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

27 March 2009

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

Re: Annual Report

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 27 March 2009.

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

Enclosures:
Annual Operating Report for 2008
Attachment A: PULSTAR Reactor Environmental Radiation Surveillance Report

A020
NRR

**NORTH CAROLINA STATE UNIVERSITY**

**DEPARTMENT OF NUCLEAR ENGINEERING**

**PULSTAR REACTOR ANNUAL REPORT**

**DOCKET NUMBER 50-297**

**For the Period: 01 January 2008 - 31 December 2008**

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 fluence and spectral measurements
- In-core detector certification
- 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
- 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.

Net loss of primary water from the reactor pool was low, but detectable in 2008. Analyses of reactor primary coolant water indicated no fission product activity was present and that activity was below 10CFR20, Appendix B, Table 3 limits for all of 2008.

**6.7.4.b Energy Output and Critical Hours:**

| | |
|---|---|
| Total Energy Output in 2008: | 28.07 Megawatt·days |
| Critical hours in 2008: | 808.75 hours |
| Cumulative Total Energy Output Since Initial Criticality: | 1173.47 Megawatt·days |

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

Emergency Shutdowns - none

Unscheduled Shutdowns – THREE

1. 13-AUG-08 – Reactor SCRAM (manual) due to fire alarm caused by an oven fire in an unrelated part of the building. Operator performed the required action.

2. 29-OCT-08 – Reactor SCRAM on Linear Channel Overpower due to channel not auto-ranging appropriately, which can happen on short reactor periods. No overpower condition existed.

3. 15-DEC-08 – Reactor SCRAM due to loss of commercial power.

**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.

0752 – PS-1-10 – Temperature RTD T3 – The T3 RTD Transmitter drifted. Channel was calibrated.

0753 – PS-1-10-17B – Stack Gas Monitor – Alarm output board failed. Board was replaced and calibrated.

0754 – PS-1-10-17C – Temperature Recorder – Main board failed. Recorder replaced. Channel calibrated prior to reactor operations.

0755 – PS-1-08-1 – Nitrogen 16 Channel – The N-16 Channel ion chamber failed. Ion chamber was replaced and calibrated prior to reactor operations above 500kW.

0757 – PS-1-09-1A – Reactor Air Compressor – Finger valves on second stage failed. Replaced finger valves.

0759 – PS-1-10 – Temperature RTD T2 replaced due to insulation deterioration. Channel calibrated prior to reactor operations.

0760 – PS-7-01-2 – PN in Reactor Channel – Light source for photoelectric sensor failed. Light source replaced.

0761 – PS-3-01-1 – Primary Pump – Primary pump failed. Primary pump replaced and appropriate channels calibrated prior to reactor operations above 100kW.

0762 – PS-7-02-1A – Auxiliary Generator – Conversion of auxiliary generator to auto-staring upon loss of commercial power. See Design Change 682.

**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:

682 – Making the Auxiliary Generator Auto-Starting – Conversion of the generator from manual starting to automatic starting upon loss of commercial power.

693 – Primary Pump Replacement – Replacement of the primary pump, which failed after nearly forty years of service.

**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.

679 – Procedure NRP-OP-105 Response to SCRAMS, Alarms and Abnormal Conditions Rev.1 – To incorporate changes of Technical Specification Amendment 17.

680 – Procedure NRP-OP-202 Service Water Rev. 1 – Combined multiple procedures into one.

683 – Procedure NRP-OP-104 Reactor Experiments Rev. 2 – The procedure was revised to incorporate changes in how experiments are reviewed and documented.

**Test and Experiments**

New experiments or changes to experiments 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 changes were made:

670 – Neutron Imaging Facility – Fuel Cell Gas Handling System – Installation of hydrogen and oxygen lines for fuel cell testing inside the Neutron Imaging Facility.

**Other Changes**

659 – License Amendment 17 was approved September 8, 2008. Major changes in Amendment 17 include changes to radiation monitor setpoints, fueled experiments, and organization and review committees.

