North Carolina State University is a land-grant university and a constituent institution of The University of North Carolina

Nuclear Reactor Program

NC STATE UNIVERSITY

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URL: www.ne.ncsu.edu/NRP reactor_program.html

30 March 2011

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

Re: Annual Report for 2010

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 2011.

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

Enclosures:
Annual Operating Report for 2010
Attachment A: PULSTAR Reactor Environmental Radiation Surveillance Report

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NRR

NORTH CAROLINA STATE UNIVERSITY

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 January 2010 - 31 December 2010

The following report 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.

An unintended exposure occurred in Dec 2010 to one individual as a result of a design flaw at an experimental facility. A dose of 0.150 mrem was assigned to this individual for this incident. Numerous corrective actions were identified and are being implemented as a result of this incident. Details of the incident were provided to the US NRC in Reportable Event 46484.

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

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

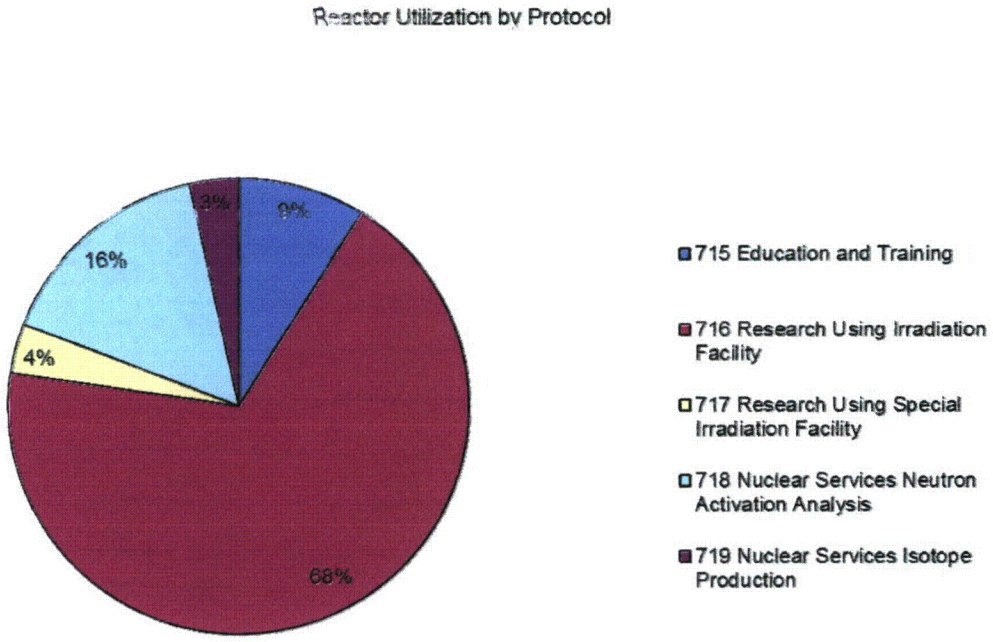


Figure 1 - Reactor Utilization by Protocol

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.

Net loss of primary water from the reactor pool was low, but detectable in until May 2010. Net loss of primary water was not detectable after May 2010. Health physics surveillance of reactor primary coolant water showed no fission products and that activity is below 10CFR20, Appendix B, Table 3 limits for all of 2010.

6.7.4.b Energy Output and Critical Hours:

Total Energy Output in 2010:	56.6 Megawatt·days
Critical hours in 2010:	1505.3 hours
Cumulative Total Energy Output Since Initial Criticality:	1263.8 Megawatt·days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

Emergency Shutdowns - NONE

Unscheduled Shutdowns – ONE

1. 13-DEC-2010 – MANUAL SHUTDOWN – Due to malfunction of the Neutron Imaging Facility. The Reactor Operator initiated a reactor shutdown by rod insertion at the request of the Designated Senior Reactor Operator. Refer to Reportable Event 46484.

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.

768 – PS-6-15-1C – Radiation Recorder – A new recorder for the radiation monitoring system was installed. This replacement was a planned preventative maintenance activity.

769 – PS-1-10-1 – T2 Temperature RTD – The unit was replaced due to deterioration of the insulation on the integral lead wire. This replacement was a planned preventative maintenance activity.

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, none required a 10CFR50.59 evaluation.

The following design changes were made:

710 – Installation of Air Effluent Probes – Air effluent probes are being relocated from the exhaust stack to exhaust ducts inside the reactor building. The relocation will facilitate inspection and maintenance on the sampling probes. The modification was approved on 22-JAN-2010 and should be completed by summer 2011.

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.

709 – NRP-OP-401 Heavy Water Transfer Rev. 0. This is a new procedure for the purpose of providing directions for the transfer of heavy water between storage drums, tanks, or experimental equipment with regard to the Ultra-cold Neutron Facility.

711 – PS-6-12-1:BW1/M1/A1 Primary and Secondary Water Chemistry Rev. 2. – An alternative method for determining the Purification System Decontamination Factor (DF) was added to the procedure.

712 – NRP-OP-101 Reactor Startup and Shutdown Rev. 7. This was a classified as a minor change. Verbiage specific to the replacement Radiation Recorder was modified. Other typographical errors were corrected.

