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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31 August 2000

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

Subject: **NCSU PULSTAR Annual Report**
Docket No. 50-297

Dear Sir or Madam:

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 July 1999 through 30 June 2000. Please feel free to contact me at (919) 515-4602 if you have any questions or comments.

Sincerely,

Pedro B. Pérez
Associate Director
Nuclear Reactor Program

A020

Ref: NCSU PULSTAR Annual Report
Docket No. 50-297

copy w/attachments:

Dr. Nino A. Masnari, Dean
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Radiation Safety Committee

Dr. Ray B. Benson, Chairman
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Dr. Charles W. Mayo, Director
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Environmental Health and Safety Center

Mr. Mark Poirier
ANI/MAELU

Mr. Alexander Adams, Jr.
Nuclear Regulatory Commission

Mr. Craig Bassett
Nuclear Regulatory Commission

PULSTAR REACTOR ANNUAL REPORT TO

UNITED STATES NUCLEAR REGULATORY COMMISSION

for

01 July 1999 - 30 June 2000

NCSU NUCLEAR REACTOR PROGRAM

31 August 2000

Reference: PULSTAR Technical Specifications
Section 6.7.4

Docket No. 50-297

Department of Nuclear Engineering
North Carolina State University
Raleigh, North Carolina 27695

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 July 1999 - 30 June 2000

The following report is submitted in accordance with Section 6.7.4 of the PULSTAR Technical Specifications:

6.7.4.a Brief Summary:

Reactor operations have been routine during this reporting period. The epoxy seal placed during the last reporting period remains intact. However, the staff identified and temporarily repaired a new liner anomaly approximately 2 millimeters in diameter about six inches from the original site. A permanent epoxy seal is scheduled to be installed later this year.

The Radiation Protection Committee officially changed its name to Radiation Safety Committee. The facility technical specifications were modified to reflect the change and submitted for approval.

The position of Chief Reactor Operator was vacated in December 1999 when that person relocated out of state. A new person was hired in April 2000 and is currently preparing for a senior operator license.

(i) (1) Reactor Operating Experience:

The NCSU PULSTAR Reactor has been utilized for the following:

• Teaching and Short Courses	96.8 hours
• Faculty and Graduate Student Research	228.3
• Isotope Production	0.0
• Neutron Activation Analysis	639.8
• Beam Tube Facilities	0.0
• Nuclear Training (Utilities)	22.5
• PULSTAR Reactor Training	22.7
• Reactor Cal/Measurements & Surveillance	79.0
• Reactor Health Physics Surveillance	25.6
• Reactor Sharing	10.6
TOTAL	1,125.3 hours

Last reporting period:	1,298.7 hours
Last reporting period as corrected:	1,309.5 hours

(2) A Summary of Experiments Performed in the Reactor:

- Teaching laboratories and research
  - Reactor thermal power measurements
  - Dynamic reactivity measurements
  - Axial power and peaking factor measurements
  - Photoneutron effects on power decay after dropped rod
  - Neutron temperature measurements
  - Neutron fluence and spectral measurements
  - Neutron transmutation doping of diamond

- Neutron Activation Analysis
  - cereal/grain
  - animal feed
  - vegetation
  - tobacco
  - vitamin pills
  - tissue
  - hair
  - sediment/soil
  - rain/river water
  - fibers
  - resins
  - polymers
  - hydrocarbons
  - fertilizers
  - rubber
  - gold foils
  - silicon crystals

(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 annual audit performed by the Reactor Safety and Audit Committee (RSAC) of the facility and records was determined to be satisfactory.

6.7.4.b Total Energy Output:

15.5 Megawatt·days

Reactor was Critical:

569.6 hours

Cumulative Total Energy Output Since Initial Criticality:

883.8 Megawatt·days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

1. Emergency Shutdowns - none

2. Unscheduled Shutdowns - 2
   a. SCRAM without annunciation
   b. Shutdown due to switch failure

Explanation of 2a. above:

The reactor had been operating at 90% power for several hours performing routine irradiations when a SCRAM occurred. None of the input channels on the SCRAM Logic Unit indicated a SCRAM demand. Additionally, there was no annunciation from the SCRAM relay circuits. All other instrument indications were normal. The SCRAM Logic Unit was successfully tested per PULSTAR Surveillance (PS-1-09-1:Q1). No cause was identified and to date the spurious SCRAM has not re-occurred. The reactor was returned to routine operations for the next scheduled startup.

Explanation of 2b. above:

The reactor operator terminated a routine startup when a Low Shutdown Margin (LSM) annunciation was received. The operator verified the annunciation was false when noting that the critical position of the control rods were well past the point at which the annunciation could have occurred. The reactor was secured and it was determined that a limit switch in the Regulating Control Rod Drive Mechanism had failed. The switch was replaced and the drive mechanism was tested over its full travel with the LSM annunciator sounding only when the control circuits were not satisfied. The reactor was returned to routine operation on the following day.

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 minor components, are maintained in these files.

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

1. Design Changes (DC)

   a. DC 99-1 with 50.59 evaluation replaces the reactor Stack Radiation Monitoring System. Change has been approved but not yet implemented.

