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

Nuclear Reactor Program

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February 28, 2006

TO: Nuclear Regulatory Commission Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

RE: NCSU PULSTAR Annual Report
License No. R-120
Docket No. 50-297

In compliance with section 6.7.4 of the North Carolina State University PULSTAR Technical Specifications, our Nuclear Reactor Program staff has prepared the attached Annual Report for the period 01 January 05 – 31 December 2005.

If you have any question please feel free to call me at (919) 515-4602.

Sincerely,

Andrew T Cook
Associate Director
Nuclear Reactor Program

A020

NORTH CAROLINA STATE UNIVERSITY

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 January 2005 - 31 December 2005

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.

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 diffusion length in graphite by foil activation
- Neutron fluence and spectral measurements
- Neutron transmutation doping of silicon
- In-core detector certification
- Radiation damage determination to fiber optic material
- Accelerated lifetime testing for nuclear detectors
- Neutron radiography
- Positron production facility

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

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.

Health physics surveillance of reactor primary coolant water showed no fission products and that activity is below 10 CFR 20, App. B, Table 3 limits.

6.7.4.b Total Energy Output:

108.6 Megawatt·days

Reactor was Critical:

3154.5 hours

Cumulative Total Energy Output Since Initial Criticality:

1074.1 Megawatt·days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

Emergency Shutdowns - none

Unscheduled Shutdowns – Two

1. 20-MAR-05: Linear Over-Power SCRAM during start-up due to removal of source with Linear Channel in a low range. No actual over-power condition existed.

2. 19-OCT-05: Pool Temperature SCRAM due to power flicker. No actual high temperature condition existed.

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.

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

Summary:

Design Changes

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

Control Rod Drive Position Indication. Servo-Synchro position indication was replace with absolute rotary encoders with and analog output.

Reactor Power Recorder. The two pen/ink recorders were replaced with one LCD recorder. The recorders provide no protective actions.

Modification of Shim Rod Drive. All abandoned in place mechanisms for the pulsing capabilities were removed.

Replace N-16 Analog Meter. The analog meter displaying percent reactor power was replaced with a digital LED display.

Stack Radiation Monitoring System Upgrade. The stack radiation system was modified to allow on-line change-out of the particulate filter.

Document Changes

Nine procedures where revised including Operational and Health Physics procedures. Five were considered procedure revisions, four were considered minor changes. All changes were reviewed to determine whether or not a 10CFR50.59 evaluation was required. Based on the reviews, none required a 10CFR50.59 evaluation.

Other Changes

License Amendment was submitted to the NRC to allow receipt, possession and use of by-product material.

Physical Security Plan was revised to revision 9.

6.7.4.f Radioactive Effluent:

Liquid Waste (summarized by quarters)

i. Radioactivity Released During the Reporting Period:

Period	(1)	(2)	(3)	(4)[1]	(5)
	Number of Batches	Total µCi	Total Volume Liters	Diluent Liters	Tritium µCi
01 JAN – 31 MAR 04	2	45	6.0 E3	1.8 E4	43
01 APR – 30 JUN 04	2	35	4.9 E3	8.0 E3	34
01 JUL – 30 SEP 04	2	84	5.8 E3	9.7 E4	73
01 OCT – 31 DEC 04	2	155	6.8 E3	7.3 E4	147

(6)	297 μCi of tritium was released during this year.
(7)	319 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 (1) above were less than 2×10^{-5} μCi/ml. Isotopic analyses of these batches indicated low levels of typical corrosion and activation products. No fission products were detected.

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

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

Gaseous Waste (summarized monthly)

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

(1) Gases:

Year	Month	Total Time Hours	Curies
2005	JANUARY	744	0.213
	FEBRUARY	696	0.199
	MARCH	744	0.404
	APRIL	720	0.345
	MAY	744	0.281
	JUNE	720	0.220
	JULY	744	0.124
	AUGUST	744	0.290
	SEPTEMBER	720	0.092
	OCTOBER	744	0.670
	NOVEMBER	720	0.225
	DECEMBER	744	0.597
	TOTAL	8760	3.660

(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 $t_{1/2}$>8days indicated on any filter during this reporting period.

ii. Gases and Particulates Discharged During the Reporting Period:

(1) Gases:

Total activity of argon-41 released was 3.660 curies in 2005.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack in 2005 was 1.2×10^{-8} µCi/ml. Dose calculations for the fiscal year were performed using the "COMPLY" code with results less than the 10 mrem constraint level given in 10CFR20.