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:

Period	(1) Number of Batches	(2) Total μCi	(3) Total Volume Liters	(4)[1] Diluent Liters	(5) Tritium μCi
01 JAN – 31 MAR 10	2	34	6.3 E3	1.5 E4	32
01 APR – 30 JUN 10	2	23	5.5 E3	4.8 E3	22
01 JUL – 30 SEP 10	3	69	1.0 E4	2.1 E4	66
01 OCT – 31 DEC 10	1	17	3.3 E3	4.3 E3	16
2010	136 μCi of tritium was released during this year.				
2010	143 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
2010	JANUARY	744	0.433
	FEBRUARY	672	0.651
	MARCH	744	0.423
	APRIL	720	0.595
	MAY	744	0.780
	JUNE	720	0.673
	JULY	744	0.587
	AUGUST	744	0.953
	SEPTEMBER	720	1.020
	OCTOBER	744	2.190
	NOVEMBER	720	1.280
	DECEMBER	744	0.487
	TOTAL	8760	10.069

(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 10.069 curies in 2010.

The yearly average concentration of Argon-41 released from the PULSTAR reactor facility exhaust stack in 2010 was 3.8×10^{-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 10CFR20 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.

Solid Waste from Reactor

i. Total Volume of Solid Waste Packaged

58 ft^3 of dry uncompacted waste.

No spent ion exchange resins were disposed.

ii. ***Total Activity Involved***

1.033 mCi of dry uncompacted waste.

No spent ion exchange resins were disposed.

iii. ***Dates of shipments and disposal***

Transfers to the university broad scope radioactive materials license were made on 7 May 2010, 20 May 2010, 18 Jun 2010, and 6 Dec 2010. The University Environmental Health and Safety Center arranges disposal of hazardous wastes.

6.7.4.g Personnel Radiation Exposure Report:

33 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 2010 to 31 Dec 2010 was 2.689 person-rem. Individual deep dose-equivalent ranged from 0.002 rem to 0.644 rem with a median of 0.053 rem.

An unintended exposure occurred in Dec 2010 to one individual as a result of a design flaw with an experimental facility. A dose of 0.150 mrem was assigned to this individual for this incident. Numerous corrective actions were identified and are being implemented as a result of this incident. Details of the incident were provided to the US NRC in Reportable Event 46484.

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

Radiation and contamination surveys performed within the facility by the PULSTAR staff indicated that:

- Radiation in the majority of areas was 5 mrem/h or less.
- Radiation in the remaining areas were 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 prepared by the Radiation Safety Division of the Environmental Health and Safety Center at the end of this document for results of environmental sampling and analysis.

Perimeter surveys were performed adjacent to the Reactor Building by the PULSTAR staff and 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.

ATTACHMENT A

PULSTAR REACTOR

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JANUARY 1, 2010 - DECEMBER 31, 2010

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:

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

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 Indiv. 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 5 Campus Stations*	Gross Beta Indiv. Gamma Emitters	RSD/EHSC RSD/EHSC	Weekly Weekly	Quarterly	10 CFR 20 10 CFR 20
Air/Dosage at 8 Campus Stations+	TLD Dosimeter	RSD/EHSC	Quarterly	Quarterly	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Indiv. Gamma Emitters	RSD/EHSC RSD/EHSC	Quarterly Quarterly	Quarterly Quarterly	NCSU NCSU
Vegetation NCSU Campus	Gross Beta Gamma	RSD/EHSC RSD/EHSC	Semi-annually	Alternate years Alternate years	NCSU NCSU
Milk Local Dairy	I-131	RSD/EHSC	Monthly	Alternate years	NCSU

N.E. = Nuclear Engineering/Reactor Facility; RSD/EHSC = Radiation Safety Division.
*These 5 stations include: Withers, Daniels, Broughton, Hill Library and Environmental Health & Safety Center.
+These 8 stations include: the PULSTAR Reactor, a control station (EHSC) and the 5 air sampling stations, and North Hall.

2. AIR MONITORING (TABLES 2.1, 2.2, AND 2.3; FIGURES 2a THROUGH 2e)

Air monitoring is performed continually for one week during each of four (4) quarters during the year. The data shows the normal fluctuations in gross beta activity levels expected 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 $fCiM^{-3}$ at the Withers Hall station during the week of 10/15/10 to 10/21/10. The annual campus average was 11.6 $fCiM^{-3}$.
Table 2.2 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.

