

**NORTH CAROLINA STATE UNIVERSITY**  
**DEPARTMENT OF NUCLEAR ENGINEERING**

**PULSTAR REACTOR ANNUAL REPORT**

**DOCKET NUMBER 50-297**

**For the Period: 01 January 2020 - 31 December 2020**

The following annual report for 2020 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.

**i Operating experience including a summary of experiments performed.**

The reactor facility had a total of 1858 utilization hours in 2020. The utilization hours exceeded critical hours (1375 h) since there was typically more than one user of the reactor facility at a given time. The following is a brief summary of the types of experiments performed, including for teaching laboratories, courses, research and service:

- 1/M Approach to criticality
- Control rod worth measurements
- Reactivity parameter measurements
- Core thermal power and coolant temperature measurements
- Axial power and peaking factor measurements (flux mapping)
- Reactor power determination using photodiode arrays
- Positron annihilation spectroscopy measurements
- Neutron diffraction measurements
- Neutron transmission measurements
- Neutron flux measurements
- Neutron detector testing and certification
- Neutron radiographic imaging
- Isotope production
- Neutron activation analysis measurements of materials including laboratory animal samples, crude oil, food samples, fish tissue, polymers and plastics, geologic samples, and water.

**ii Changes in Performance Characteristics Related to Reactor Safety:**

None

### iii Results of Surveillance, Tests, and Inspections:

The reactor surveillance program has monitored the following trend in reactor systems performance during this reporting period:

In 2020 an unaccounted loss of water from the reactor coolant system (RCS) occurred. RCS water was not observed in surface locations or storm sewer locations outside the reactor building. Therefore the unaccounted RCS water was assumed to be continuously released to grounds beneath the surface on the reactor site at the measured RCS loss rates over the year. The concentration of radionuclides detected in the reactor coolant met regulatory limits for release to unrestricted areas (10 CFR 20 Appendix B Table 2). In 2020, the unaccounted loss rate rose to a level that permitted detection of a leak site. A patching repair was made in October 2020 that was successful in decreasing the leak rate to lower levels. Efforts to fully repair and patch this leak site in the pool liner are ongoing. These efforts are detailed below under Maintenance Log items ML#808 and ML#859.

No other significant or unexpected trends in reactor systems performance have been identified 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 2020:	52.9 Megawatt-days
Critical hours in 2020:	1355.7 hours
Cumulative Total Energy Output Since Initial Criticality:	2100.7 Megawatt-days

#### 6.7.4.c Number of Emergency and Unscheduled Shutdowns:

Emergency Shutdowns - NONE

Unscheduled Shutdowns – Three

04-JUN-2020 SCRAM due to low primary flow. The reactor was operating at 1 MW and the staff were performing work at the reactor console. A piece of radiation monitoring equipment positioned above the console dropped and momentarily depressed the primary pump stop button. This stopped the primary pump and initiated a low primary flow SCRAM, causing the safety system to perform its intended function and automatically shut down the reactor. Following shutdown, the primary pump stop switch was inspected and no damage to the switch was found. The reactor was authorized for restart.

Corrective actions implemented by the senior staff include: 1) assuring that no non-essential work is performed in the area immediately above the control console when the reactor is not shutdown; and 2) assuring that staff follow safe handling practices and properly brace and secure equipment while performing work.

24-JUL-2020 SCRAM due to temporary loss of commercial power. The reactor was operating at 1 MW when the commercial power momentarily flickered and was interrupted. This caused power to be lost to the SCRAM logic unit and magnet power supply, triggering an automatic scram and shutdown of the reactor. Commercial power was restored, a full startup checklist was completed, the reactor was authorized for restart, and the reactor was returned to normal operations.