(2) Particulates:

See gaseous waste i.(2) above.

Solid Waste from Reactor[1]

i. Total Volume of Solid Waste Packaged

65 ft^3 of dry uncompacted waste
12 ft^3 of dried resins.

ii. Total Activity Involved

0.2 mCi in dry compacted waste
0.5 mCi in dried resins

iii. Dates of shipments and disposal

Transfer to the university broad scope radioactive materials license was made on 27 January 2005, 23 March 2005, 15 June 2205, and 5 October 2005. The University Environmental Health and Safety Center arranges disposal of hazardous wastes.

6.7.4.g Personnel Radiation Exposure Report:

35 individuals were monitored for external radiation dose during the reporting period. Collective dose for 2005 was 2.179 person-rem. Individual doses ranged from 0.001 to 0.146 rem with an average of 0.062 rem. No visitors required official monitoring during 2005.

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 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:

See Attachment A prepared by the Radiation Safety Division of the Environmental Health and Safety Center at the end of this document.

Perimeter surveys were performed adjacent to the Reactor Building by the PULSTAR staff and indicated that:

- Radiation was at background levels for most areas (10 µrem/h).
- Contamination was not detectable.

- Net radiation readings ranged from background levels to 40 µrem/h in some areas 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, 2005 - DECEMBER 31, 2005

NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY CENTER

RADIATION SAFETY DIVISION

by

Ralton J. Harris
Environmental Health Physicist

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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

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

Abbreviations Used in Table:
N.E. = Nuclear Engineering/Reactor Facility; RSD/EHSC = Radiation Safety Division.
*These 5 stations include:
Withers, Riddick, Broughton, Hill Library and Environmental Health & Safety Center.
+These 8 stations include: the PULSTAR stack, 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 21.4 $fCiM^{-3}$ at the Riddick Hall station during the week of 09/23/05 to 09/30/05. The annual campus average was 11.7 $fCiM^{-3}$.

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.

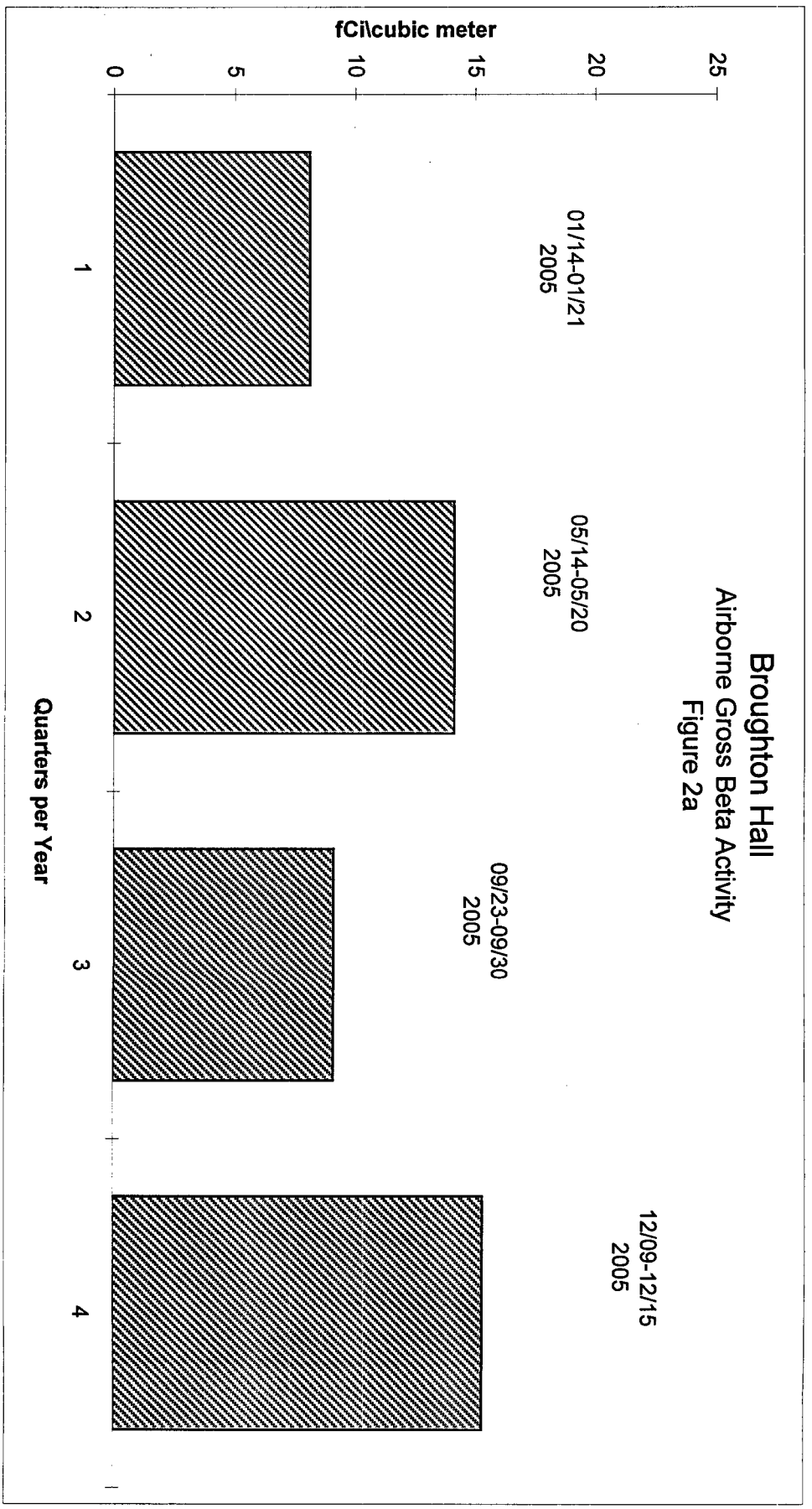
TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