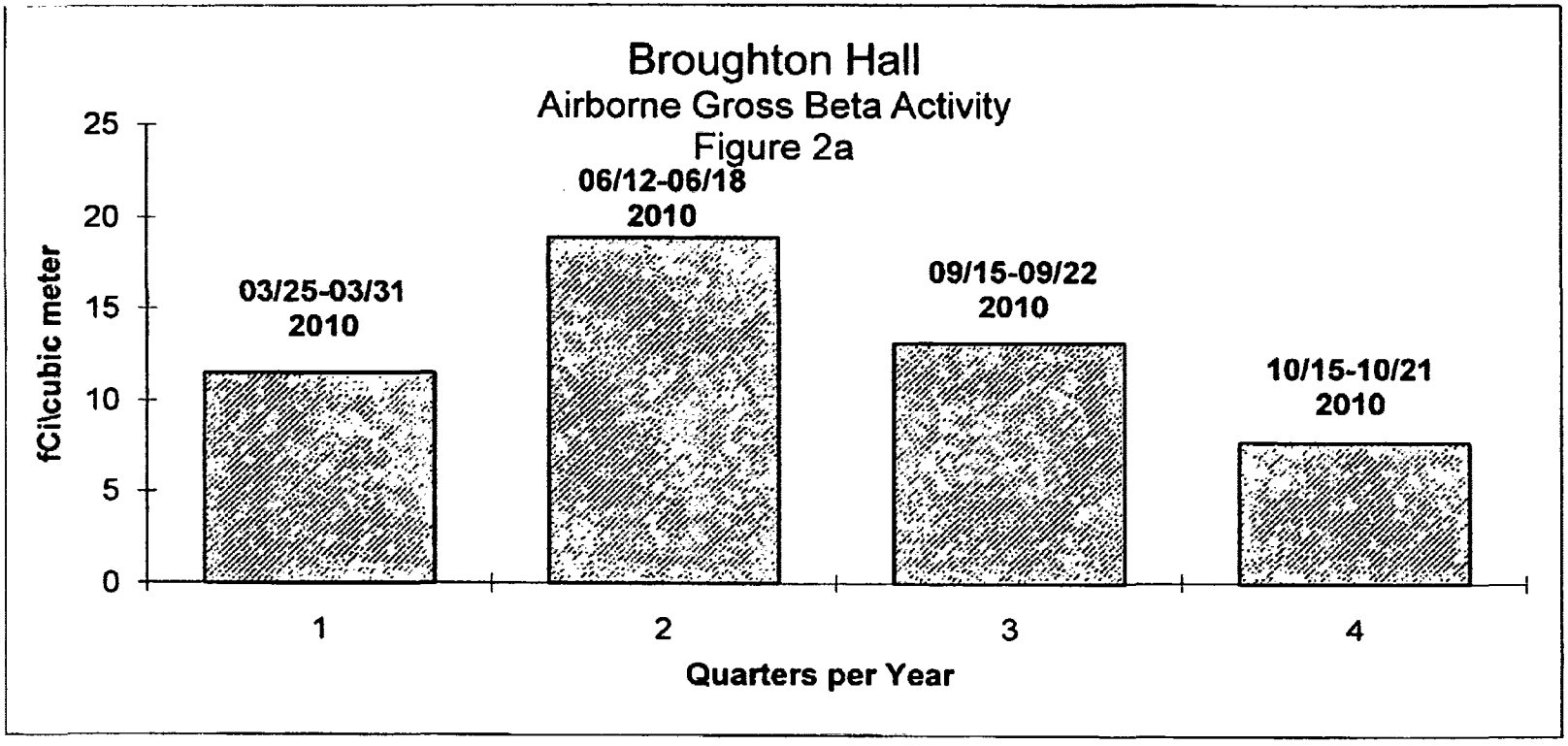
Table 2.3 lists regulatory limits, alert levels, and average background levels for airborne radioactivity.

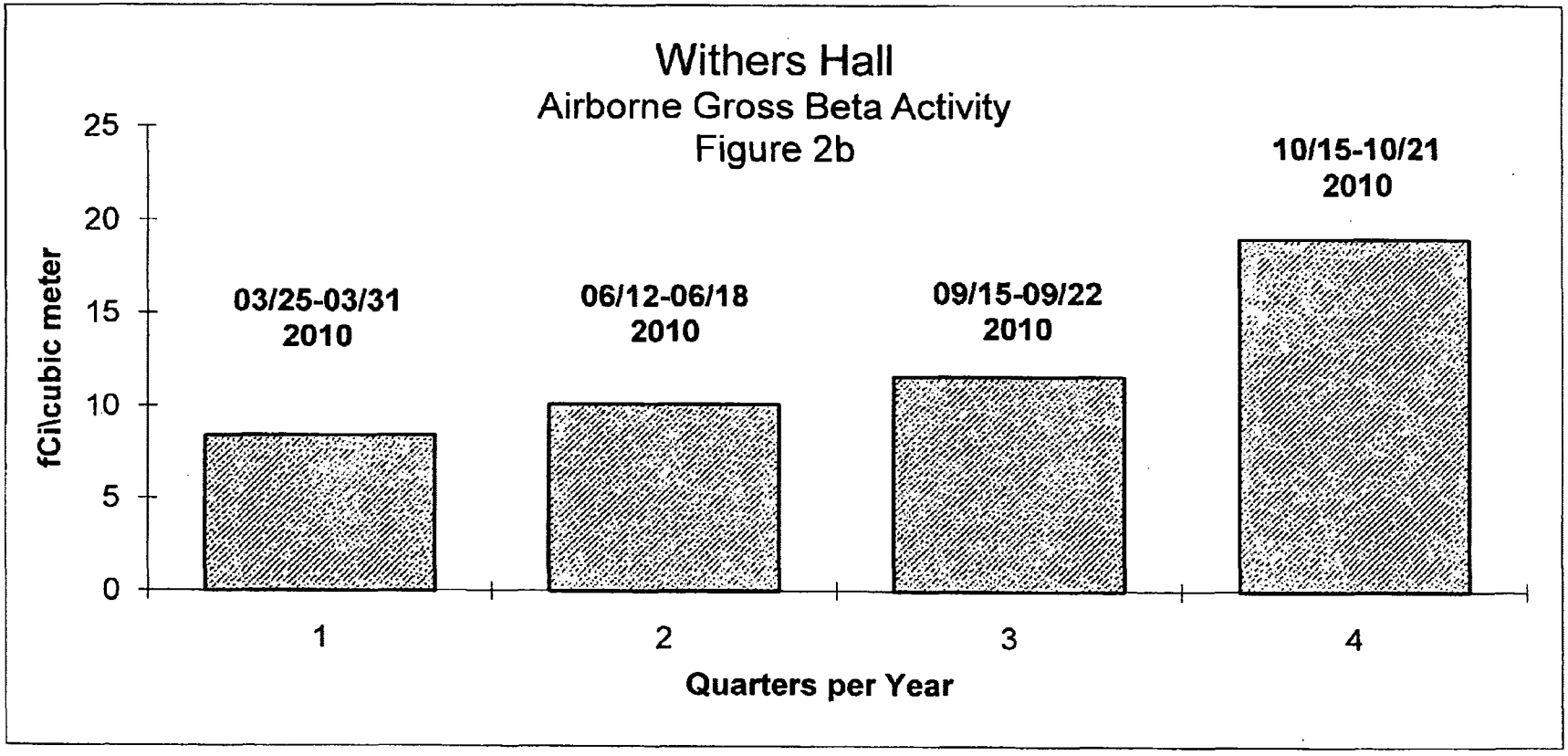
TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

