24	4.26	2.98 – 5.54
Zn65	3.51	0.22	3.13	2.19 – 4.07

THE SAMPLE CONSISTS OF ONE 50 MM DIAMETER GLASS FIBER FILTER WHICH HAS BEEN SPIKED WITH 0.10 GRAM OF SOLUTION AND DRIED. THE REPORTED VALUES AND THE KNOWN VALUES ARE GIVEN IN BQ/FILTER.

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

[1]THE LISTED VALUE (0.12) WAS A DATA ENTRY ERROR MADE DURING DATA SUBMISSION TO THE MAPEP PROGRAM. THE CORRECT VALUE SHOULD HAVE BEEN 1.20.

TABLE 7.1c MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 February 2013

NCSU - ENVIRONMENTAL LABORATORY RESULTS

RADIONUCLIDE	REPORTED VALUE	REPORTED ERROR	MAPEP VALUE	ACCEPTANCE RANGE
Co60	20.0	1.0	19.56	13.69 – 25.43
Cs137	-0.05	2.0	------	False + Test
Cs134	21.0	1.0	24.4	17.1 – 31.7
Co57	28.2	2.2	30.9	21.6 – 40.2
Mn54	27.8	1.8	27.4	19.2 – 35.6
Zn65	33.3	2.6	30.4	21.3 – 39.5

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 February 2013

NCSU - ENVIRONMENTAL LABORATORY RESULTS

RADIONUCLIDE	REPORTED VALUE	REPORTED ERROR	MAPEP VALUE	ACCEPTANCE RANGE
Gross Alpha	2.22	0.46	2.31	0.69 – 3.93
Gross Beta	13.03	0.30	13.0	6.5 – 19.5

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 February 2013

NCSU - ENVIRONMENTAL LABORATORY RESULTS

RADIONUCLIDE	REPORTED VALUE	REPORTED ERROR	MAPEP VALUE	ACCEPTANCE RANGE
Co60	5.18	0.31	5.85	4.10 – 7.61
Cs137	6.71	0.52	6.87	4.81 – 8.93
Cs134	0.21	0.28	------	False + Test
Co57	8.72	0.68	8.68	6.08 – 11.28
Mn54	0.20	0.25	------	False + Test
Zn65	6.13	0.76	6.25	4.38 – 8.13

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.