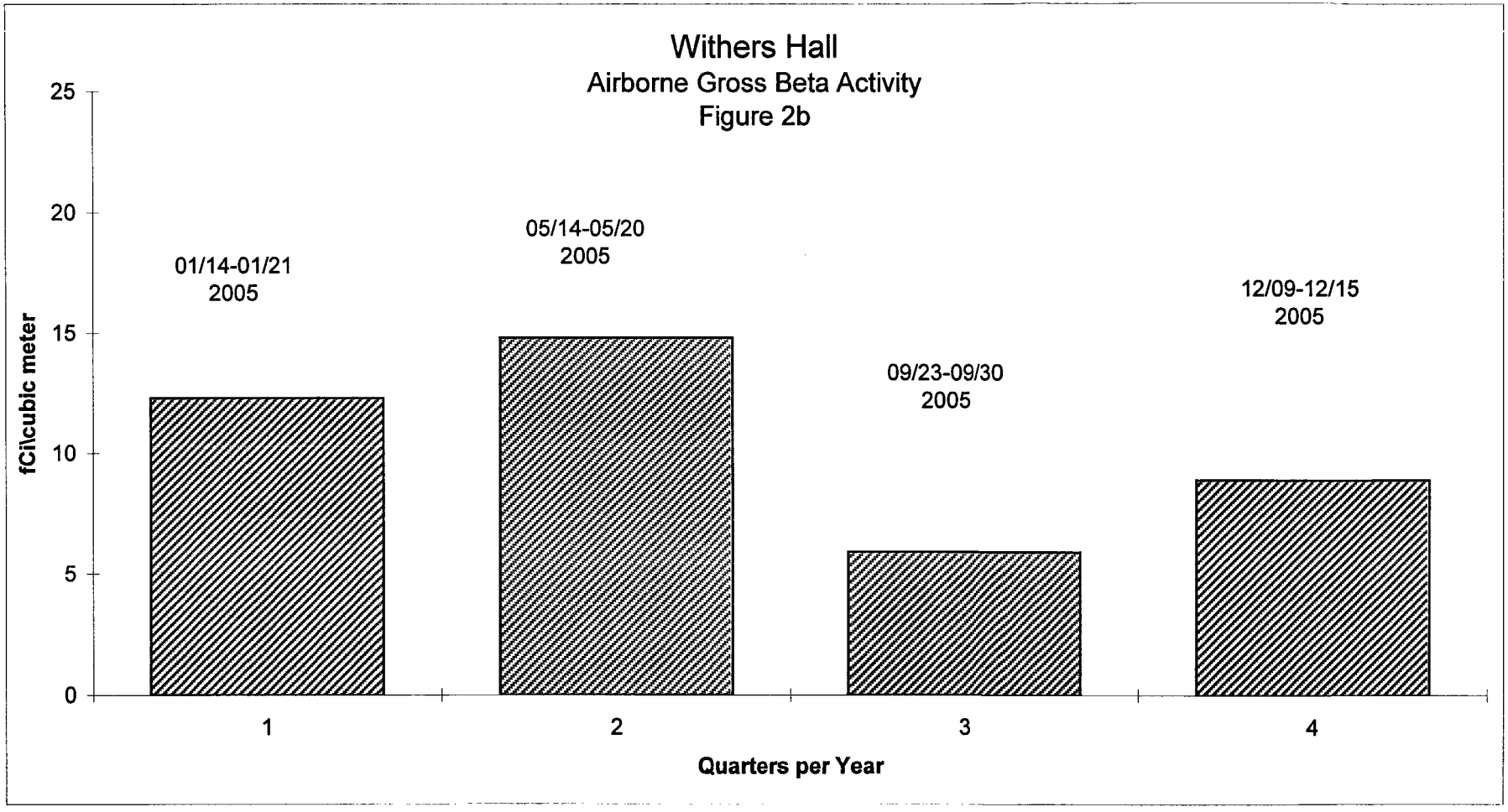
SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
LIBRARY	NORTHWEST	192	+11
RIDDICK	SOUTHEAST	99	-14
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL	NORTHEAST	402	-4