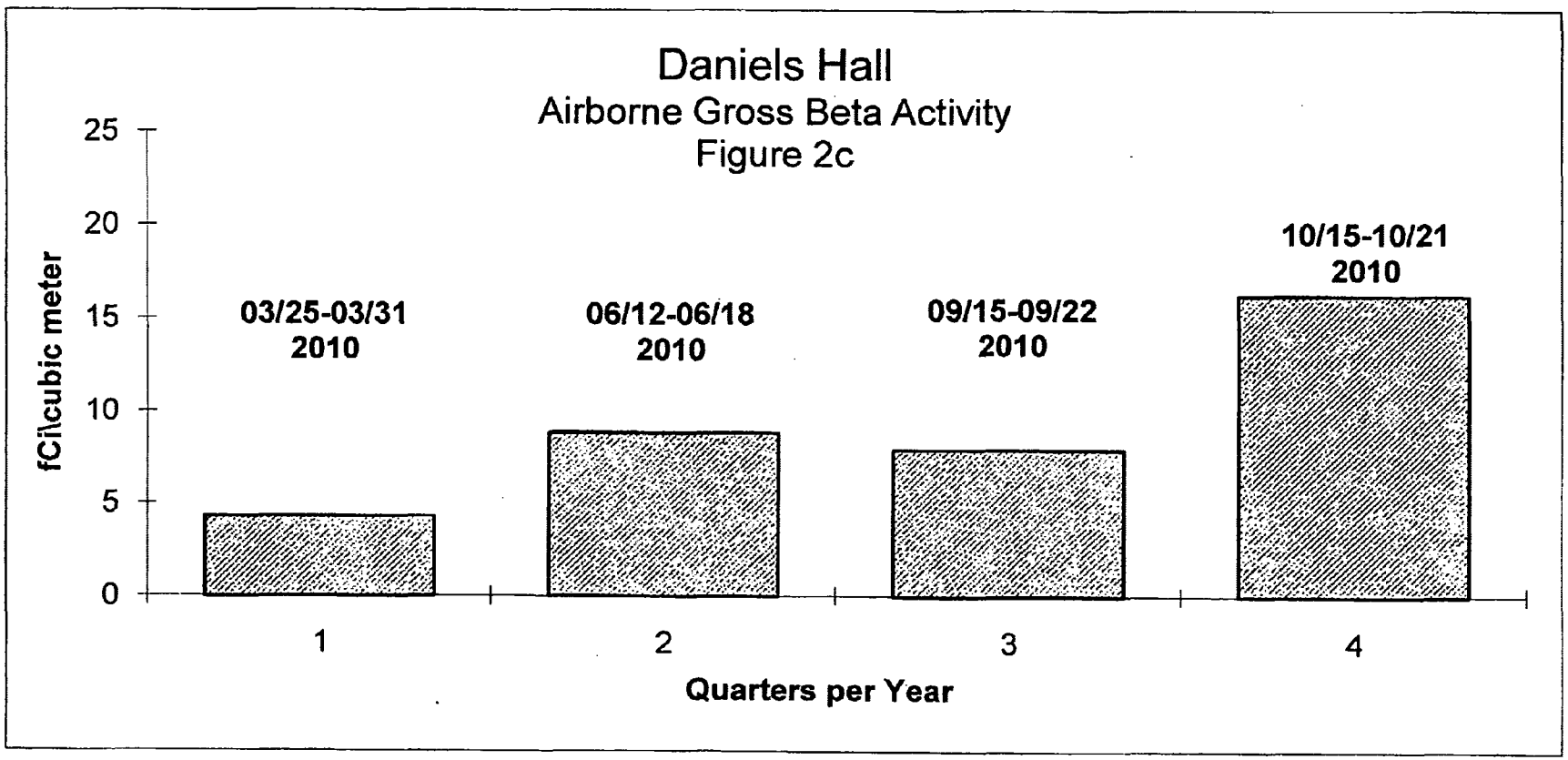
SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
LIBRARY	NORTHWEST	192	+11
DANIELS	SOUTHEAST	90	-8
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL	NORTHEAST	402	-4