25-AUG-2020 Shutdown due to immediate operation action following evacuation. The reactor was operating at 1 MW and the reactor health physicist was performing weekly radiation monitor setpoint verification surveillance checks as required by TS 4.4(b). While performing the setpoint check procedure, incorrect settings in the computer program memory were inadvertently sent to the Control Room Monitor control unit. Before the operation could be cancelled, the reactor evacuation alarm and confinement system initiated based on the incorrect alarm setpoint being exceeded. Per OP105 Section 5, Response to Evacuation and Confinement, the reactor was immediately shutdown.

Following shutdown the correct calibration parameters for the Control Room Monitor were reset, and the radiation monitor and radiation recorder responses to a radiation source were verified to be correct. Monitor alarms were then tested for the annunciator and evacuation alarms and confinement system initiation. These tests were completed satisfactorily and the monitor was then returned to service. The reactor was authorized for restart.

Procedure PS 6-19-1 was subsequently revised (see Procedure Change under CN#852 referenced below) to require that the reactor be shutdown and the radiation monitor channel be placed in by-pass to perform section 6.10 for the weekly set-point checks required by TS 4.4.b.

#### **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. Any reactor equipment or components requiring corrective or preventative maintenance are tracked in the Maintenance Log (ML) file. Maintenance Log items tracked during 2020 are listed below.

- ML#808 *PS-4-061 – Pool Liner* – Potential liner leak sites were assessed throughout the year. Additional liner patches were installed along the thermal column weld, and along the south east fuel pit rim, with only nominal subsequent changes observed to the unaccounted water loss rate. In October 2020, the unaccounted water loss rate increased and a new leak site was detected on the west liner wall. Maintenance Log #859 (detailed below) was opened to track ongoing repair activities for this liner location.
- ML#851 *PS-4-06-10 – Thermal Column* – Plans were made to repair a deformed portion of the outer thermal column BORAL lining and aluminum trim piece in early 2021.
- ML#853 *PS-8-05-1 – NIF Facility* – The bearings that support the NIF beam shutter started to fail causing the shutter to not operate properly. The original shutter bearings were removed and replaced with 16 new bearings in order to increase longevity. The NIF shutter was tested satisfactorily and returned to service.
- ML#854 *PS-1-03-4A – Linear Monitor* – During a startup checklist the Linear Monitor Recorder was reading ~10% low on the 100% test point. This problem had occurred previously and the issue was found to have been caused by the Linear Channel Isolated Output. The Isolated Output was therefore replaced with a spare. The Linear Channel was checked for proper operation and performed satisfactorily. The power recorder test was completed satisfactorily and the instrument was returned to service.

- ML#855 *PS-3-03-2 –Primary Resin Replaced*– The resistivity in the primary system had been trending lower than 1MΩ·cm but greater than 500kΩ·cm, indicating that the primary demineralizer resin needed to be replaced. The resin and the pre/post filters in the primary demineralizer loop were replaced.
- ML#856 *PS-6-12-6 – Stack Sample Pump* – The Stack Flow Fault Alarm was found to be tripped on when the stack sample pump was in operation. The stack sample pump vanes were replaced. During replacement the flow indication failed and the cause of the annunciator initiation was determined to be a faulty flow switch. A rotameter was temporarily installed to monitor flow. Following replacement of the flow switch and flow measuring device, the stack sample unit was calibrated and returned to normal operation.
- ML#857 *PS-5-02-2A – HVAC System* - Following cycling of the Main HVAC system, the Bay to Atmosphere differential pressure reading was indicating >0.2" of H<sub>2</sub>O but lower than normal. The reactor was not operating at the time. Inspections of bay penetrations, ventilation system dampers, and differential pressure gauges were all normal. The cause was determined to be a loose belt on the exhaust fan. The belt was tightened and the differential pressure returned to normal.
- ML#858 *PS-1-01-6 – Source Range* - During the Source Range Channel calibration the isolated output failed low. The isolated output was replaced with a spare. The 100kHz and 12.2 Hz tests were verified and the calibration was completed satisfactorily.
- ML#859 *PS-4-06-1 – Pool Liner* - In October 2020 a leak site was detected located on the lower west wall of the pool liner. Epoxy patches were applied to the leak site and the unaccounted water loss rate was substantially reduced, but not eliminated. It was determined that a reduced leak rate persists in the same location. The design of a full repair for the west wall leak site is currently in process.
- ML#860 *PS-1-01-6 – Source Range* - During a startup checklist, while performing the Source Range Channel test, it was found that the source range indication on the power recorder read -OVER. This problem had occurred previously and the issue was found to have been caused by the Source Range Isolated Output. The isolated output was replaced with a spare. A test of the Source Range Monitor drawer was performed satisfactorily. The startup checklist test of the source range monitor was performed satisfactorily and the instrument was returned to service.