**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 08 | 2 | 90 | 5.84 E3 | 1.35 E5 | 76 |
| 01 APR – 30 JUN 08 | 1 | 58 | 3.10 E3 | 1.39 E4 | 56 |
| 01 JUL – 30 SEP 08 | 1 | 78 | 2.64 E3 | 3.14 E5 | 47 |
| 01 OCT – 31 DEC 08 | 2 | 171 | 6.23 E3 | 1.24 E5 | 158 |
| (6) Total yearly tritium | 337 μCi of tritium was released during 2008. | | | | |
| (7) Total yearly activity | 397 μCi of total activity was released during 2008. | | | | |
| [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 $2 \times 10^{-5}$ 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 requirements given in 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 |
|---|---|---|---|
| 2008 | JANUARY | 744 | 0.561 |
| | FEBRUARY | 672 | 0.418 |
| | MARCH | 744 | 0.377 |
| | APRIL | 720 | 0.290 |
| | MAY | 744 | 0.879 |
| | JUNE | 720 | 0.255 |
| | JULY | 744 | 0.373 |
| | AUGUST | 744 | 0.635 |
| | SEPTEMBER | 720 | 0.398 |
| | OCTOBER | 744 | 0.404 |
| | NOVEMBER | 720 | 0.557 |
| | DECEMBER | 744 | 0.198 |
| TOTAL | | 8760 | 5.345 |

**(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 5.345 curies in 2008.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack in 2008 was $2.6\times10^{-8}$ 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**

67 $ft^3$ of dry uncompacted waste.

21 $ft^3$ of dries ion exchange resins.

**ii. Total Activity Involved**

0.51 mCi of dry uncompacted waste.

5.45 mCi of dry ion exchange resins.

**iii. Dates of shipments and disposal**

Transfers to the university broad scope radioactive materials license were made on 18 Jan, 8 Feb, 23 Jul , 5 Sep, and 12 Dec 2008 . The University Environmental Health and Safety Center arranges disposal of hazardous wastes.

**6.7.4.g Personnel Radiation Exposure Report:**

23 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 2008 to 31 Dec 2008 was 2.432 person-rem. Individual deep dose-equivalent ranged from 0 to 0.869 rem with an average of 0.106 rem. No visitors required official radiation dose monitoring during 2008.

**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, 2008 - DECEMBER 31, 2008

## 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<br>T.S. 6.7.4 |
| Stack Particles | Gross Beta<br>Indiv. Gamma Emitters | N.E.<br>N.E. | Monthly | Monthly | 10 CFR 20<br>T.S. 6.7.4 |
| Water from Reactor Facility | Gross Beta<br>Gross Gamma<br>Tritium | N.E.<br>N.E.<br>N.E. | Prior to Discharge (~ Monthly) | Prior to Discharge ~ Monthly | 10 CFR 20<br>T.S. 6.7.4<br>City of Raleigh Ordinance |
| Air/Particles at 5 Campus Stations* | Gross Beta<br>Indiv. Gamma Emitters | RSD/EHSC<br>RSD/EHSC | Weekly<br>Weekly | Quarterly | 10 CFR 20<br>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<br>Indiv. Gamma Emitters | RSD/EHSC<br>RSD/EHSC | Quarterly<br>Quarterly | Quarterly<br>Quarterly | NCSU<br>NCSU |
| Vegetation NCSU Campus | Gross Beta<br>Gamma | RSD/EHSC<br>RSD/EHSC | Semi-annually | Alternate years<br>Alternate years | NCSU<br>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 20.2 $fCiM^{-3}$ at the EH&S Center Hall station during the week of 06/24/06 to 06/30/06. The annual campus average was 12.5 $fCiM^{-3}$.
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.

