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 1998

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

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

Dear Sir:

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 1997 through 30 June 1998. 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

IE47
1/1

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

copy w/attachments:

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College of Engineering

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Dr. Charles W. Mayo, Chairman
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Mr. Stephen J. Bilyj
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Dr. Nelson Couch
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Mr. Mark Poirier
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PULSTAR REACTOR ANNUAL REPORT TO

UNITED STATES NUCLEAR REGULATORY COMMISSION

for

01 July 1997 - 30 June 1998

NCSU NUCLEAR REACTOR PROGRAM

31 August 1998

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 1997 - 30 June 1998

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. One exception was the reoccurrence of a small unaccounted water loss at the original liner seal which was installed in 1990. There have not been any unexpected maintenance or operational problems during this reporting period.

(i) (1) Reactor Operating Experience:

The NCSU PULSTAR Reactor has been utilized for the following:

• Teaching and Short Courses	145.7 hours
• Faculty and Graduate Student Research	9.1
• Isotope Production	8.8
• Neutron Activation Analysis	787.1
• Beam Tube Facilities	5.4
• Nuclear Training (Utilities)	46.0
• PULSTAR Reactor Training	9.1
• Reactor Cal/Measurements & Surveillance	52.8
• Reactor Health Physics Surveillance	19.1
• Reactor Sharing	13.0
TOTAL	1,096.1 hours

Last reporting period: 1,241.0 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
  - Neutron temperature measurements
  - Neutron diffusion length in graphite
  - Neutron fluence and spectral measurements
  - Neutron Transmutation Doping of GaN and Si

- Neutron Activation Analysis
  - cereals
  - tissue
  - finger nails
  - bone
  - sediments/soil
  - rain/river water
  - vegetation
  - fibers
  - polymers
  - ceramics
  - graphite
  - copper
  - silicon crystals
  - fertilizers
  - dust
  - sludge
  - coal
  - rubber

(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 facility and records inspection was determined to be satisfactory by the Reactor Safety and Audit Committee (RSAC).

6.7.4.b Total Energy Output:

16.8 Megawatt · days

Reactor was Critical:

619.2 hours

Cumulative Total Energy Output Since Initial Criticality:

849.2 Megawatt · days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

1. Unscheduled Shutdowns - 6 total

   a. Spurious Manual SCRAM
   b. Manual SCRAM
   c. Linear Channel SCRAM
   d. Manual SCRAM due to building fire alarm (2)
   e. Shutdown due to high differential pressure in Reactor Building

Explanation of 1a. above:

Reactor operations were unexpectedly terminated by a spurious Manual SCRAM while the operator was increasing reactor power using the control rod Gang switch, which is located approximately 5 inches from the Manual SCRAM switch. The Manual SCRAM switch contact block was cleaned and operations resumed without further incident.

Explanation of 1b. above:

A sample being irradiated in the Pneumatic System did not return at the end of its automatic timed cycle. The operator shut down the reactor by Manual SCRAM to avoid production of excess activity and radiation levels in the sample. The sample was retrieved at the Pneumatic System terminal adjacent to the reactor and operations were resumed.

Explanation of 1c. above:

While the reactor was at 10 watts a utility trainee downranged the Linear Channel Picoammeter instead of upranging causing an Overpower SCRAM.

Explanation of 1d. above:

A fire alarm smoke detector was inadvertently activated by fumes produced by a metal lathe located in a machine shop in the basement of the building. This event was repeated a second time before the lathe operator finally realized he was the cause of the fire alarm.

Explanation of 1e. above:

A pneumatically operated damper partially closed about fifteen minutes into a routine reactor startup. The operator aborted the startup and maintenance was performed on the damper linkage. Operations resumed the following day.

6.7.4.d Corrective and Preventative Maintenance:

Unaccounted primary water loss approached operational limits of 0.7 gal/hr during the month of November. Reactor operations were suspended until the source of the water loss was identified. Using underwater hydrophones and cameras, a detailed grid search of the pool liner was initiated after external piping and components were eliminated as the source of the problem. The original leak site was found to be the source of water loss.