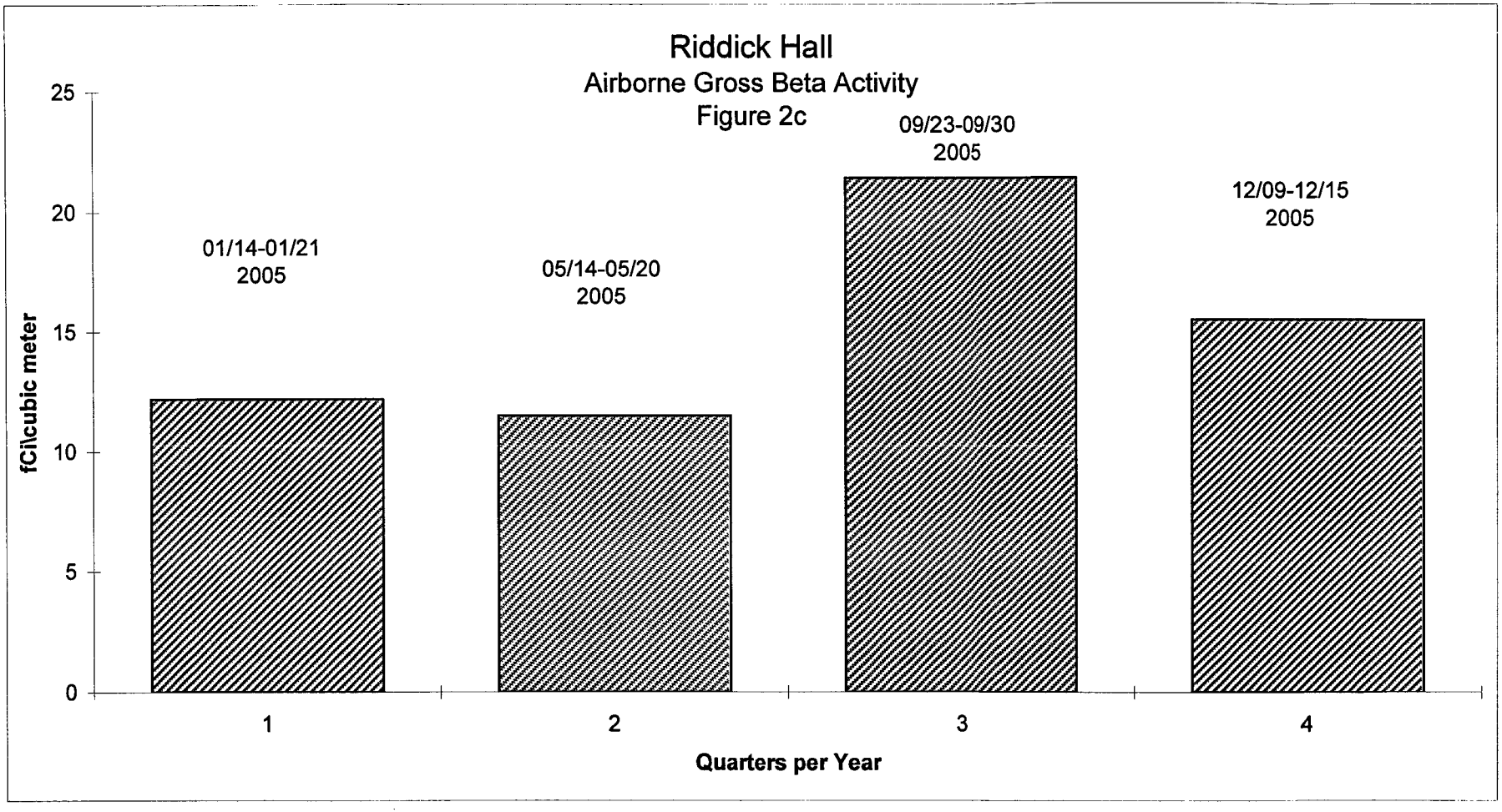
[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