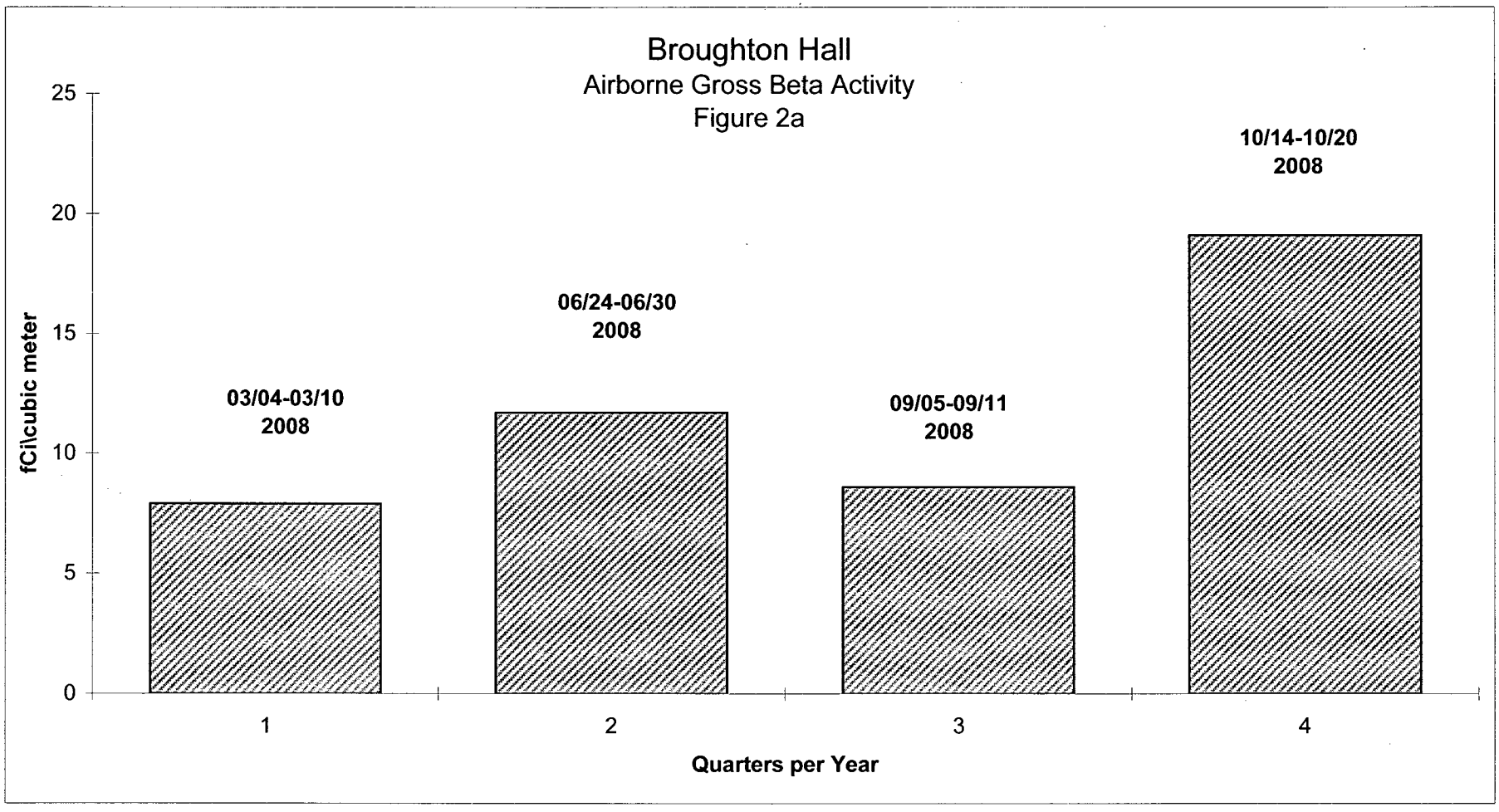
Table 2.3 lists regulatory limits, alert levels, and average background levels for airborne radioactivity.