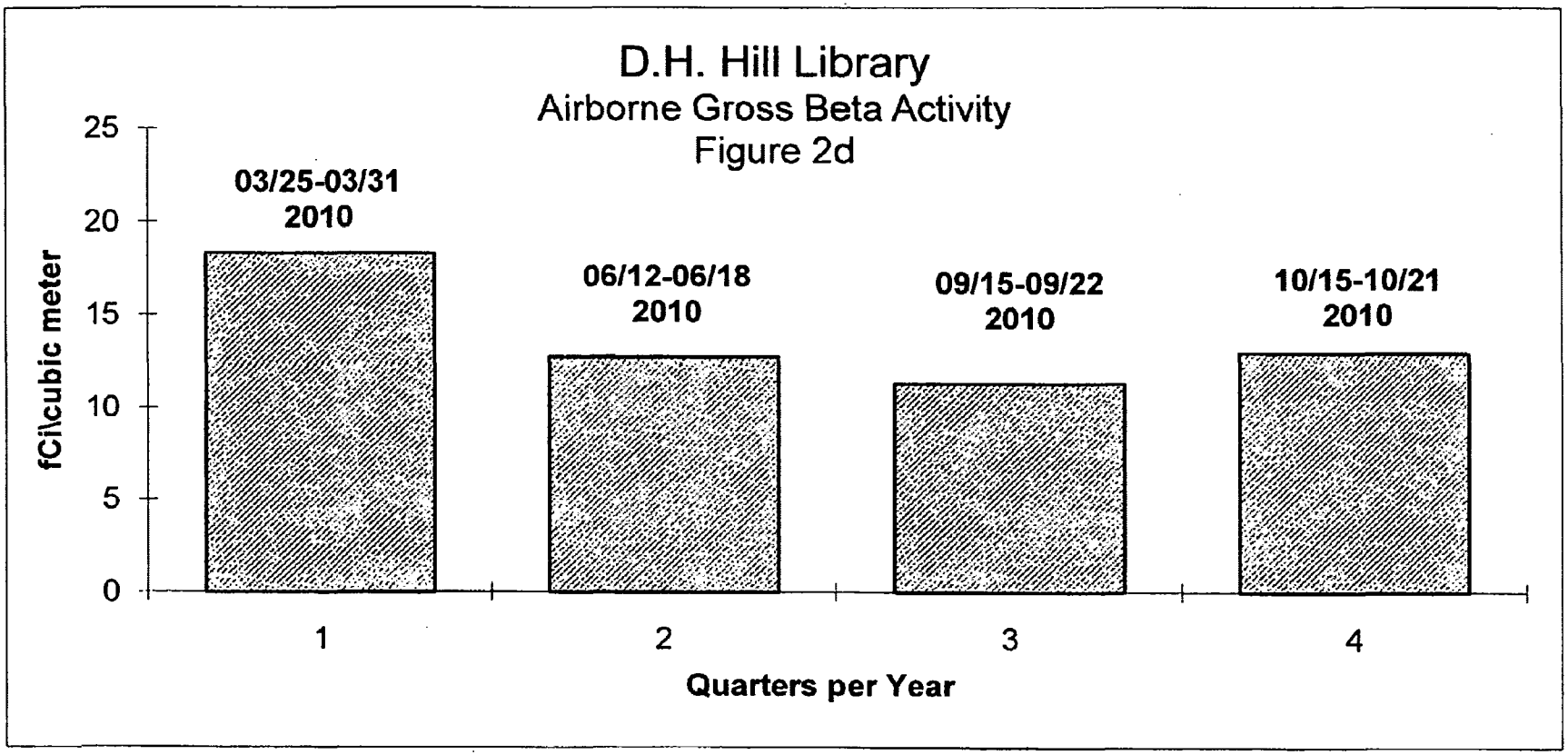
[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

Table 2.2 Aerially Transported Gamma Activity				LLD values fCi/cubic meter					
					NUCLIDES				
SAMPLING PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
2010									
03/25 - 03/31	0.21	0.35	0.29	0.47	0.27	2.37	0.26	0.38	1.22
06/12 - 06/18	0.2	0.37	0.28	0.48	0.28	2.48	0.29	0.34	1.28
09/15 - 09/22	0.18	0.35	0.31	0.54	0.33	2.51	0.29	0.43	1.40
10/15 - 10/21	0.17	0.37	0.37	0.50	0.32	2.41	0.29	0.39	1.41


Broughton Hall
Airborne Gross Beta Activity
Figure 2a
fCi/cubic meter
25
20
15
10
5
0
03/25-03/31
2010
06/12-06/18
2010
09/15-09/22
2010
10/15-10/21
2010
1
2
3
4
Quarters per Year


Withers Hall
Airborne Gross Beta Activity
Figure 2b
fCi\cubic meter
25
20
15
10
5
0
03/25-03/31
2010
06/12-06/18
2010
09/15-09/22
2010
10/15-10/21
2010
1
2
3
4
Quarters per Year


Daniels Hall
Airborne Gross Beta Activity
Figure 2c
fCi\cubic meter
25
20
15
10
5
0
03/25-03/31
2010
06/12-06/18
2010
09/15-09/22
2010
10/15-10/21
2010
1
2
3
4
Quarters per Year


D.H. Hill Library
Airborne Gross Beta Activity
Figure 2d
fCi\cubic meter
25
20
15
10
5
0
03/25-03/31
2010
06/12-06/18
2010
09/15-09/22
2010
10/15-10/21
2010
1
2
3
4
Quarters per Year