A mechanical cantilevered sealing device, originally constructed in case the 1990 epoxy seal failed during application, was positioned over the epoxy seal material stopping the unaccounted water loss. The company which manufactured the original epoxy was contacted and additional material was purchased. The PULSTAR staff can reapply new epoxy using the original seal application device at a future time.

Preventative maintenance, tests and calibrations are performed under a system called 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 timely maintenance and calibrations. 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 97-3 with 50.59 evaluation authorized the relocation of the Primary System Low Point Drain Valve (P-7) to a location immediately adjacent to the pipe. This change also eliminated a segment of pipe buried beneath the concrete floor where inspection was not possible.

   b. DC 97-4 with a 10 CFR 50.59 evaluation authorized the use of ten beryllium reflectors on the core periphery. The design change is now awaiting NRC approval.

   c. DC 98-1 Dry fresh fuel pin storage. (pending RSAC review)

   d. DC 98-2 with a 50.59 evaluation authorized the relocation of the Radiation Monitoring Rack to a position immediately adjacent to the control console. This change allowed unrestricted access to the rear of the radiation instruments for calibration purposes.

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

   a. NP 98-1 re-established Radiological Surveys (HP3) as an approved procedure. It had originally been a procedure, but was changed to an instruction. This action converts it back to a procedure.

   b. NP 98-2 re-established Radiation Program Self-Assessment (HP4) as an approved procedure. It had originally been a procedure, but was changed to an instruction. This action converts it back to a procedure.

   c. NP 98-3 established Assessment of Airborne Effluent (PS-6-16-1) as an approved surveillance procedure. It had originally been an instruction. This action converts it to a surveillance procedure.

   d. NP 98-4 re-established Sampling, Analysis, and Assessment of Liquid Effluent (PS-6-16-2) as an approved surveillance procedure. It had originally been a HP procedure, but was changed to an instruction. This action converts it to a surveillance procedure.

   e. NP 98-5 re-established Receipt, Transfer, and Shipment of Radioactive Materials and Disposal of Solid Radioactive Waste (HP6)

as an approved procedure. It had originally been a procedure, but was changed to an instruction. This action converts it back to a procedure.

f. NP 98-6 re-established Leak Test, Inventory and Accountability of Special Nuclear Material and Sealed Sources (HP7) as an approved procedure. It had originally been a procedure, but was changed to an instruction. This action converts it back to a procedure.

g. NP 98-7 re-established Radiation Work Permits and Protective Clothing (HP8) as an approved procedure. It had originally been a procedure, but was changed to an instruction. This action converts it back to a procedure.

h. NP 98-8 re-established Respirators and Bioassays (HP9) as an approved procedure. It had originally been a procedure, but was changed to an instruction. This action converts it back to a procedure.

i. NP 98-9 re-established Program for Calibration, Operation, and Maintenance of Radiation Survey and Chemical Instruments (HP10) as an approved procedure. It had originally been a procedure, but was changed to an instruction. This action converts it back to a procedure.

j. NP 98-10 was a new PULSTAR Surveillance procedure (PS-6-15-1C) to perform the annual calibration of the PULSTAR Radiation Monitoring Rack Recorder.

k. NP 98-11 was a new PULSTAR Surveillance procedure (PS-5-06-4) to perform quarterly tests on a differential pressure alarm switch.

l. NP 98-12 was a new PULSTAR Surveillance procedure (PS-8-02-1) to calculate excess reactivity and shutdown margin on a monthly basis.

m. NP 98-13 was a new procedure to document the receipt and subsequent inspection of new fuel pins received from the Buffalo PULSTAR at State University of New York.

n. NP 98-14 was a new procedure to trim excess seal material from the original liner repair.

o. NP 98-15 was a new PULSTAR Surveillance procedure (PS-6-17-1A) to calibrate the area monitors and ratemeters along with channel testing of the radiation recorder and ratemeter.