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

Design changes to the facility, procedure changes, changes in tests and experiments, and other changes are tracked utilizing a Control Number (CN) indexing system. Changes tracked during 2020 are listed below.

#### **Facility Changes**

Design changes to the reactor facility are reviewed to determine whether or not a 10 CFR Part 50.59 evaluation is required. Evaluations were performed for all design changes. Based on the screening reviews performed, none of the changes listed below required a full 10 CFR 50.59 evaluation.

- CN#842 *Pool Water Level Measuring Channel* – Replacement of the Pool Water Level Measuring Channel with a Guided Wave Radar level sensor.
- CN#855 *PULSTAR Bay Sampling Well (MW2)* - Installation of new monitoring well in south east bay floor to allow for sampling and monitoring of soil and groundwater.

#### **Test and Experiments**

Tests and experiments are reviewed to determine whether or not a 10 CFR Part 50.59 evaluation is required.

Based on the screening review performed, the change listed did not require a full 10 CFR 50.59 evaluation.

CN#841 *Modification of Rotating Exposure Ports* – Allows for the use of dry sample baskets in the rotating exposure ports.

## Document Changes

Procedure changes are reviewed to determine whether or not a 10 CFR Part 50.59 evaluation is required. Based on the screening reviews performed, none of the changes listed below required a full 10 CFR 50.59 evaluation.

CN#843 *PS-2-02-5:S1 Pool Water Level Measuring Channel Calibration*. Revision to calibration instructions for performing the channel calibration for the Pool Water Level Measuring System.

CN#844 *NRP-OP-101 - Reactor Startup and Shutdown*; Revision to startup checklist instructions for performing the channel check and channel test for the Pool Water Level Measuring System.

CN#846 *SP-1.0 REV 6 Unauthorized Intrusion in Controlled Access Area*. Update personnel titles and references to match current revisions to Technical Specifications, the Physical Security Plan, the Emergency Plan, and Emergency Procedures.

CN#847 *SP-2.0 REV 6 Theft or Theft Threat and Acts of Civil Disturbance*. Unauthorized Intrusion in Controlled Access Area. Update personnel titles and references to match current revisions to Technical Specifications, the Physical Security Plan, the Emergency Plan, and Emergency Procedures.

CN#848 *SP-3.0 REV 6 Bomb Threat in Burlington Engineering Lab*. Unauthorized Intrusion in Controlled Access Area. Update personnel titles and references to match current revisions to Technical Specifications, the Physical Security Plan, the Emergency Plan, and Emergency Procedures.

CN#849 *SP-4.0 REV 6 Intrusion in Controlled Access Area by Authorized Personnel*. Unauthorized Intrusion in Controlled Access Area. Update personnel titles and references to match current revisions to Technical Specifications, the Physical Security Plan, the Emergency Plan, and Emergency Procedures.

CN#850 *SP-5.0 REV 6 Key Control. Unauthorized Intrusion in Controlled Access Area*. Update personnel titles and references to match current revisions to Technical Specifications, the Physical Security Plan, the Emergency Plan, and Emergency Procedures.

CN#851 *SP-2.1 REV 11 Review and Approval of Documentation*. Add clarification and guidance for the preparation of annual reports. Adds requirement for the review of the annual report and provides guidance to ensure compliance with TS 6.7.4. Also updates references.