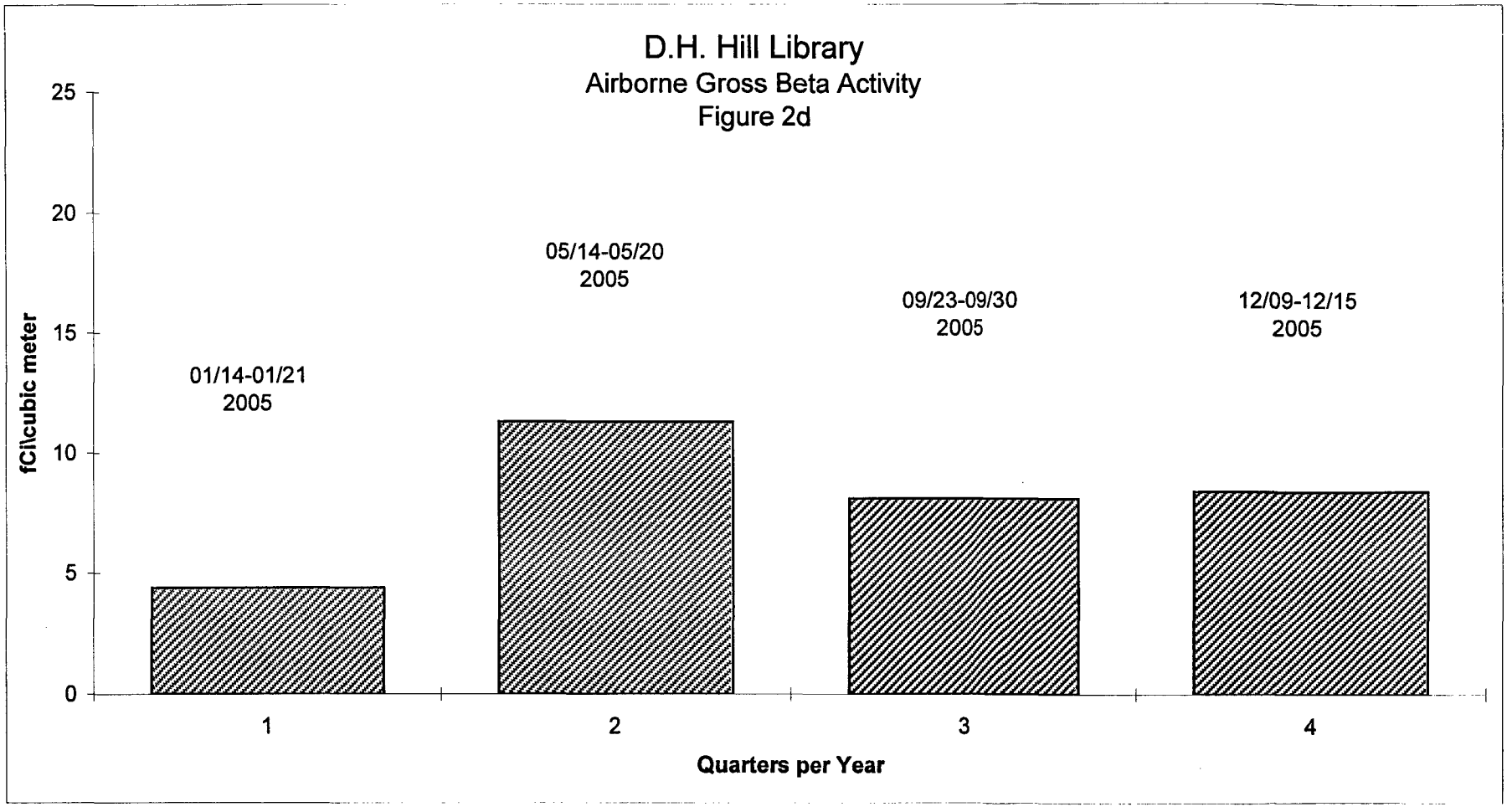
A wind rose is included in Appendix 2 to indicate the prevailing wind direction trends for the years 1996-2003.