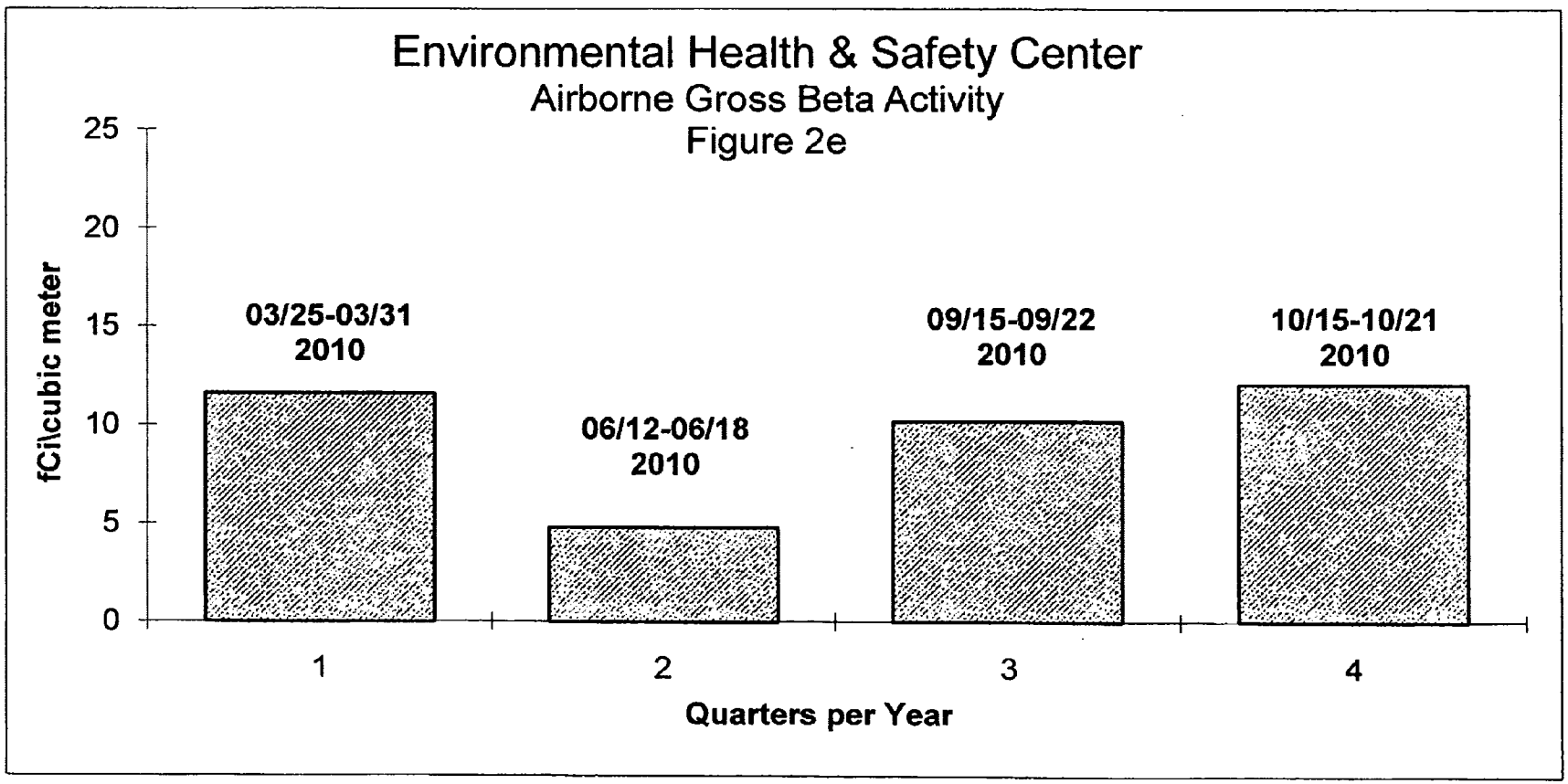

Environmental Health & Safety Center
Airborne Gross Beta Activity
Figure 2e
fCi/cubic meter
25
20
15
10
5
0
03/25-03/31
2010
06/12-06/18
2010
09/15-09/22
2010
10/15-10/21
2010
1
2
3
4
Quarters per Year

TABLE 6.1 ENVIRONMENTAL TLD EXPOSURES (mrem/QUARTER YEAR)

DATE	WITHERS	DANIELS	BROUGHTON	DH HILL*	EH&S	PULSTAR	NORTH	CONTROL
2010								
01/01-03/31	**M**	7	3	22,32,42	7	23	6	**M**,6
04/01-06/30	**M**	2	5	28,23,35	7	24	9	**M****
07/01-09/30	2	5	3	24,35,30	7	29	8	**M**,6
10/01-12/31	1	7	3	30,32,27	7	14	6	**M**,7

* Entries for D.H. Hill are for three (3) independent dosimeter readings for that station.
Entries for CONTROL are for two (2) independent dosimeter readings in two (2) separate office locations.

** Only one control reading was available

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 values reported are Deep DDE

TABLE 2.3 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi M^{-3}).

NUCLIDE	REGULATORY LIMIT	ALERT LEVEL	AVERAGE N.C. BACKGROUND LEVEL
GROSS ALPHA	20	10	4
GROSS BETA*	1000	500	3.3 -13.9 *
Cs-137	5×10^5	10	2
Ce-144	2×10^5	100	0
Ru-106	2×10^5	30	0
I-131	1×10^5	10	0

* These data represent a range of minimum to maximum annual average values measured in North Carolina.

3. **MILK** (TABLE 3.1)

Milk samples are collected in alternate years from the Campus Creamery and the Lake Wheeler Road Dairy and analyzed for I-131. No milk samples were collected for 2010. The next sample collection and analysis will be in 2011.