CN#852 *PS-6-19-1 REV 2 Thermo Radiation Monitor Calibration, Operation and Maintenance*. Revised to require that the reactor be shutdown and the radiation monitor channel be placed in by-pass to perform section 6.10 for the weekly set-point checks required by TS 4.4.b.

CN#853 *EP-1 REV 20 Emergency Plan Activation and Response*. Updated personnel call out list.

CN#854 *OP-101 REV 13 Reactor Startup & Shutdown*. Changes to the checklist and instructions to incorporate the installation of the Thermo Area Radiation monitors for the Control Room, Over-the-Pool, and West Wall, as well as other minor changes to the checklist procedure for the purpose of formatting and clarity.

CN#856 *EP-2 REV 23 Offsite Notification*. Update to the authentication code list for the State of North Carolina.

CN#857 *PS-6-16-2 REV 4, Processing, Sampling, Analysis, and Assessment of Liquid Effluent and Environmental Releases*. Add information and instructions for sampling, analysis, and assessment of liquid environmental releases.

## Other Changes

License Renewal Documentation:

A response to items discussed during the November 2019 NRC site audit was submitted on March 24, 2020 including:

1. Technical Specifications for the NCSU PULSTAR Reactor, DRAFT REV2.
2. Reactor Thermal Power and SCRAM Setpoint Determination (SAR Reference 7-4).
3. Fueled Experiment Analysis Report – A revised report analyzing fueled experiments for the PULSTAR reactor. This revised analysis replaces all previous submittals.

Final Safety Analysis Report, REV May 26, 2020 - A revised FSAR was submitted on May 26, 2020 in response to items discussed during the November 2019 NRC site audit.

## Other Items

None.

### 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) <sup>1</sup>	(5)
2020	Number of Batches	Total $\mu$ Ci	Total Volume Liters	Diluent Liters	Tritium $\mu$ Ci
01 JAN – 31 MAR	3	309	9,481	10,817	283
01 APR – 30 JUN	3	166	9,822	10,826	146
01 JUL – 30 SEP	8	338	25,753	26,692	320
01 OCT – 31 DEC	3	188	9,652	9,781	186
2020	935 $\mu$ Ci of tritium was released during this year.				
2020	1001 $\mu$ Ci of total activity was released during this year.				
<sup>1</sup> 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  $2 \times 10^{-5}$   $\mu$ Ci/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 Part 20 for release to the sanitary sewer.

**iv. Releases to Unrestricted Areas:**

In 2020 an unaccounted loss of water from the reactor coolant system (RCS) occurred. The RCS water loss is measured every work day and occurred at variable rates over the year. RCS water was not observed in surface locations or storm sewer locations outside the reactor building. Therefore the unaccounted RCS water was assumed to be continuously released to grounds beneath the surface on the reactor site at the measured RCS loss rates over the year. Reactor coolant activity and volume assumed to be released to unrestricted areas are given below for 2020:

Period in 2020	Total μCi	Tritium μCi	Volume Liters
01 JAN – 31 MAR	4,092	3,989	53,696
1 APR – 30 JUN	2,826	2,770	40,442
1 JUL – 30 SEP	3,742	3,703	68,802
1 OCT – 31 DEC	2,847	2,800	49,344
CALENDAR YEAR TOTAL	13,507	13,262	212,284

The concentration of radionuclides detected in the reactor coolant met regulatory limits for release to unrestricted areas (10 CFR 20 Appendix B Table 2). Detected radionuclides in reactor coolant were tritium and activation products. Fission products were not detected. No tritium or activation products were detected in environmental samples (refer to Section 6.7.4.i below).