2. Procedure Changes
   (NP = New Procedure, PC = Procedure Change, MC = Minor Change)

   a. NP 99-1 is a new procedure providing specific instructions for the calibration and operation of the Radioiodine Monitor. It will be implemented with DC 99-1.

   b. NP 99-2 is a new procedure providing specific instructions for the operation and maintenance of the Stack Particulate Channel and the Stack Grab Sampling Equipment. It is to be implemented with DC 99-1.

   c. NP 99-3 is a new procedure providing specific instructions for the test and inspection of the stack sample system. It will be implemented with DC 99-1.

   d. NP 00-1 is a new procedure combining several identical setpoint verification procedures for different radiation measuring instruments into one procedure. MC 99-2 was incorporated into this procedure.

   e. NP 00-2 is a new Special Procedure 5.11, which will used to hydrostatically test various components of the Primary Piping System.

   f. PC 6-99 was Revision 2 to the PULSTAR Health Physics Procedure HP 2 "Use of Irradiation Facilities" updating various sections to comply with license documents and correct typographical errors.

   g. PC 6.1-99 updated PULSTAR Surveillance procedure (PS-6-05-1) "Moving Stack Particulate Filter Paper Maintenance". It will be implemented with DC 99-1.

   h. PC 6.2-99 updated PULSTAR Surveillance procedure (PS-6-12-3A) "Continuous Flow Air Sampler Lubrication". It will be implemented with DC 99-1.

   i. PC 7-99 was Revision 1 to the PULSTAR Health Physics Procedure HP 9 "Respirator Use and Bioassay" updating tests and frequencies of tests as required by N. C. State University policies.

j. PC 8-99 was Revision 1 to the PULSTAR Surveillance procedure (PS-6-12-5A) "Operation and Maintenance of Eberline Model AMS-3A Continuous Air Monitor" updating the procedure to include the use of charcoal impregnated filters and to specify types of filters acceptable for use.

k. PC 9-99 updated PULSTAR Surveillance procedure (PS-6-13-1) "Primary and Secondary Water Chemistry" and was withdrawn prior to final approval.

l. PC 10-99 updated PULSTAR Surveillance procedure (PS-6-05-2A) "Stack Particulate Radiation Monitoring Channel Calibration Verification" to implement approved setpoint changes.

m. PC 11-99 updated PULSTAR Surveillance procedure (PS-6-13-1) "Primary and Secondary Water Chemistry" to implement T.S. required frequencies. Also included is the required surveillance for corrosion control coupons, beam tube water, and other optional analyses.

n. PC 1-00 was Revision 3 to the PULSTAR Health Physics Procedure HP 1 "Radiation Protection Program" implementing 10 CFR 20 changes.

o. PC 2-00 was Revision 1 to the PULSTAR Health Physics Procedure HP 8 "Radiation Work Permit and Protective Clothing" implementing 10 CFR 20 changes.

p. PC 3-00 was Revision 2 to the PULSTAR Health Physics Procedure HP 9 "Respirator Use and Bioassay" implementing 10 CFR 20 changes.

q. PC 4-00 updated PULSTAR Surveillance procedure (PS-6-12-5A) "Calibration and Maintenance of Eberline Model AMS-3A Continuous Air Monitor" to address calibration and setpoint determination for use of charcoal impregnated filters.

r. PC 5-00 updated PULSTAR Surveillance procedure (PS-6-17-1) "Area Radiation Monitor Channel Calibration" to implement one procedure for calibration of all area monitors.

s. PC 6-00 updated PULSTAR Surveillance procedure (PS-6-17-2) "Process Radiation Monitor Channel Calibration" to implement one procedure for calibration of all process monitors. PC 10-99 was superceded by this procedure.

t. MC 99-2 was cancelled.

u. MC 99-3 was reassigned as PC 6.1-99.

v. MC 99-4 was reassigned as PC 6.2-99.

w. MC 99-5 was Revision 29 to the PULSTAR Operations Manual substituting text required by the re-installation of the new Linear Channel Wide Range Monitor after repairs were made by the vendor.

x. MC 99-6 added model numbers of equipment used in HP 10 "Calibration, Operation, and Maintenance of Radiation Survey and Chemistry Instruments".

y. MC 99-6.1 is pending.

z. MC 99-7 clarified wording of steps in PULSTAR Surveillance procedure (PS-6-09-1A) "Waste Tank No. 1 Channel Calibration Verification".

aa. MC 99-8 clarified wording of steps in PULSTAR Surveillance procedure (PS-6-11-1A) "Waste Tank No. 3 Channel Calibration Verification".

ab. MC 99-9 changed electrical units from VDC to mA on Attachment 2 in the PULSTAR Surveillance procedure (PS-6-17-1) "Area Radiation Monitor Channel Calibration".

ac. MC 99-10 changed electrical units from VDC to mA on Attachment 2 in the PULSTAR Surveillance procedure (PS-6-17-2) "Process Radiation Monitor Channel Calibration".

ad. MC 00-1 was Revision 2 which added additional equipment used in HP 10 "Calibration, Operation, and Maintenance of Radiation Survey and Chemistry Instruments".

Summary:

Procedures were written or revised covering the calibration of installed equipment, reactor operations, surveillance, and Health Physics. These procedures have been reviewed and/or approved by the Reactor Safety and Audit Committee (RSAC) and where required, approved by the Radiation Safety Committee (RSC).

6.7.4.f Radioactive Effluent:

1. Liquid Waste (summarized by quarters)

i. Radioactivity Released During the Reporting Period:

Period	(1) No. of Batches	(2) Total μCi	(3) Tot. Vol. Liters	(4)[1] Diluent Liters	(5) Tritium μCi
01 Jul - 30 Sep 99	0	0	0	0	0
01 Oct - 31 Dec 99	0	0	0	0	0
01 Jan - 31 Mar 00	2	59	4,760	2.4E4	56
01 Apr - 30 Jun 00	1	44	3,420	3.1E4	41

(6) 97 μCi of tritium was released during this reporting period.