p. NP 98-16 was a new PULSTAR Surveillance procedure (PS-6-17-2A) to calibrate the radiation process monitors and ratemeters along with channel testing the radiation recorder and ratemeter.

q. PC 6-97 revised the NCSU Emergency Plan.

r. PC 7-97 was a temporary change to the PULSTAR Operations Manual.

s. PC 8-97 was Revision 21 to the PULSTAR Operations Manual.

t. PC 9-97 updated PULSTAR Special Procedure 3.5 (SP 3.5) Rod Worth Curve Verification.

u. PC 10-97 updated PULSTAR Surveillance procedure (PS-4-08-1) Gang Control Rod Worth Verification.

v. PC 11-97 was Amendment 12 to the PULSTAR Technical Specifications updating street name changes on campus.

w. PC 12-97 is pending as Amendment 13 to the PULSTAR Technical Specifications for the utilization of beryllium as a reflector along the core periphery. See (b) above.

x. PC 13-97 was Revision 2 which updated PULSTAR Surveillance procedure (PS-5-03-1) for testing Confinement Fan No. 1 with auxiliary power.

y. PC 14-97 was Revision 2 which updated PULSTAR Surveillance procedure (PS-5-04-1) for testing Confinement Fan No. 2 with auxiliary power.

z. PC 15-97 was Revision 1 which updated the Reactor Health Physics Radiation Protection Program (HP1).

aa. PC 16-97 was Revision 5 which updated Special Procedure 2.1 (SP 2.1) Review and Approval of Changes and Deviations.

bb. PC 1-98 was Revision 6 which updated Special Procedure 2.1 (SP 2.1) Review and Approval of Changes and Deviations.

cc. PC 2-98 was Revision 2 which updated the Reactor Health Physics Radiation Protection Program (HP1).

Summary: A total of thirty-five procedures were written or revised, some of which were just minor changes, 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 Protection Committee (RPC).

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 97	2	8	5,100	2.6E4	5
01 Oct - 31 Dec 97	1	21	3,000	5.7E4	15
01 Jan - 31 Mar 98	0	0	0	0	0
01 Apr - 30 Jun 98	1	17	3,400	2.7E4	14

(6) 34 μCi of tritium was released during this reporting period.

(7) 46 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.

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

2. Gaseous Waste (summarized monthly)

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

(1) Gases:

Year	Period	Total Time In Hours	Curies
1997	01 Jul - 31 Jul	744	0.087
	01 Aug - 31 Aug	744	0.224
	01 Sep - 30 Sep	720	0.275
	01 Oct - 31 Oct	744	0.064
	01 Nov - 30 Nov	720	0
	01 Dec - 31 Dec	744	0.082
1998	01 Jan - 31 Jan	744	0.150
	01 Feb - 28 Feb	672	0.086
	01 Mar - 31 Mar	744	0.142
	01 Apr - 30 Apr	720	0.132
	01 May - 31 May	744	0.220
	01 Jun - 30 Jun	720	0.128
	Totals	8,760	1.590

(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 1.590 curies.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack during this period was 4.8E-9 μCi/cc. This is below the regulatory limit of 1×10^{-8} μCi/cc in 10 CFR 20 Appendix B. Dose calculations were performed using "COMPLY" code for the fiscal year. Results were less than the 10 mrem constraint levels given in 10 CFR 20.

(2) Particulates:
See gaseous waste i.(2) above.

3. Solid Waste from Reactor[2]

- Total volume of solid waste - 22 ft^3 (0.61 m^3)
- Total activity of solid waste - 0.042 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. Only one transfer was performed and it occurred on 09 March 1998.

6.7.4.g Personnel Radiation Exposure Report

Twenty-nine members of the faculty and staff were monitored for external radiation exposure during the reporting period. Eleven of the twenty-nine received measurable exposure which ranged from 0.01 to 0.03 rem. Total person-rem for the faculty and staff was 0.15 through May 1998. June 1998 data was not available at the time of the report.