**Gaseous Waste (summarized monthly)**

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

**(1) Gases:**

Year	Month	Total Time Hours	Curies
2020	JANUARY	744	0.652
	FEBRUARY	696	0.520
	MARCH	744	0.412
	APRIL	720	0.156
	MAY	744	0.038
	JUNE	720	1.301
	JULY	744	1.033
	AUGUST	744	0.506
	SEPTEMBER	720	0.426
	OCTOBER	744	0.558
	NOVEMBER	720	0.680
	DECEMBER	744	1.011
	TOTAL	8784	7.293

**(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 detected.

**ii. Gases and Particulates Discharged During the Reporting Period:**

**(1) Gases:**

Total activity of Argon-41 released was 7.293 Curies in 2020.

The yearly average concentration of Argon-41 released from the PULSTAR reactor facility exhaust stack in 2020 was  $3.5 \times 10^{-8}$   $\mu\text{Ci/ml}$ . Dose calculations for the year were performed using methods given in the Final Safety Analysis Report and gave results less than the 10 CFR Part 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. No activation or fission products were detected.

**Solid Waste from Reactor**

**i. Total Volume of Solid Waste Packaged**

Total volume of solid waste was 17 ft<sup>3</sup>.

**ii. Total Activity Involved**

Total activity for solid waste was 0.260 mCi.

**iii. Dates of shipments and disposal**

Transfer of solid radioactive waste to the university broad scope radioactive materials license was made in November 2020. 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 was 2.186 person-rem. Individual deep dose-equivalent ranged from 0.000 rem to 0.666 rem with an average of 0.095 rem. Three individuals were above 0.250 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 (background is approximately 10  $\mu\text{rem/h}$ ).
- Contamination was not detectable.
- Net radiation readings ranged from 0 to 30  $\mu\text{rem/h}$  while the reactor was operating at power. Radiation was at background levels in all routinely occupied spaces.
- Water samples from Rocky Branch Creek and an on-site ground water monitoring well were analyzed in 2020 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 and groundwater is routinely performed in accordance with facility procedures.

**ATTACHMENT A**

**PULSTAR REACTOR  
ENVIRONMENTAL RADIATION SURVEILLANCE  
REPORT**

**FOR THE PERIOD  
JANUARY 1, 2020 - DECEMBER 31, 2020**

**NORTH CAROLINA STATE UNIVERSITY**

**ENVIRONMENTAL HEALTH AND SAFETY  
CENTER**

**RADIATION SAFETY DIVISION**

**by**

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## 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:

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

**Table 1****Environmental Monitoring Programs for the PULSTAR Reactor at North Carolina State University**

<b>Sample</b>	<b>Activity Measured</b>	<b>Conducted By</b>	<b>Frequency</b>	<b>Basis For Measurement</b>
Stack Gases	Gross Gamma	N.E.	Continuous	10 CFR 20 T.S. 6.7.4
Stack Particles	Gross Beta Gamma Emitters	N.E. N.E.	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)	10 CFR 20 T.S. 6.7.4 City of Raleigh Ordinance
Air Filters at 4 Campus Stations*	Gross Beta Gamma Emitters	RSD RSD	Quarterly Quarterly	10 CFR 20 10 CFR 20
Air Dose at 7 Campus Stations+	OSD Dosimeter	RSD	Quarterly	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Gamma Emitters	RSD RSD	Quarterly Quarterly	NCSU NCSU
	Tritium	N.E.	Quarterly	10 CFR 20
Vegetation NCSU Campus	Gross Beta Gamma	RSD RSD	Every Other Year	NCSU NCSU
Milk Local Dairy	I-131	RSD	Every Other Year	NCSU

Abbreviations Used in Table:

N.E. = Nuclear Engineering/Reactor Facility; RSD = Radiation Safety Division.

\*These 4 stations include: Withers, 111 Lampe Drive, Polk and the Environmental Health & Safety Center. +These 7 stations include: PULSTAR Reactor and the 4 air sampling stations, North Hall and a control station (EH&S).