TABLE 3.1A I-131 IN COW'S MILK (pCi Liter^{-1} ± 2 σ) LLD ~ 3 pCi Liter^{-1}

	pCi Liter^{-1}	
DATE	Campus Creamery	Lake Wheeler
2010	No Data	No 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) 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 Alert Level is 5 pCi Liter^{-1} and the Regulatory Limit is 15 pCi Liter^{-1}. For gross beta activity the Alert Level is 5 pCi Liter^{-1} and the Regulatory Limit is 50 pCi Liter^{-1}. Samples with gross alpha or beta activities exceeding these Alert Levels would require gamma analysis to identify the radionuclides present. 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 2010	ON	< 0.4	2.7 ± 0.7
	OFF	0.6 ± 0.3	2.1 ± 0.7
SECOND QUARTER 2010	ON	< 0.4	3.2 ± 0.7
	OFF	0.4 ± 0.3	3.1 ± 0.7
THIRD QUARTER 2010	ON	0.5 ± 0.3	3.4 ± 0.7
	OFF	< 0.4	3.1 ± 0.7
FOURTH QUARTER 2010	ON	< 0.4	3.4 ± 0.7
	OFF	< 0.4	3.1 ± 0.7

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. The vegetation sampling is performed in alternate years. No vegetation samples were collected in 2010. The next sample collection and analysis will be in 2011.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ± 2σ)
2010	NORTH CAMPUS	No Data
2010	SOUTH CAMPUS	No Data
2010	EAST CAMPUS	No Data
2010	WEST CAMPUS	No Data

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. THERMOLUMINESCENT DOSIMETERS (TLDs) (TABLE 6.1)

TLD analysis is contracted to Landauer, Inc. for determination of ambient gamma exposures. Exposures are integrated over a three-month period at each of the five air monitor stations listed in Table 2.1 and inside the PULSTAR Reactor building (In July 2006, the dosimeter previously located in the PULSTAR stack was relocated inside the reactor building at the exhaust duct) and at North Hall. A control station is located in two office locations of the Environmental Health & Safety Center. Table 6.1 gives the data for these eight (8) locations.
The exposures (dose equivalents) are reported as millirem per quarter year. Readings falling below the dosimeters' minimum measurable quantities (i.e., 1 millirem for gamma radiations and 10 millirems for beta radiations) are reported by the contract vendor with the designation **"M"**. The observed readings are all 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 are included at the D.H. Hill Library station to supplement the existing dosimeter. These two additional dosimeters are a routine part of the quarterly monitoring schedule.

TABLE 6.1 ENVIRONMENTAL TLD EXPOSURES (mrem/QUARTER YEAR)

DATE	WITHERS	DANIELS	BROUGHTON	DH HILL*	EH&S	PULSTAR	NORTH	CONTROL
2010								
01/01-03/31	**M**	7	3	22,32,42	7	23	6	**M**,6
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07/01-09/30	2	5	3	24,35,30	7	29	8	**M**,6
10/01-12/31	1	7	3	30,32,27	7	14	6	**M**,7

* Entries for D.H. Hill are for three (3) independent dosimeter readings for that station.
Entries for CONTROL are for two (2) independent dosimeter readings in two (2) separate office locations.

** Only one control reading was available

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 values reported are Deep DDE

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory (ERSL) of the Radiation Safety Division has analyzed samples provided by the U.S. DOE Mixed-Analyte Performance Evaluation Program (MAPEP Test Session 22) 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 and inorganic analyte, the laboratory result and the RESL 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%

In addition to the MAPEP Quality Assurance Program, the ERSL conducts an intralaboratory QC program to track the performance of routine radioactivity measurements. The types of calculations employed for this program are shown in an example calculation in Appendix 1.

TABLE 7.1a
GROSS ALPHA & BETA ACTIVITY AIR FILTER--INTERCOMPARISON STUDY
01 March 2010

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.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Gross Alpha	0.54	0.05	0.427	> 0.0 – 0.854
Gross Beta	1.25	0.06	1.29	0.65 – 1.94

TABLE 7.1b
MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 March 2010

The sample consists of one 7 cm diameter glass fiber filter that has been spiked with 0.10 gram of solution and dried. The reported values and the known values are given in Bq/filter.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Co60	2.50	0.05	2.473	1.731 – 3.215
Cs137	1.59	0.04	1.53	1.07 – 1.99
Cs134	1.61	0.03	2.13	1.49 – 2.77
Co57	NR	-----	-----	----------
Mn54	3.27	0.07	3.02	2.11 – 3.93
Zn65	NR	-----	-----	----------

NR = No Result. These were tests for false positive results. No analyte present.

TABLE 7.1c
MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 March 2010

The sample consists of a spiked, 455 mL aliquot of acidified water (~1 N HCl). The reported values and the known values are given in Bq/Liter.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Co60	NR	-----	-----	----------
Cs137	60.03	1.39	60.6	42.4 - 78.8
Cs134	NR	-----	-----	----------
Co57	26.21	0.75	28.3	19.8 - 36.8
Zn65	43.29	1.56	40.7	28.5 - 52.9
Mn54	26.78	0.76	26.9	18.8 - 35.0

NR = No Result. These were tests for false positive results. No analyte present.

TABLE 7.1d
GROSS ALPHA AND BETA WATER SAMPLE - INTERCOMPARISON STUDY
01 March 2010

The sample consists of a 5% HNO_3 matrix free solution. The reported values and the known values are given in Bq/Liter.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Gross Alpha	1.66	0.42	0.676	> 0.0 - 1.352
Gross Beta	4.51	0.53	3.09	1.55 - 4.64

TABLE 7.1e
MULTINUCLIDE VEGETATION SAMPLE - INTERCOMPARISON STUDY
01 March 2010

The sample consists of milled hay grass spiked with radiological constituents. The reported values and the known values are given in Bq/sample.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Cs134	4.02	0.08	4.39	3.07 - 5.71
Cs137	3.28	0.12	3.06	2.14 - 3.98
Co57	NR	-----	-----	----------
Co60	3.65	0.08	3.27	2.29 - 4.25
Mn54	NR	-----	-----	----------
Zn65	8.19	0.24	7.10	4.97 - 9.23

NR = No Result. These were tests for false positive results. No analyte present.