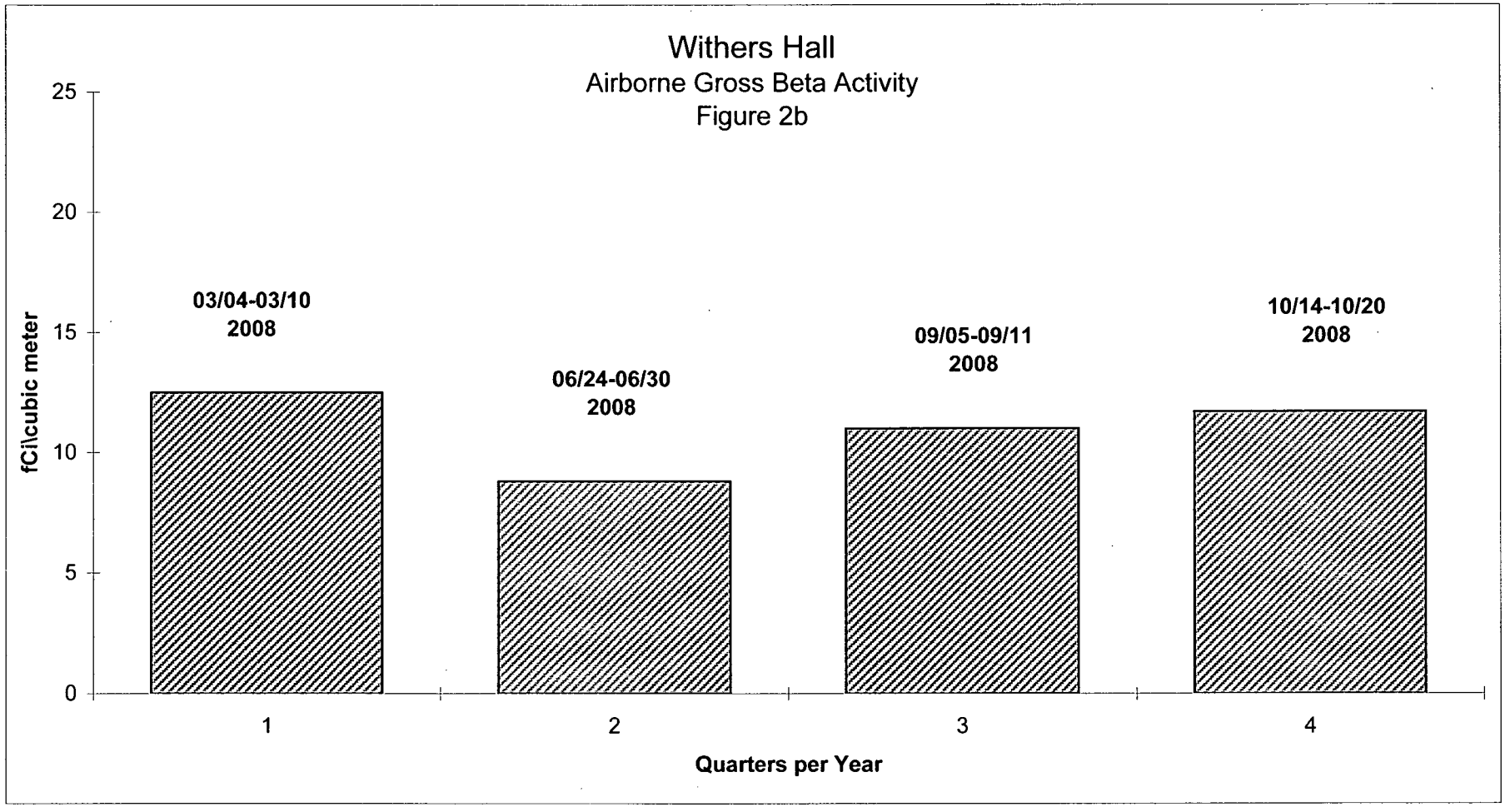
**TABLE 2.1 LOCATION OF AIR MONITORING STATIONS**