## 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 14.8 fCi/cubic meter at the EH&S Center station during the week of 03/10/2020 to 03/17/2020. The annual campus average value was 12.4 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**

<u>SITE</u>	<u>DIRECTION</u> <sup>1</sup>	<u>DISTANCE</u> <sup>2</sup> (meters)	<u>ELEVATION</u> <sup>3</sup> (meters)
111 LAMPE DRIVE	SOUTHEAST	90	-8
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL **	NORTHEAST	402	-4
POLK HALL	WEST	100	-7

<sup>1</sup>DIRECTION - DIRECTION FROM REACTOR STACK

<sup>2</sup>DISTANCE - DISTANCE FROM REACTOR STACK

<sup>3</sup>ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

\*\* ONLY DOSIMETER MONITORING

**TABLE 2.2 Airborne Gross Beta Activity (fCi/cubic meter  $\pm 2\sigma$ )**

<b>PERIOD</b>	<b>Polk</b>	<b>111 Lampe</b>	<b>Withers</b>	<b>EH&amp;S</b>
<b>2020</b>				
03/10-03/17	12.7 $\pm$ 1.4	14.0 $\pm$ 1.4	8.3 $\pm$ 1.2	14.8 $\pm$ 1.4
06/22-06/29	13.4 $\pm$ 1.4	13.4 $\pm$ 1.4	11.7 $\pm$ 1.3	13.9 $\pm$ 1.4
09/14-09/21	11.2 $\pm$ 1.3	11.6 $\pm$ 1.3	12.7 $\pm$ 1.4	14.2 $\pm$ 1.4
11/05-11/12	10.9 $\pm$ 1.3	11.0 $\pm$ 1.3	11.5 $\pm$ 1.4	12.5 $\pm$ 1.4

**TABLE 2.3 Airborne Gamma Activity LLD Values (fCi/cubic meter)**

<b>PERIOD</b>	<b>Co-57</b>	<b>Co-60</b>	<b>Nb-95</b>	<b>Zr-95</b>	<b>Ru-103</b>	<b>Ru-106</b>	<b>Cs-137</b>	<b>Ce-141</b>	<b>Ce-144</b>
<b>2020</b>									
03/10- 03/17	0.19	0.54	0.48	0.74	0.32	3.41	0.38	0.36	1.37
06/22 - 06/29	0.20	0.56	0.43	0.71	0.31	3.56	0.40	0.31	1.46
09/14 - 09/21	0.18	0.54	0.46	0.75	0.31	3.32	0.40	0.34	1.32
11/05 - 11/12	0.17	0.52	0.41	0.70	0.29	3.17	0.37	0.29	1.27

**TABLE 2.4 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS  
FOR AIRBORNE RADIOACTIVITY (fCi M<sup>-3</sup>).**

<u>NUCLIDE</u>	<u>REGULATORY LIMIT</u>	<u>INVESTIGATION LEVEL</u>	<u>*AVERAGE N.C. BACKGROUND LEVEL</u>
GROSS BETA	1000	500	20
Cs-137	2 X 10 <sup>5</sup>	100	2
Ce-134	2 X 10 <sup>5</sup>	100	0
Nb-95	2 X 10 <sup>6</sup>	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 Health and Human Services 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 samples were collected in 2020. Milk sampling is performed every other year.

**TABLE 3.1 I-131 IN COW' S MILK (pCi Liter<sup>-1</sup> ± 2 σ) LLD ~ 2 pCi Liter<sup>-1</sup>**

<u>DATE</u>	<u>pCi Liter<sup>-1</sup></u>	
	<u>Campus Creamery</u>	<u>Lake Wheeler</u>
2020	No Data	Not Data

#### 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  $\sim 0.4 \text{ pCi Liter}^{-1}$ . For gross alpha activity the Investigation Level is  $5 \text{ pCi Liter}^{-1}$  and the Regulatory Limit is  $15 \text{ pCi Liter}^{-1}$ . For gross beta activity the Investigation Level is  $12.5 \text{ pCi Liter}^{-1}$  and the Regulatory Limit is  $50 \text{ pCi Liter}^{-1}$ . 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 ( $\text{pCi Liter}^{-1} \pm 2\sigma$ )**