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
2005									
01/14 - 01/21	0.21	0.35	0.29	0.47	0.27	2.37	0.26	0.38	1.22
05/14 - 05/20	0.2	0.37	0.28	0.48	0.28	2.48	0.29	0.34	1.28
09/23-09/30	0.18	0.35	0.31	0.54	0.33	2.51	0.29	0.43	1.40
12/09-12/15	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
0
5
10
15
20
25
1
2
3
4
Quarters per Year
01/14-01/21
2005
05/14-05/20
2005
09/23-09/30
2005
12/09-12/15
2005


Withers Hall
Airborne Gross Beta Activity
Figure 2b
25
20
15
10
5
0
fCi/cubic meter
01/14-01/21
2005
05/14-05/20
2005
09/23-09/30
2005
12/09-12/15
2005
1
2
3
4
Quarters per Year


Riddick Hall
Airborne Gross Beta Activity
Figure 2c
01/14-01/21
2005
05/14-05/20
2005
09/23-09/30
2005
12/09-12/15
2005
fCi\cubic meter
25
20
15
10
5
0
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
01/14-01/21
2005
05/14-05/20
2005
09/23-09/30
2005
12/09-12/15
2005
1
2
3
4
Quarters per Year

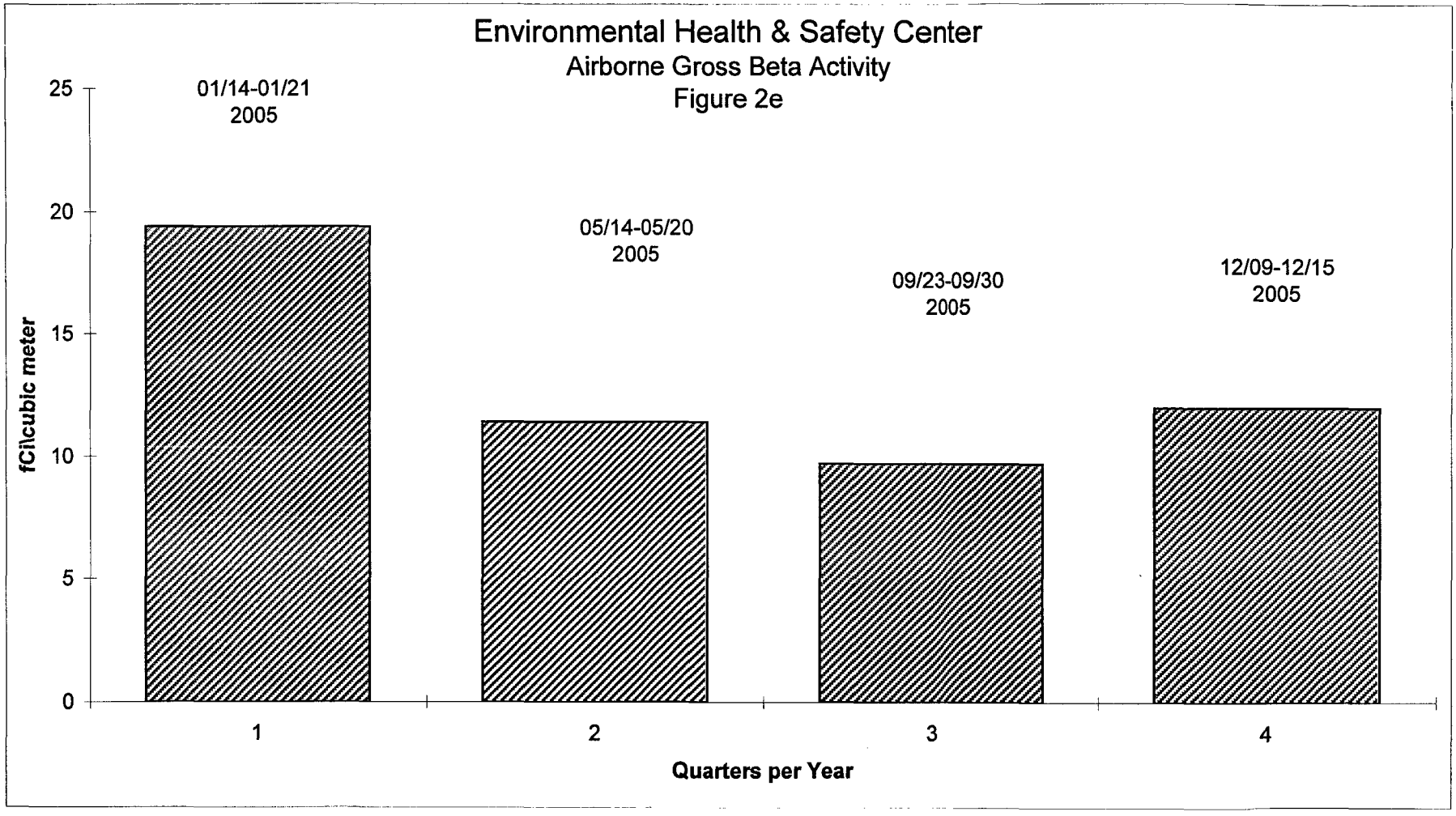

Environmental Health & Safety Center
Airborne Gross Beta Activity
Figure 2e
01/14-01/21
2005
05/14-05/20
2005
09/23-09/30
2005
12/09-12/15
2005
25
20
15
10
5
0
fCi\cubic meter
1
2
3
4
Quarters per Year

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	13.9 ; 3.3*
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 annual average values measured in North Carolina. Data courtesy of Dale Dusenbury of the N.C. Division of Radiation Protection.

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. Data given for the year 2005 shows that no I-131 activity was detected. The next sample collection will be in 2007.

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
May 2005	< 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 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 2005	ON	< 0.4	2.5 ± 0.7
	OFF	< 0.4	2.7 ± 0.7
SECOND QUARTER 2005	ON	< 0.4	2.1 ± 0.7
	OFF	< 0.4	2.7 ± 0.7
THIRD QUARTER 2005	ON	< 0.4	3.0 ± 0.7
	OFF	< 0.4	2.8 ± 0.7
FOURTH QUARTER 2005	ON	< 0.4	3.7 ± 0.7
	OFF	< 0.4	3.6 ± 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 Carnpus. Table 5.2 lists LLD values for several gamma emitters. The vegetation sampling is performed in alternate years. 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. The next sample collection will be in 2007.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ± 2σ)