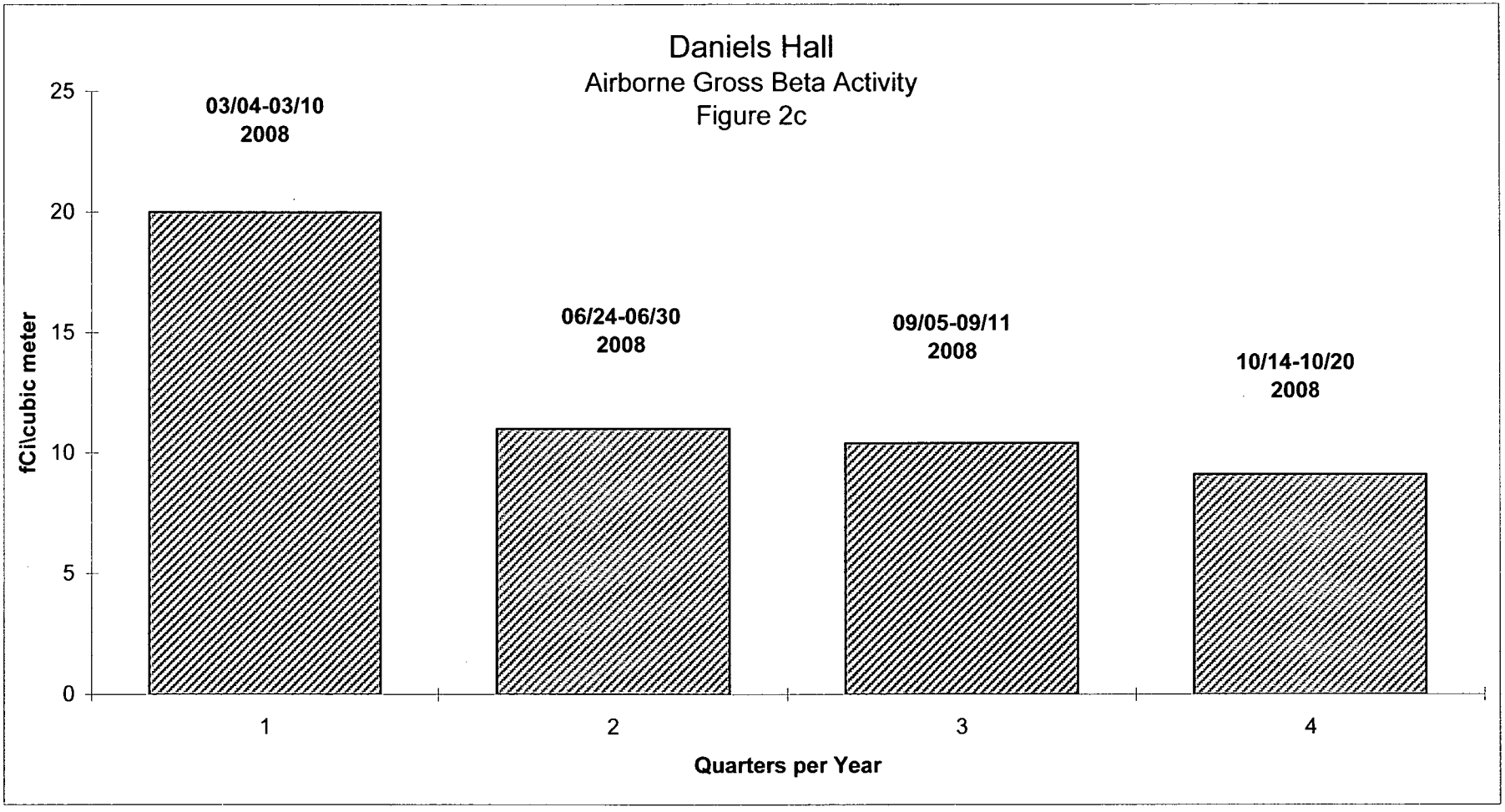
| SITE | DIRECTION[1] | DISTANCE[2] (meters) | ELEVATION[3] (meters) |
|---|---|---|---|
| BROUGHTON | SOUTHWEST | 125 | -17 |
| LIBRARY | NORTHWEST | 192 | +11 |
| DANIELS | SOUTHEAST | 90 | -8 |
| WITHERS | NORTHEAST | 82 | -6 |
| EH & S CENTER | WEST | 1230 | -3 |
| NORTH HALL | NORTHEAST | 402 |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