(7) 103 μCi total activity was released during this reporting period.

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.

2. Gaseous Waste (summarized monthly)

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

(1) Gases:

Year	Period	Total Time In Hours	Curies
1999	01 Jul - 31 Jul	744	0.259
	01 Aug - 31 Aug	744	0.119
	01 Sep - 30 Sep	720	0.197
	01 Oct - 31 Oct	744	0.203
	01 Nov - 30 Nov	720	0.096
	01 Dec - 31 Dec	744	0.056

[1] *Based on gross beta activity only. Tritium did not require further dilution.*

2000	01 Jan - 31 Jan	744	0.220
	01 Feb - 29 Feb	696	0.174
	01 Mar - 31 Mar	744	0.239
	01 Apr - 30 Apr	720	0.194
	01 May - 31 May	744	0.108
	01 Jun - 30 Jun	720	0.123
	Totals	8,784 hours	1.988 curies

(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 $t_{1/2}$ >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 release was 1.988 curies.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack during this period was 5.9×10^{-9} μCi/cc . This is below the regulatory limit of 1×10^{-8} μCi/cc given in 10 CFR 20 Appendix B. Dose calculations were performed using the "COMPLY" code for the fiscal year. "COMPLY" code results were less than the 10 mrem constraint level given in 10 CFR 20.

(2) Particulates:

See gaseous waste i.(2) above.

3. Solid Waste from Reactor[2]

- Total volume of solid waste - 23.3 ft^3 (0.66 m^3)
- Total activity of solid waste - 0.525 mCi
- Dates of shipments and disposal - All waste is transferred to the NCSU Environmental Health and Safety Center for temporary storage and disposal under the NCSU state license. Transfers were made on 13 Sep 99, 07 Jan 00, and 11 Apr 00.

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[2] *Solid waste generated by the PULSTAR Reactor is transferred to the NCSU Radiation Safety Division for storage or disposal.*

6.7.4.g Personnel Radiation Exposure Report:

Twenty-nine members of the faculty and staff were monitored for external radiation dose during the reporting period. Collective dose for this reporting period was 0.884 person-rem. Individual doses ranged from 0.004 to 0.084 rem with an average of 0.03 rem. No visitors required official monitoring during this reporting period.

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:

- external radiation levels in the majority of areas were 2 mrem/h or less
- external radiation levels 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:

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:

- external radiation levels were at background levels for most areas (10 μrem/h)
- contamination was not detectable
- Net external radiation levels ranged up to 20 μrem/h in some areas when the reactor was operating at power. However, external radiation levels were at background levels in routinely occupied spaces.

ATTACHMENT A

NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY CENTER

RADIATION SAFETY DIVISION

PULSTAR REACTOR

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JULY 1, 1999 - JUNE 30, 2000

by
Ralton J. Harris

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.

The specific sample types and monitoring frequencies are listed in Table 1.

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 7 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 7 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 25.5 $fCim^{-3}$ at the D.H. Hill Library station during the week of 09/20/99 to 09/27/99. During the 1st quarter of 2000 for the week of 02/07 to 02/14, the measured gross beta specific activities ranged from ~ 1.6 to 5.6 $fCim^{-3}$ and were much lower than those for the other monitoring periods. This is apparently due to a seasonal variation of natural radioactivity in the air. The annual campus average was 13.1 $fCim^{-3}$.

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.

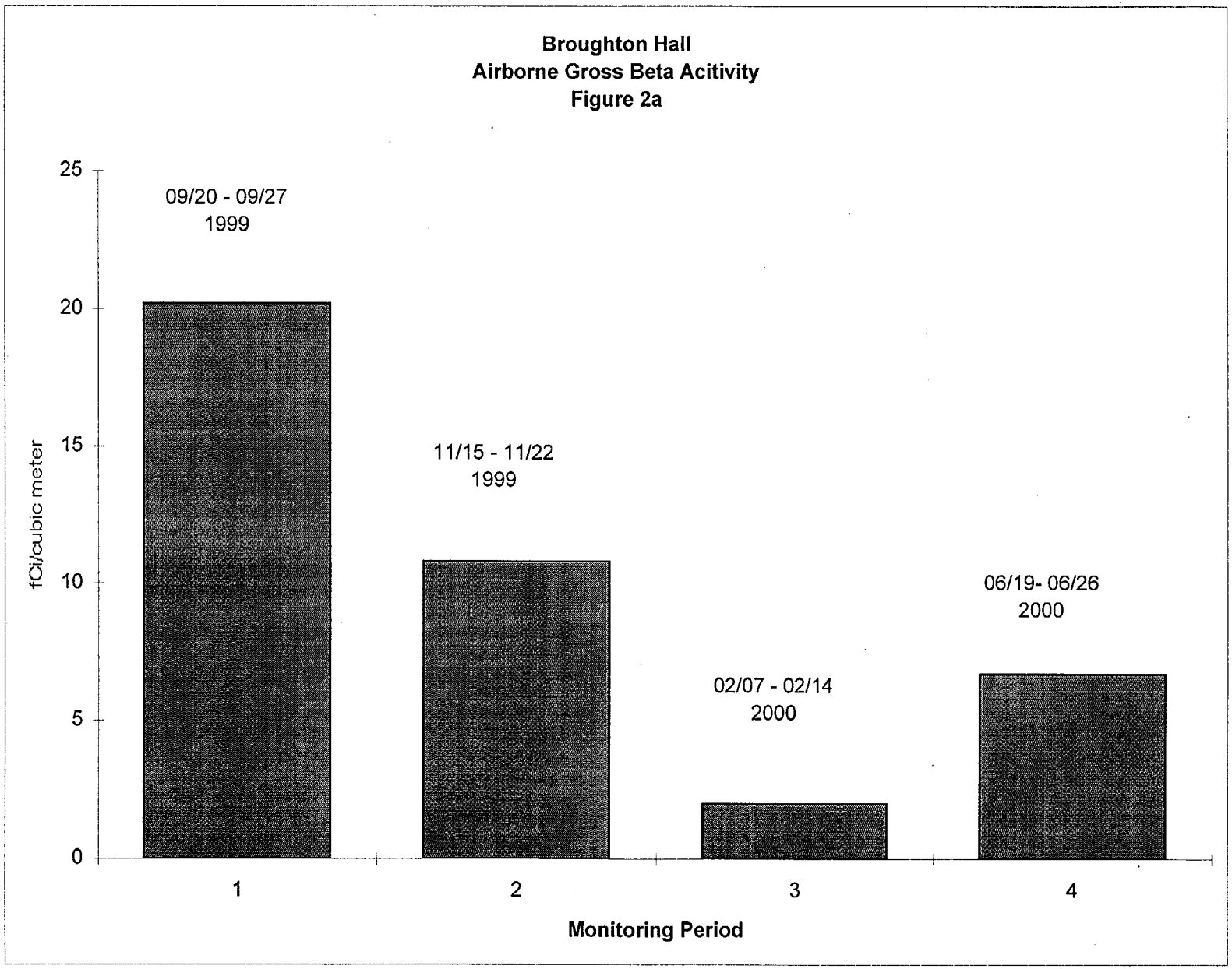
TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
*DAVID CLARK LABS	WEST	500	-18
LIBRARY	NORTHWEST	192	+11
RIDDICK	SOUTHEAST	99	-14
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL	NORTHEAST	402	-4