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 that 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.

APPENDIX 1

The following example calculation gives a set of data, the mean value, the experimental sigma, and the range. These statistics provide measures of the central tendency and dispersion of the data.

The normalized range is computed by first finding mean range, R, the control limit, CL, and the standard error of the range, σ_R. The normalized range measures the dispersion of the data (precision) in such a form that control charts may be used. Control charts allow one to readily compare past analytical performance with present performance. In the example, the normalized range equals 0.3 that is less than 3, which is the upper control level. The precision of the results is acceptable.

The normalized deviation is calculated by computing the deviation and the standard error of the mean, σ_m. The normalized deviation allows one to measure central tendency (accuracy) readily through the use of control charts. Trends in analytical accuracy can be determined in this manner. For this example, the normalized deviation is -0.7 which falls between +2 and -2 that are the upper and lower warning levels. The accuracy of the data is acceptable. Any bias in methodology or instrumentation may be indicated by these results.

EXAMPLE CALCULATIONS

Experimental Data:

Known value = μ = 3273 pCi ^{3}H/Liter on September 24, 1974

Expected laboratory precision = σ = 357 pCi/liter

Sample	Result
X_1	3060 pCi/liter
X_2	3060 pCi/liter
X_3	3240 pCi/liter

Mean = $\bar{x}$

$$\bar{x} = \frac{\sum_{x=i}^{N} X_i}{N} = \frac{9360}{3} = 3120 \text{ pCi/liter}$$

where N = number of results = 3

Experimental sigma = s

$$s = \sqrt{\frac{\sum_{i=1}^{N} (X_i)^2 - \frac{(\sum_{i=1}^{N} X_i)^2}{N}}{N-1}}$$

$$s = \sqrt{\frac{(3060)^2+(3060)^2+(3240)^2-\frac{(3060+3060+3240)^2}{3}}{2}}$$

s = 103.9 pCi/liter

Range = r

r = | maximum result - minimum result |

r = |3240 - 3060|

r = 180 pCi/liter

Range Analysis (RNG ANLY)*

Mean range = $\bar{R}$

$\bar{R} = d_2\sigma$ where d_2** = 1.693 for N = 3

$= (1.693)\ (357)$

$\bar{R}$ = 604.4 pCi/liter

Control limit = CL

$CL = \bar{R} + 3\sigma_R$

$= D_4\bar{R}$ where D_4** = 2.575 for N = 3

$= (2.575)\ (604.4)$

CL = 1556 pCi/liter

Standard error of the range = σ_R

$\sigma_R = (R + 3\sigma_R - \bar{R}) \div 3$

$= (D_4\bar{R} - \bar{R}) \div 3$

$= (1556 - 604.4) \div 3$

σ_R = 317.2 pCi/liter

Let Range = $r = w\bar{R} + x\sigma_R$ = 180 pCi/liter

Define normalized range = w + x

for $r > \bar{R}$, w = 1

then $r = w\bar{R} + x\sigma_R = \bar{R} + x\sigma_R$

or $x = \dfrac{r - \bar{R}}{\sigma_R}$

therefore $w + x = 1 + x = 1 + \dfrac{r - \bar{R}}{\sigma_R}$

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*Rosentein, M., and A. S. Goldin, "Statistical Techniques for Quality Control of Environmental Radioassay," AQCS Report Stat-1, U.S. Department of Health Education and Welfare, PHS, November 1964.
**From table "Factors for Computing Control Limits," Handbook of Tables for Probability and Statistics, 2nd Edition, The Chemical Rubber Co., Cleveland, Ohio, 1968, p. 454.

for $r \leq \bar{R}$, $x = 0$

then $r = w\bar{R} + x\sigma_R = w\bar{R}$

or $$w = \frac{r}{\bar{R}}$$

therefore $$w + x = w + 0 = \frac{r}{\bar{R}}$$

since $r < \bar{R}$, $(180 < 604.4)$

$$w + x = \frac{180}{604.4}$$

$$w + x = 0.30$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

$$D = \bar{\bar{x}} - \mu$$

$$= 3120 - 3273$$

$$D = -153 \text{ pCi/liter}$$

Standard error of the mean = σ_m

$$\sigma_m = \frac{\sigma}{\sqrt{N}}$$

$$= \frac{357}{\sqrt{3}}$$

$$\sigma_m = 206.1 \text{ pCi/liter}$$

$$ND = \frac{D}{\sigma_m}$$

$$= \frac{-153}{206.1}$$

$$ND = -0.7$$

Control limit = CL

$$CL = (\mu \pm 3\sigma_m)$$

Warning limit = WL

WL = $(\mu \pm 2\sigma_m)$

Experimental sigma (all laboratories) = s_t

$$s_t = \sqrt{\frac{\sum_{i=1}^{N} x_i^2 - \frac{(\sum_{i=1}^{N} x_i)^2}{N}}{N-1}}$$

$$= \sqrt{\frac{162639133 - \frac{(49345)^2}{15}}{14}}$$

s_t = 149 pCi/liter

Grand Average = GA

$$GA = \frac{\sum_{i=1}^{N} x_i}{N}$$

$$= \frac{49345}{15}$$

GA = 3290 pCi/liter

Normalized deviation from the grand average = ND'

Deviation of the mean from the grand average = D'

$D' = \bar{x} - GA$

$= 3120 - 3290$

$D' = -170$ pCi/liter

$$ND' = \frac{D'}{\sigma_m}$$

$$= \frac{-170}{206.1}$$

ND' = - 0.8