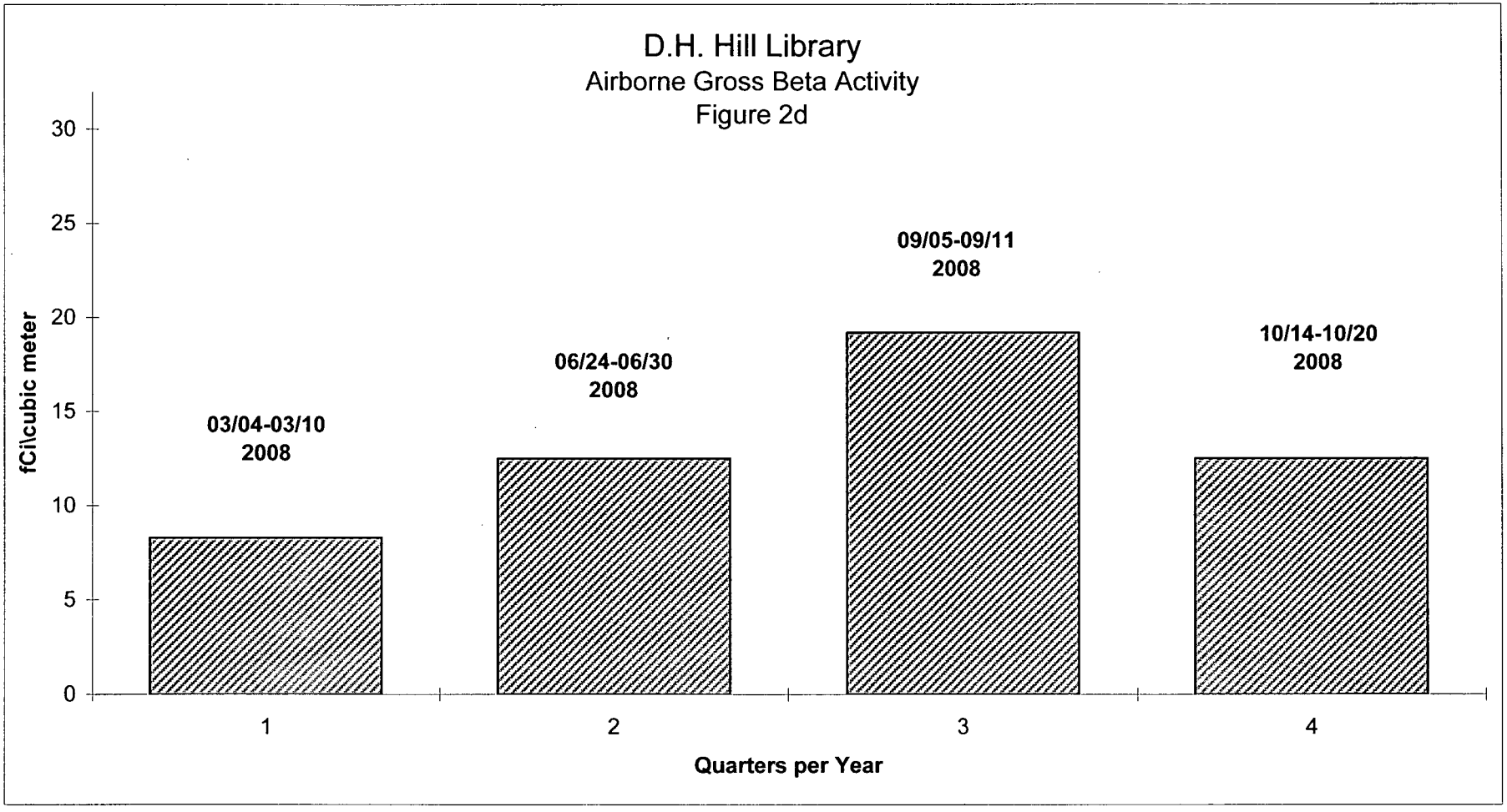
[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

| 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** |
| **2008** | | | | | | | | | |
| 03/04 - 03/10 | 0.21 | 0.35 | 0.29 | 0.47 | 0.27 | 2.37 | 0.26 | 0.38 | 1.22 |
| 06/24 - 06/30 | 0.2 | 0.37 | 0.28 | 0.48 | 0.28 | 2.48 | 0.29 | 0.34 | 1.28 |
| 09/05 - 09/11 | 0.18 | 0.35 | 0.31 | 0.54 | 0.33 | 2.51 | 0.29 | 0.43 | 1.40 |
| 10/14 - 10/20 | 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
03/04-03/10
2008
06/24-06/30
2008
09/05-09/11
2008
10/14-10/20
2008
1
2
3
4
Quarters per Year


Withers Hall
Airborne Gross Beta Activity
Figure 2b
25
20
15
10
5
0
fCi/cubic meter
03/04-03/10
2008
06/24-06/30
2008
09/05-09/11
2008
10/14-10/20
2008
1
2
3
4
Quarters per Year


Daniels Hall
Airborne Gross Beta Activity
Figure 2c
03/04-03/10
2008
06/24-06/30
2008
09/05-09/11
2008
10/14-10/20
2008
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
30
25
20
15
10
5
0
03/04-03/10
2008
06/24-06/30
2008
09/05-09/11
2008
10/14-10/20
2008
1
2
3
4
Quarters per Year