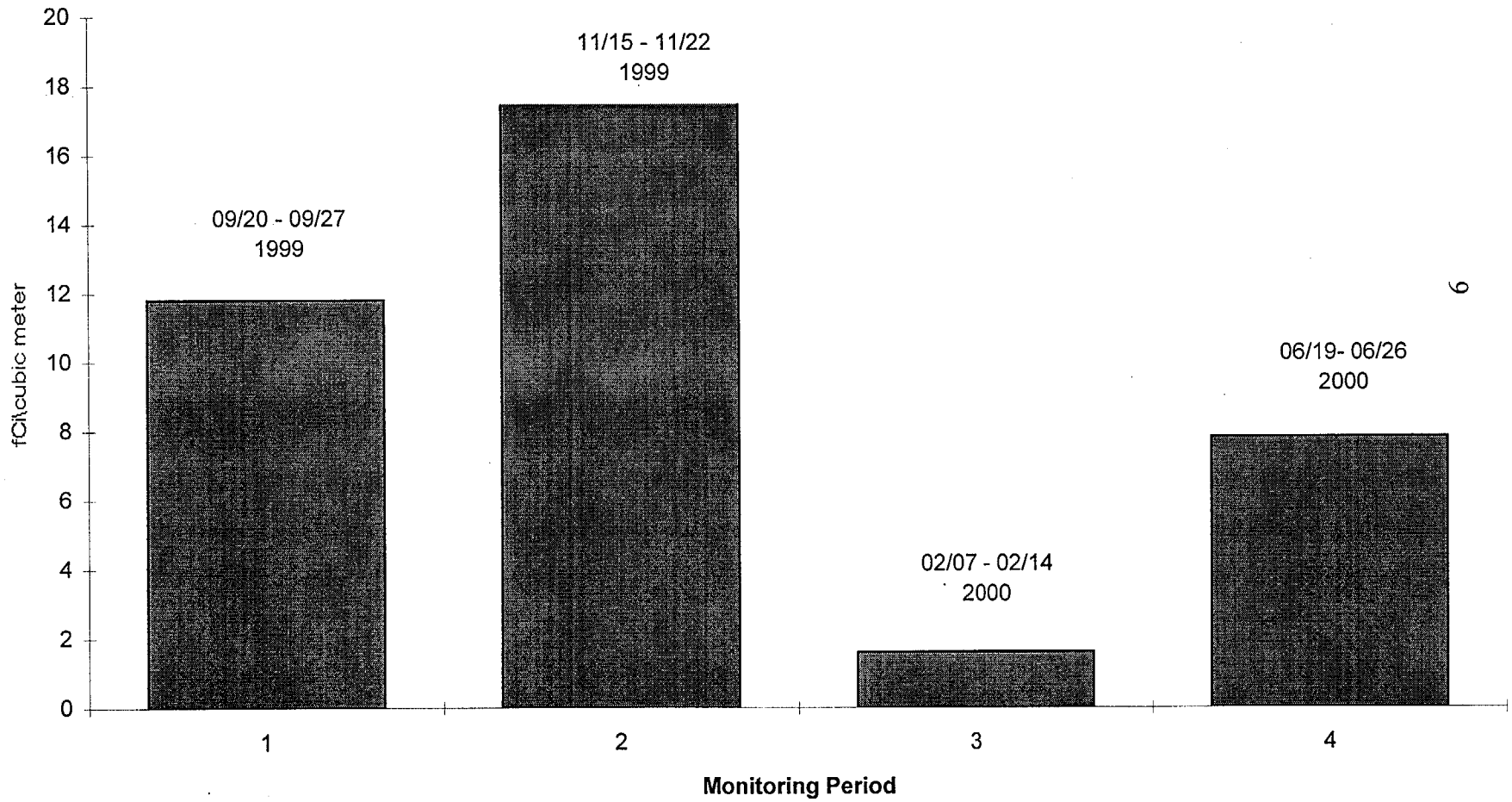
[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

*The station at David Clark Labs was relocated to the EH & S Center in January 1996, however a TLD monitor is maintained at David Clark Labs for the State of N.C. Division of Radiation Protection.