06/03/2005	NORTH CAMPUS	2.0 ± 0.2
06/03/2005	SOUTH CAMPUS	1.9 ± 0.2
06/03/2005	EAST CAMPUS	1.6 ± 0.2
06/03/2005	WEST CAMPUS	1.7 ± 0.2

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 stack and at North Hall. A control station is located in Room 107 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 which fall 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	RIDDICK	BROUGHTON	DH HILL*	EH&S	PULSTAR STACK	NORTH	CONTROL
2005								
01/01-03/31	2	8	2	29,21,57	7	5	5	**M**,5
04/01-06/30	4	14	7	23,27,29	8	4	2	**M**,8
07/01-09/30	3	10	2	19,20,50	7	3	2	**M**,3
10/01-12/31	3	7	3	42,45	7	8	7	**M**,7

*The entries for D.H. Hill are for three (3) independent dosimeter readings for that station.

Only 2 results were reported by the vendor for the 4th quarter 2005.

The "CONTROL" column indicates the use of dual control dosimeters for all the monitoring periods.

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

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 Sessions 13 and 14) 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-d) 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 July 2005

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	0.525	0.116	0.482	>0.0 – 0.80
Gross Beta	0.869	0.057	0.827	0.55 – 1.22

TABLE 7.1b
MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 July 2005
The sample consists of one 7 cm 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.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Co60	2.817	0.155	2.85	2.00 – 3.71
Cs137	2.109	0.121	3.23	2.26 – 4.20
Cs134	1.964	0.121	3.85	2.70 – 5.01
Co57	5.930	0.268	6.20	4.34 – 8.06
Mn54	4.543	0.214	4.37	3.06 – 5.68
Zn65	5.063	0.324	4.33	3.03 – 5.63

TABLE 7.1c
MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 July 2005

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	260.123	8.316	261	182.70 - 339.30
Cs137	314.194	19.226	333	233.10 - 432.90
Cs134	142.218	5.186	167	116.90 - 217.10
Co57	391.021	26.394	272	190.40 - 353.60
Mn54	398.881	18.434	418	293.60- 543.40
Zn65	342.210	14.502	330	231.00- 429.00

TABLE 7.1d
GROSS ALPHA AND BETA WATER SAMPLE - INTERCOMPARISON STUDY
01 January 2005

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	0.68	0.34	0.525	> 0.0 – 1.05
Gross Beta	1.64	0.45	1.67	0.83 – 2.50

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.