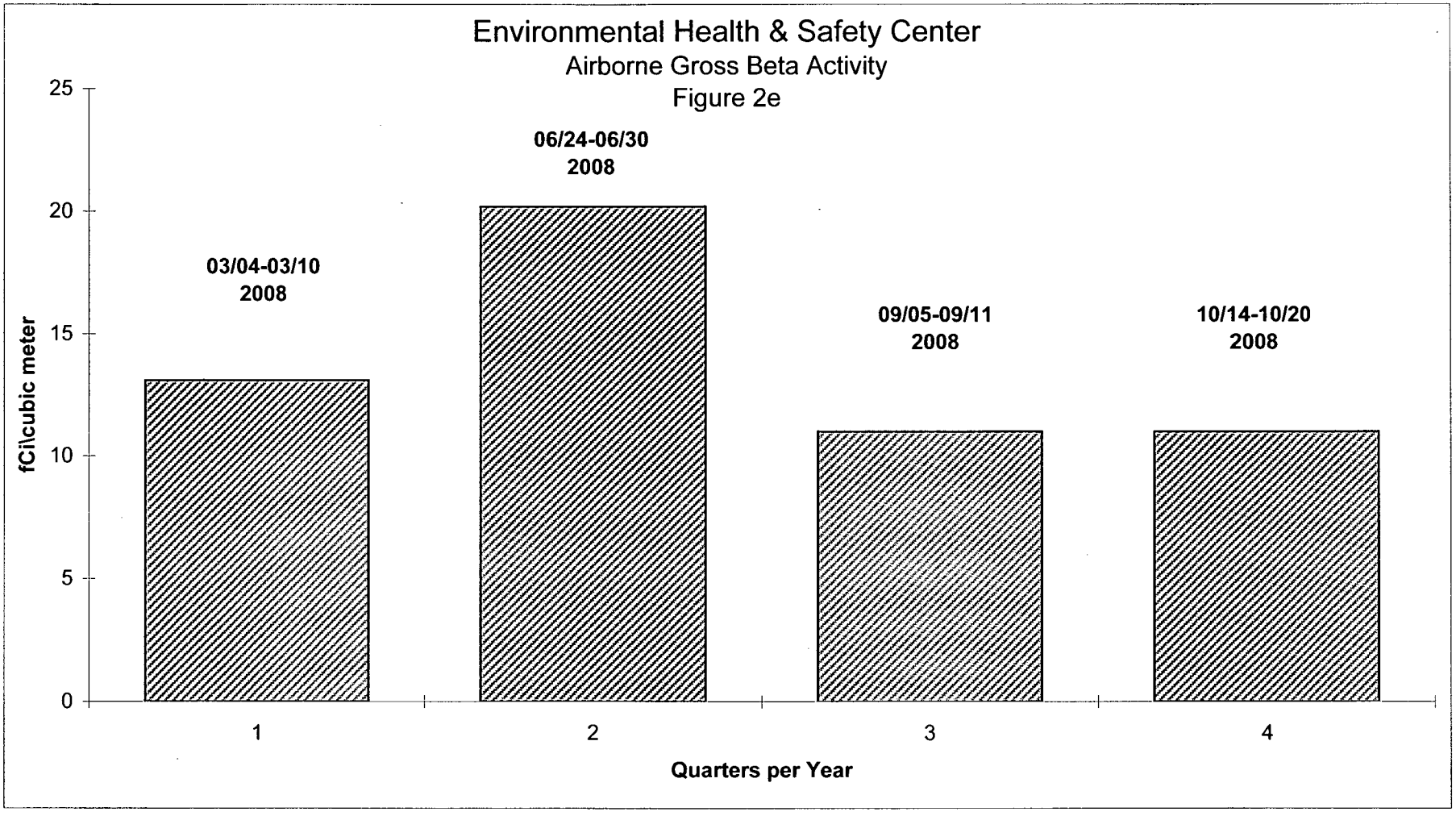

Environmental Health & Safety Center
Airborne Gross Beta Activity
Figure 2e
25
20
15
10
5
0
fCi\cubic meter
03/04-03/10
2008
06/24-06/30
2008
09/05-09/11
2008
10/14-10/20
2008
1
2
3
4
Quarters per Year

**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 | 3.3 -13.9 * |
| Cs-137 | $5 \times 10^5$ | 10 | 2 |
| Ce-144 | $2 \times 10^5$ | 100 | 0 |
| Ru-106 | $2 \times 10^5$ | 30 | 0 |
| I-131 | $1 \times 10^5$ | 10 | 0 |

* These data represent a range of minimum to maximum 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. No milk samples were collected for 2008. The next sample collection and analysis will be in 2009.