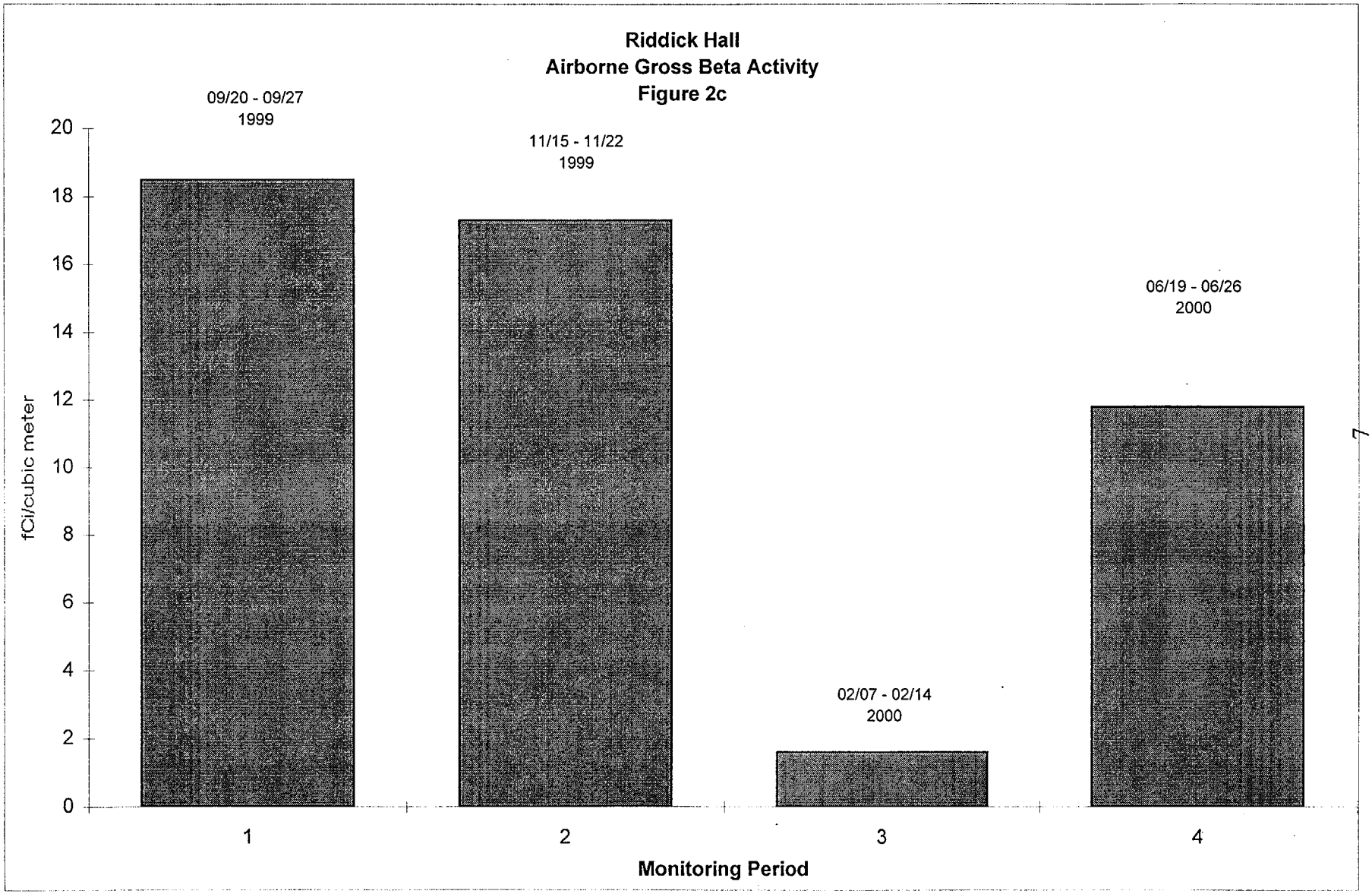
Table 2.2 Aerially Transported Gamma Activity				LLD values fCi/cubic meter					
					NUCLIDES				
SAMPLING PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
1999									
09/20 - 09/27	0.21	0.44	0.29	0.46	0.27	2.25	0.33	0.36	1.21
11/15 - 11/22	0.21	0.44	0.28	0.48	0.28	2.48	0.35	0.34	1.28
2000									
02/07-02/14	0.17	0.37	0.32	0.53	0.32	2.49	0.23	0.42	1.42
06/19-06/26	0.17	0.31	0.31	0.51	0.36	2.43	0.26	0.38	1.41


Broughton Hall
Airborne Gross Beta Acitivity
Figure 2a
25
20
15
10
5
0
fCi/cubic meter
09/20 - 09/27
1999
11/15 - 11/22
1999
02/07 - 02/14
2000
06/19- 06/26
2000
1
2
3
4
Monitoring Period