		$\text{pCi Liter}^{-1}$	
		GROSS ALPHA	GROSS BETA
<u>DATE</u>	<u>LOCATION</u>		
FIRST QUARTER 2020	ON	$0.1 \pm 0.1$	$3.4 \pm 0.7$
	OFF	$0.1 \pm 0.1$	$3.5 \pm 0.7$
	GYM	$0.2 \pm 0.2$	$2.0 \pm 0.6$
SECOND QUARTER 2020	ON	$0.2 \pm 0.2$	$3.6 \pm 0.7$
	OFF	$0.1 \pm 0.2$	$2.3 \pm 0.6$
	GYM	$0.1 \pm 0.2$	$3.9 \pm 0.7$
THIRD QUARTER 2020	ON	$0.3 \pm 0.2$	$3.1 \pm 0.7$
	OFF	$0.1 \pm 0.1$	$1.5 \pm 0.6$
	GYM	$0.1 \pm 0.1$	$3.0 \pm 0.7$
FOURTH QUARTER 2020	ON	$0.2 \pm 0.2$	$4.2 \pm 0.7$
	OFF	$0.1 \pm 0.2$	$2.6 \pm 0.6$
	GYM	$0.1 \pm 0.2$	$2.6 \pm 0.6$

**TABLE 4.2    LLD VALUES FOR GAMMA EMITTERS IN SURFACE WATER**

<u>NUCLIDE</u>	<u>LLD (pCi Liter<sup>-1</sup>)</u>
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. No vegetation samples were analyzed in 2020. The vegetation sampling is performed every other year.

**TABLE 5.1 GROSS BETA ACTIVITY IN CAMPUS VEGETATION \* LLD – 0.5 pCi g<sup>-1</sup>**

<u>SAMPLE DATE</u>	<u>SAMPLE LOCATION</u>	<u>(pCi g<sup>-1</sup> ± 2σ)</u>
2020	NORTH CAMPUS	No Data
2020	SOUTH CAMPUS	No Data
2020	EAST CAMPUS	No Data
2020	WEST CAMPUS	No Data

**TABLE 5.2 LLD VALUES FOR GAMMA EMITTERS IN VEGETATION**

<u>NUCLIDE</u>	<u>LLD (pCi gram<sup>-1</sup>)</u>
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 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 seven (7) 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**

<b>Period</b>	<b>Control</b>	<b>Polk</b>	<b>Withers</b>	<b>Daniels</b>	<b>EHS</b>	<b>North</b>	<b>PULSTAR</b>
<b>2020</b>							
01/01-03/31	41	M,M	M,M	M,M	M	M	11
04/01-06/30	36	M,M	M,M	M,M	M	8	17
07/01-09/30	41	M,M	M,M	M,M	M	M	12
10/01-12/31	46	M	M	M,M	M	M	****

\*\*\*\* No data available for this 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 43) 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. Due to DOE/MAPEP funding issues, cross-check test samples are currently not being supplied for gross alpha/beta water and gross alpha/beta air filter analyses.

The MAPEP value listed in the Tables 7.1 (a-c) to which the ERS� 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**

**MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY  
01 August 2020**

The sample consists of a spiked aliquot of acidified water (~5 % HNO<sub>3</sub>). The reported values and the known values are given in Bq/Liter.