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 which 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 which 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 = $\overline{x}$

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

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

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

$$= 3120 - 3273$$

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

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'

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

$= 3120 - 3290$

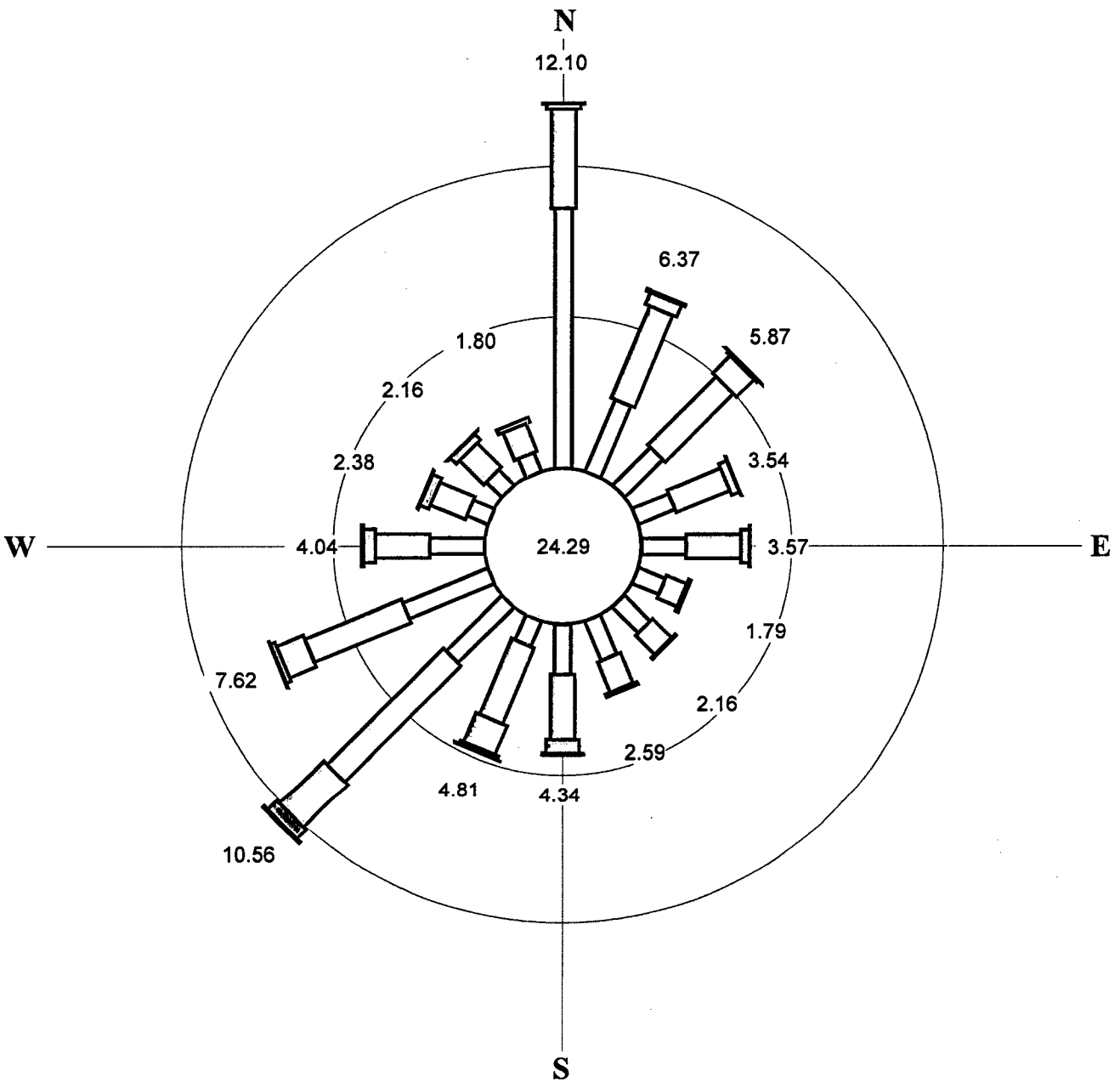
$D' = -170$ pCi/liter

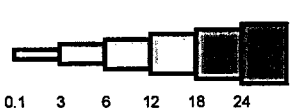
$$ND' = \frac{D'}{\sigma_m}$$

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

ND' = - 0.8

Joint Frequency Distribution
Based on Hourly Observations from Raleigh-Durham Airport
July 1, 1996 - August 24, 2003





Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.