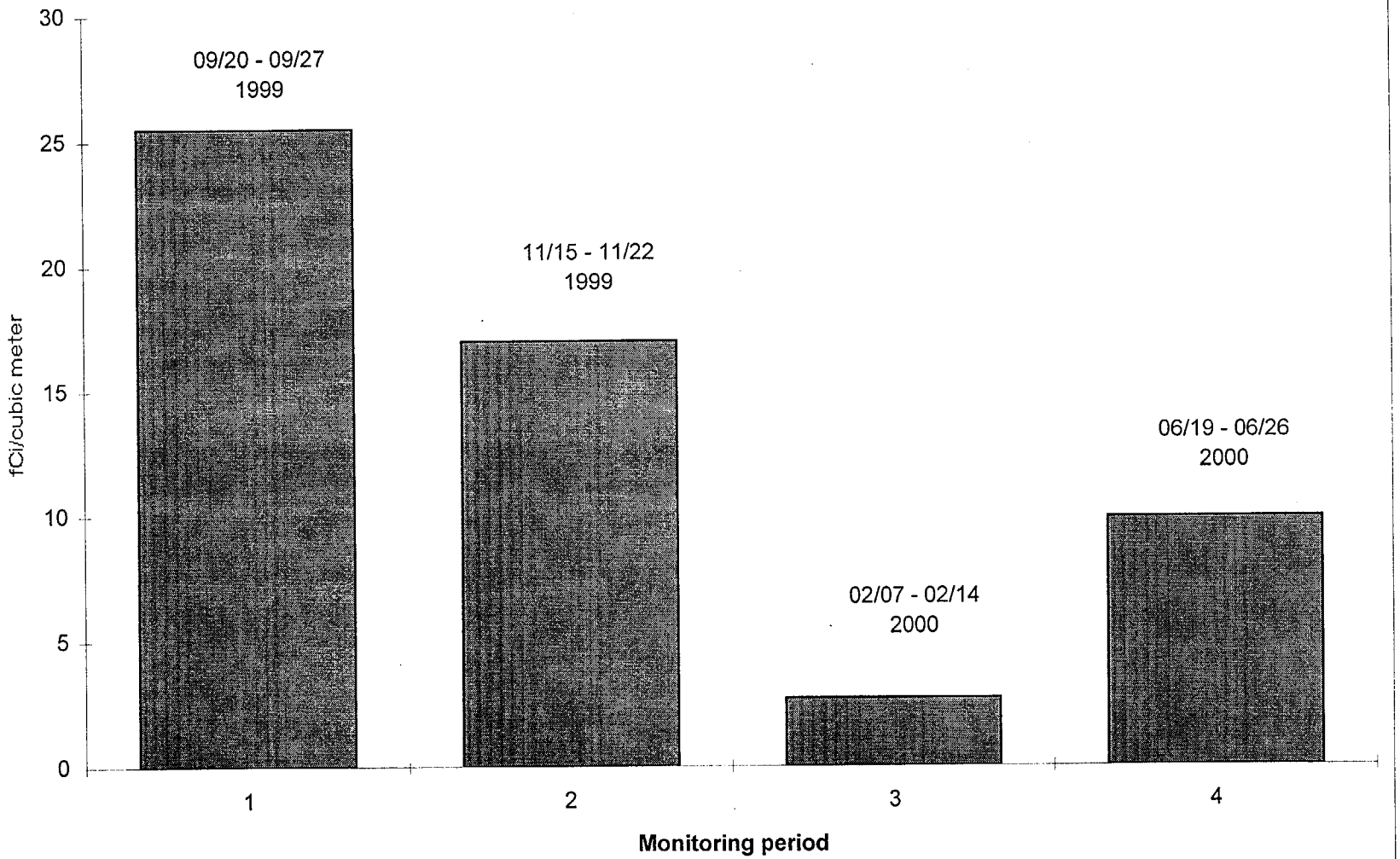
Withers Hall
Airborne Gross Beta Activity
Figure 2b