<b>*NCSU - ENVIRONMENTAL LABORATORY RESULTS</b>				
<b>Radionuclide</b>	<b>*Reported Value</b>	<b>*Reported Error</b>	<b>MAPEP Value</b>	<b>Acceptance Range</b>
<b>Co60</b>	<b>13.0</b>	<b>0.4</b>	<b>12.2</b>	<b>8.5 – 15.9</b>
<b>Cs137</b>	<b>14.5</b>	<b>0.7</b>	<b>14.3</b>	<b>10.0 – 18.6</b>
<b>Cs134</b>	<b>12.2</b>	<b>0.6</b>	<b>15.2</b>	<b>10.6 – 19.8</b>
<b>Co57</b>	<b>0.2</b>	<b>0.4</b>	<b>----</b>	<b>False + Test</b>
<b>Mn54</b>	<b>0.2</b>	<b>0.3</b>	<b>----</b>	<b>False + Test</b>
<b>Zn65</b>	<b>16.2</b>	<b>1.2</b>	<b>16.9</b>	<b>11.8 – 22.0</b>
<b>Gross Alpha</b>	<b>0.60</b>	<b>0.17</b>	<b>0.62</b>	<b>0.19 – 1.05</b>
<b>Gross Beta</b>	<b>1.12</b>	<b>0.21</b>	<b>0.83</b>	<b>0.42 – 1.25</b>

**Note:** The entry “-----” indicates no analyte was present for purposes of conducting a False Positive (+) Test.

**TABLE 7.1b****MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY  
01 August 2020**

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.

**\*NCSU - ENVIRONMENTAL LABORATORY RESULTS**

<b>Radionuclide</b>	<b>*Reported Value</b>	<b>*Reported Error</b>	<b>MAPEP Value</b>	<b>Acceptance Range</b>
<b>Co60</b>	<b>1.62</b>	<b>0.05</b>	<b>1.73</b>	<b>1.21 – 2.25</b>
<b>Cs137</b>	<b>0.93</b>	<b>0.03</b>	<b>0.996</b>	<b>0.697 – 1.295</b>
<b>Cs134</b>	<b>1.89</b>	<b>0.03</b>	<b>1.83</b>	<b>1.28 – 2.38</b>
<b>Co57</b>	<b>0.02</b>	<b>0.04</b>	<b>----</b>	<b>False + Test</b>
<b>Mn54</b>	<b>1.31</b>	<b>0.05</b>	<b>1.40</b>	<b>0.98 – 1.82</b>
<b>Zn65</b>	<b>1.65</b>	<b>0.05</b>	<b>2.00</b>	<b>1.40 – 2.60</b>
<b>Gross Alpha</b>	<b>0.37</b>	<b>0.02</b>	<b>0.528</b>	<b>0.158 – 0.898</b>
<b>Gross Beta</b>	<b>0.94</b>	<b>0.04</b>	<b>0.915</b>	<b>0.458 – 1.373</b>

**Note:** The entry “-----” indicates no analyte was present for purposes of conducting a False Positive (+) Test.



**TABLE 7.1c****MULTINUCLIDE VEGETATION SAMPLE - INTERCOMPARISON STUDY  
01 August 2020**

The sample consists of a spiked sample of vegetation. The reported values and the known values are given in Bq/sample.

**\*NCSU - ENVIRONMENTAL LABORATORY RESULTS**

<b>Radionuclide</b>	<b>*Reported Value</b>	<b>*Reported Error</b>	<b>MAPEP Value</b>	<b>Acceptance Range</b>
<b>Co60</b>	<b>4.71</b>	<b>0.12</b>	<b>4.13</b>	<b>2.89 – 5.37</b>
<b>Cs137</b>	<b>0.6</b>	<b>0.5</b>	<b>-----</b>	<b>False + Test</b>
<b>Cs134</b>	<b>5.46</b>	<b>0.13</b>	<b>4.94</b>	<b>3.46 – 6.42</b>
<b>Co57</b>	<b>7.30</b>	<b>0.08</b>	<b>6.67</b>	<b>4.67 – 8.67</b>
<b>Mn54</b>	<b>6.93</b>	<b>0.13</b>	<b>5.84</b>	<b>4.09 – 7.59</b>
<b>Zn65</b>	<b>8.53</b>	<b>0.16</b>	<b>6.38</b>	<b>4.47 – 8.29</b>

**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.