**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 |
| 2008 | 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)**

*$LLD_{\alpha}$ ~ 0.4 pCi Liter$^{-1}$ $LLD_{\beta}$ ~ 0.4 pCi Liter $^{-1}$

| | | pCi Liter $^{-1}$ | |
|---|---|---|---|
| DATE | LOCATION | GROSS ALPHA | GROSS BETA |
| FIRST QUARTER 2008 | ON | < 0.4 | 3.2 ± 0.7 |
| | OFF | < 0.4 | 1.7 ± 0.6 |
| SECOND QUARTER 2008 | ON | < 0.4 | 3.8 ± 0.7 |
| | OFF | < 0.4 | 1.7 ± 0.6 |
| THIRD QUARTER 2008 | ON | < 0.4 | 5.2 ± 0.8 |
| | OFF | < 0.4 | 3.0 ± 0.7 |
| FOURTH QUARTER 2008 | ON | < 0.4 | 3.5 ± 0.7 |
| | OFF | < 0.4 | 2.8 ± 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 2008. The next sample collection and analysis will be in 2009.

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

| SAMPLE DATE | SAMPLE LOCATION | (pCi $g^{-1}$ ± 2σ) |
|---|---|---|
| 2008 | NORTH CAMPUS | No Data |
| 2008 | SOUTH CAMPUS | No Data |
| 2008 | EAST CAMPUS | No Data |
| 2008 | 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 | |
| **2008** | | | | | | | | | |
| 01/01-03/31 | **M** | 8 | 7 | 13,16,13 | 10 | 28 | 7 | **M**,6 | |
| 04/01-06/30 | **M** | 8 | 4 | 17,10,14 | 10 | 17 | 8 | **M**,6 | |
| 07/01-09/30 | 3 | 4 | 5 | 28,25,30 | 9 | 31 | 8 | **M**,7 | |
| 10/01-12/31 | **M** | 3 | **M** | 10,7,10 | 6 | 25 | 4 | **M**,5 | |

* 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.

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 19) 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 $\leq$ 20%
Acceptable with Warning... 20% < Bias $\leq$ 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 August 2008

**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 | 0.0003 | 0.001 | 0 | ---------- |
| Gross Beta | 0.480 | 0.025 | 0.525 | 0.263 – 0.788 |

TABLE 7.1b
MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 August 2008

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 | NR | NR | ----- | ---------- |
| Cs137 | NR | NR | ----- | ---------- |
| Cs134 | 2.26 | 0.096 | 2.63 | 1.84 – 3.42 |
| Co57 | 1.33 | 0.07 | 1.50 | 1.05 – 1.95 |
| Mn54 | 2.61 | 0.15 | 2.64 | 1.34 – 2.50 |
| Zn65 | 1.07 | 0.11 | 0.94 | 0.66 – 1.22 |

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

TABLE 7.1c
MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 August 2008

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 | 11.97 | 0.77 | 11.6 | 8.1 - 15.1 |
| Cs137 | 24.44 | 1.80 | 23.6 | 16.5 - 30.7 |
| Cs134 | 16.94 | 0.86 | 19.5 | 13.7 - 25.4 |
| Co57 | NR | NR | ---- | ---------- |
| Zn65 | 17.56 | 2.04 | 17.1 | 12.0 - 22.2 |
| Mn54 | 14.16 | 1.09 | 13.7 | 9.6 - 17.8 |

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 August 2008

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 | 0.09 | 0.09 | < 0.56 | ---------- |
| Gross Beta | 0.136 | 0.092 | < 1.85 | ---------- |

TABLE 7.1e
MULTINUCLIDE VEGETATION SAMPLE - INTERCOMPARISON STUDY
01 August 2008

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 |
|---|---|---|---|---|
| Am241 | 0.14 | 0.04 | 0.28 | 0.200 - 0.372 |
| Cs134 | 5.24 | 0.22 | 5.5 | 3.9 - 7.2 |
| Cs137 | NR | NR | ---- | ---------- |
| Co57 | 8.18 | 0.48 | 7.1 | 5.0 - 9.2 |
| Co60 | 4.10 | 0.17 | 4.7 | 3.3 - 6.1 |
| Mn54 | 5.83 | 0.33 | 5.8 | 4.1 - 7.5 |
| Zn65 | 5.92 | 0.41 | 6.9 | 4.8 - 9.0 |

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, $\sigma_R$. 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, $\sigma_m$. 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 = $\sigma_R$

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

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

$= (1556 - 604.4) \div 3$

$\sigma_R$ = 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 = $\sigma_m$

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

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

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

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

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

$$ND = -0.7$$

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

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

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

$ND' = -0.8$