Riddick Hall
Airborne Gross Beta Activity
Figure 2c



D. H. Hill Library
Airborne Gross Beta Activity
Figure 2d



Environmental Health & Safety Center
Airborne Gross Beta Activity
Figure 2e

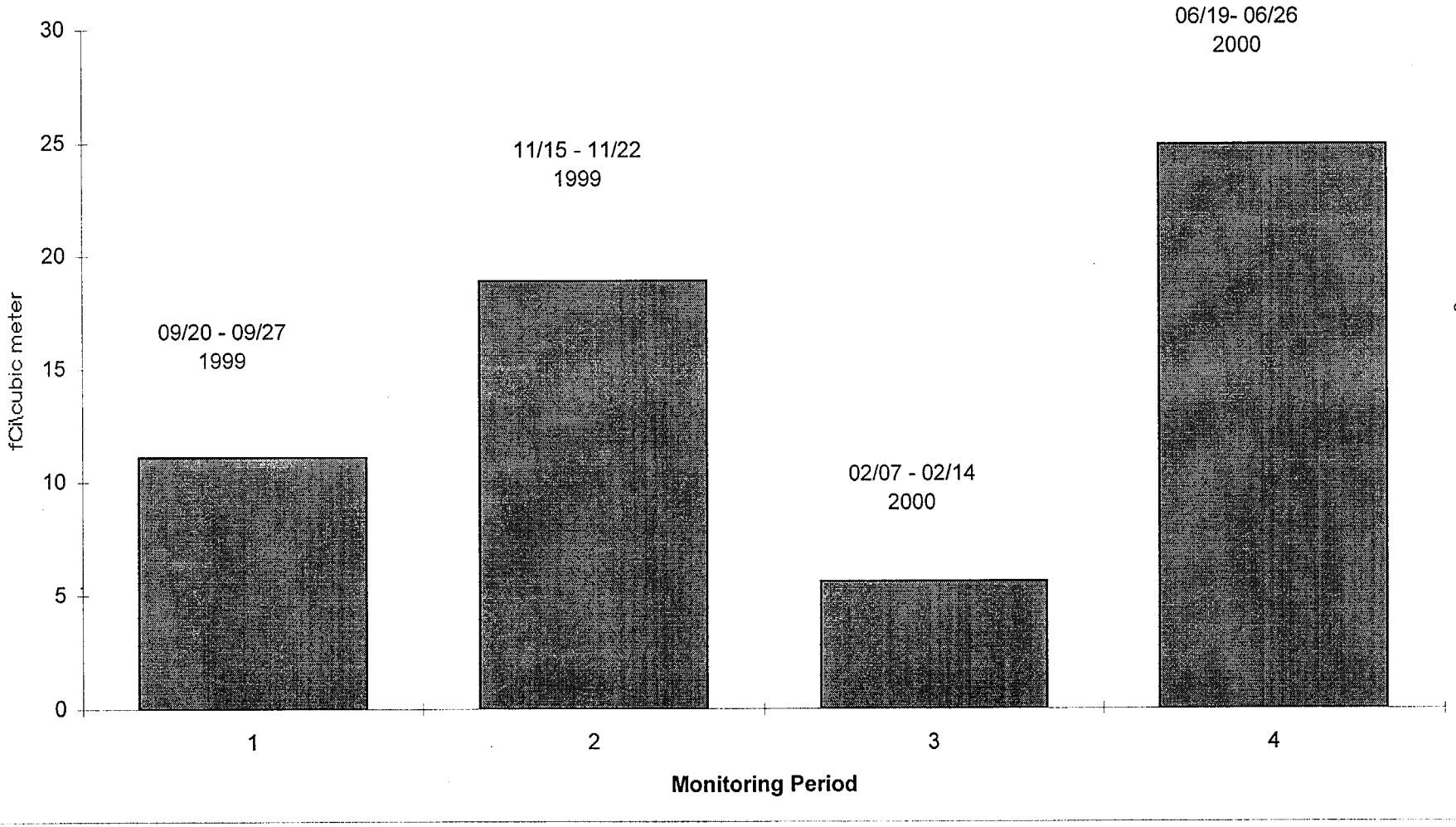


TABLE 2.3 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi M^{-3}).

NUCLIDE	REGULATORY LIMIT	ALERT LEVEL	AVERAGE N.C. BACKGROUND LEVEL
GROSS ALPHA	20	10	4
GROSS BETA	1000	500	100
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

Reference: Environmental Radiation Surveillance Report 1986-88, State of N.C. Radiation Protection Section

3. MILK (TABLE 3.1)

Milk samples are collected in alternate years from the Campus Creamery and the Lake Wheeler Road Dairy. Data was last supplied in April 1999. The next data will be supplied in 2001.

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

	pCi Liter^{-1}	
DATE	Campus Creamery	Lake Wheeler
Not Applicable	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 values for gross alpha and beta activities are ~ 0.3 pCi Liter^{-1} and ~ 0.4 pCi Liter^{-1}, respectively. 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. The water samples for the 4th quarter of 1999 and the 2nd quarter of 2000 exhibited gross beta specific activities exceeding 5 pCi Liter^{-1}, but gamma isotopic analysis of these samples indicated that this was due only to naturally-occurring radionuclides.

TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER (pCi Liter^{-1} ± 2σ)

*LLD_{α} ~ 0.3 pCi Liter^{-1} LLD_{β} ~ 0.4 pCi Liter^{-1}

		pCi Liter^{-1}	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
THIRD QUARTER 1999	ON	< 0.3	3.4 ± 0.7
	OFF	< 0.3	2.1 ± 0.6
FOURTH QUARTER 1999	ON	< 0.3	6.1 ± 0.8
	OFF	< 0.3	2.9 ± 0.7
FIRST QUARTER 2000	ON	< 0.3	2.9 ± 0.7
	OFF	< 0.3	2.6 ± 0.7
SECOND QUARTER 2000	ON	< 0.3	7.4 ± 0.9
	OFF	< 0.3	6.0 ± 0.8

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

*LLD VALUES ARE FOR THE 3RD QUARTER OF 1999

5. VEGETATION (TABLE 5.1 AND 5.2)

Table 5.1 gives gross beta activities for grass samples collected on the NCSU Campus. Table 5.2 lists LLD values for several gamma emitters. Beginning in January of 1996, the vegetation sampling has been revised to be performed in alternate years. The data will be supplied next in 2001.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ±2σ)
Not Applicable	NORTH CAMPUS	No data
Not Applicable	SOUTH CAMPUS	No data
Not Applicable	EAST CAMPUS	No data
Not Applicable	WEST CAMPUS	No data

TABLE 5.2 LLD VALUES FOR GAMMA EMITTERS IN VEGETATION

The next data for specific activities in vegetation will be supplied In the year 2001.

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 also inside the PULSTAR Reactor stack. During July 1996, a TLD station was added to North Hall which is a student dormitory located 402 meters northeast of Burlington Labs. Also, the TLD station on David Clark Labs was moved to the Environmental Health and Safety Center. A control station is located in Room 107 of the Environmental Health & Safety Center. Table 6.1 gives the data for these seven (7) 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 dosimeter readings for D.H. Hill Library were higher than those for other areas, including the PULSTAR Reactor stack. Also, D.H. Hill Library is not in the prevailing downwind direction from the reactor stack. Based on these two observations, it is concluded that the higher dosimeter readings at D.H. Hill Library did not result from reactor effluent.

TABLE 6.1	ENVIRONMENTAL TLD EXPOSURES (mrem/QUARTER YEAR)							
DATE	WITHERS	RIDDICK	BROUGHTON	DH HILL	EH&S	PULSTAR STACK	NORTH	CONTROL
1999								
07/15-10/14	2	M	M	5	M	3	M	M
10/15-12/31	M	2	M	12	M	M	M	M
2000								
01/01-03/31	M	M	M	20	M	M	M	M
04/01-06/30	M	8	M	16	3	M	5	M
***1999**	This data was not previously available from the contractor for inclusion in the 1998-1999 report							
04/16-06/30	M	M	M	M	M	M	M	M
** 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 participated in the U.S. DOE Environmental Measurements Laboratory Quality Assurance Division Program (QAP 51) 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 'EML value' listed in the Tables 7.1 (a-c) to which the ERSL results are compared is the mean of replicate determinations for each nuclide. The EML uncertainty is the standard error of the mean. All other uncertainties are as reported by the participants.

The control limit was established from percentiles of historic data distributions (1982-1992). The evaluation of historic data and the development of the control limits are presented in DOE report EML-564. The control limits for QAP 51 were developed from the percentiles of data distributions for the years 1993-1999.

Participants' analytical performance is evaluated based on the historical analytical capabilities for individual analyte/matrix pairs. The criteria for acceptable performance, "A", has been chosen to be between the 15^{th} and 85^{th} percentile of the cumulative normalized distribution, which can be viewed as the middle 70% of all historic measurements. The acceptable with warning criteria, "W", is between the 5^{th} and 15^{th} percentile and between the 85^{th} and 95^{th} percentile. In other words, the middle 90% of all reported values are acceptable, while the outer 5^{th}-15^{th} (10%) and 85^{th}-95^{th} percentiles (10%) are in the warning area. The not acceptable criteria, "N", is established at less than the 5^{th} percentile and greater than the 95^{th} percentile, that is, the outer 10% of the historical data.

The following are recommended performance criteria for analysis of environmental levels of analytes:

Acceptable: Lower Middle Limit $\leq$ A $\leq$ Upper Middle Limit
Acceptable with Warning: Lower Limit $\leq$ W < Lower Middle Limit or
Upper Middle Limit < W $\leq$ Upper Limit
Not Acceptable: N < Lower Limit or N > Upper Limit

Control Limits are reported as the ratio of Reported Value vs. EML Value. The results of the intercomparison studies are given in Table 7.1 (a-c), and are stated in the SI unit becquerel (Bq) as required by the EML reporting protocol.

In addition to the EML 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 September 1999

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. The errors are reported as ±2 standard deviations.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radio-nuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported EML
Gross Alpha	2.375	0.253	2.770	0.260	0.857
Gross Beta	2.853	0.142	2.660	0.260	1.073

QAP 51 Statistical Summary

Radio-nuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Gross Alpha	2.770	0.260	0.998	0.975	0.154	85
Gross Beta	2.660	0.260	1.080	1.069	0.133	86

QAP 51 Control Limits by Matrix

Radio-nuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Gross Alpha	0.50	0.81	1.32	1.55
Gross Beta	0.72	0.89	1.39	1.67

Control Limits are reported as: the ratio of Reported Value vs. EML Value

TABLE 7.1b
MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 September 1999
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. The errors are reported as ±2 standard deviations.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radio-nuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported EML
Co57	8.236	0.284	7.730	0.033	1.065
Co60	6.508	0.148	6.350	0.410	1.025
Cs137	7.025	0.279	6.430	0.420	1.093
Mn54	9.054	0.414	7.910	0.450	1.145

QAP 51 Statistical Summary

Radio-nuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Co57	7.730	0.033	1.020	1.034	0.092	115
Co60	6.350	0.410	1.049	1.039	0.094	119
Cs137	6.430	0.420	1.073	1.061	0.106	121
Mn54	7.910	0.450	1.095	1.097	0.113	116

QAP 51 Control Limits by Matrix

Radio-nuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Co57	0.65	0.72	1.13	1.39
Co60	0.75	0.83	1.10	1.32
Cs137	0.73	0.82	1.14	1.37
Mn54	0.76	0.84	1.18	1.42

Control Limits are reported as: the ratio of Reported Value vs. EML Value

TABLE 7.1c
MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 September 1999

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. The errors are reported as ±2 standard deviations.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radio-nuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported EML
Co60	51.081	1.606	52.400	2.200	0.975
Cs137	71.409	3.683	76.000	3.400	0.940

QAP 51 Statistical Summary

Radio-nuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Co60	52.400	2.200	1.025	1.030	0.051	122
Cs137	76.000	3.400	1.032	1.032	0.063	125

QAP 51 Control Limits by Matrix

Radio-nuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Co60	0.80	0.90	1.14	1.20
Cs137	0.80	0.90	1.18	1.26

Control limits are reported as: the ratio of Reported Value vs. EML Value

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 $r \leq \overline{R}$, $x = 0$

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

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

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

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

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

$$w + x = 0.30$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

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

$$= 3120 - 3273$$

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

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' = $\overline{x}$ - GA

= 3120 - 3290

D' = -170 pCi/liter

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

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

ND' = - 0.8