Film badges were issued to 25 students, short course participants, and visitors. All of these exposures were in the "no measurable exposure" range.

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
- external radiation levels in the remaining areas were as expected due to reactor operations
- contamination levels in most areas were not detectable
- when contamination was detected, the area or item was confined or decontaminated

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

6.7.4.i Description of Environmental Surveys Outside of the Facility

See Attachment A prepared by the Radiation Protection Division of the Environmental Health and Safety Center.

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 levels were 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

DEPARTMENT
OF
ENVIRONMENTAL HEALTH AND SAFETY

RADIATION PROTECTION DIVISION

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JULY 1, 1997 - JUNE 30, 1998

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.

During 1995, the Director of the Environmental Health and Safety Center created a committee to assess the environmental monitoring program for the PULSTAR Reactor. This committee issued a detailed report entitled "Report of the Committee to Assess the Environmental Monitoring Program for the North Carolina State PULSTAR Reactor" in which several recommendations were proposed regarding modifications to this program. This information is summarized in Table 1 which has been excerpted from the committee's report. In brief, the committee recommended the following changes:

1) Discontinue the monthly milk sampling, but instead collect and analyze one milk sample in alternate years. This recommendation has been put into effect.

2) Discontinue the semi-annual vegetation collection, but instead collect and analyze one vegetation sample in alternate years. This recommendation has been put into effect.

3) Change the frequency of air sampling from continuous sampling with filters being collected each week (7-day cycle) to a periodic sampling mode in which air samplers are operated for only one week (7 days) during each 3 month period of the year. This recommendation has been put into effect.

4) Move the air sampler at David Clark Labs to the Environmental Health and Safety Center. This recommendation has been put into effect.

5) Move the air sampler at Withers Hall to North Hall (a student dormitory). This recommendation could not be accomplished due to restrictions on

locating equipment on the building which could damage the rubber-lined roof. To achieve partial compliance with the committee's recommendations, a TLD station has been located at North Hall to monitor environmental gamma radiation levels.

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	RPD/EHSC RPD/EHSC	Weekly Weekly	Quarterly	10 CFR 20 10 CFR 20
Air/Dosage at 7 Campus Stations+	TLD Dosimeter	RPD/EHSC	Quarterly	Quarterly	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Indiv. Gamma Emitters	RPD/EHSC RPD/EHSC	Quarterly Quarterly	Quarterly Quarterly	NCSU NCSU
Vegetation NCSU Campus	Gross Beta Gamma	RPD/EHSC RPD/EHSC	Semi-annually	Alternate years Alternate years	NCSU NCSU
Milk Local Dairy	I-131	RPD/EHSC	Monthly	Alternate years	NCSU

Abbreviations Used in Table:

N.E. = Nuclear Engineering/Reactor Facility; RPD/EHSC = Radiation Protection 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)

Beginning in January 1996, air monitoring frequency has been changed such that air sampling 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 11.8 $fCim^{-3}$ at the EH&S Center station during the week of 08/01/97 to 08/08/97. The annual campus average was 9.9 $fCim^{-3}$.

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. Radiation Protection Division.

Table 2.2 Aerially Transported Gamma Activity (fCi m E-3)

					NUCLIDES				
SAMPLING PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
1997									
08/01 - 08/08	0.13	0.23	0.21	0.38	0.2	1.51	0.18	0.28	1.01
11/10 - 11/17	0.11	0.3	0.28	0.45	0.26	2.21	0.24	0.3	0.94
1998									
03/24-03/31	0.14	0.23	0.25	0.40	0.24	1.96	0.21	0.31	1.23
06/01-06/08	0.16	0.20	0.21	0.27	0.22	2.10	0.20	0.28	1.19

FIGURE 2a
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3 (0.037 Bq/M^3)
ALERT LEVEL = 500 fCi/M^3 (0.0185 Bq/M^3)
LLD ~ 1 fCi/M^3 (3.7 X 10^{-5} Bq/M^3)

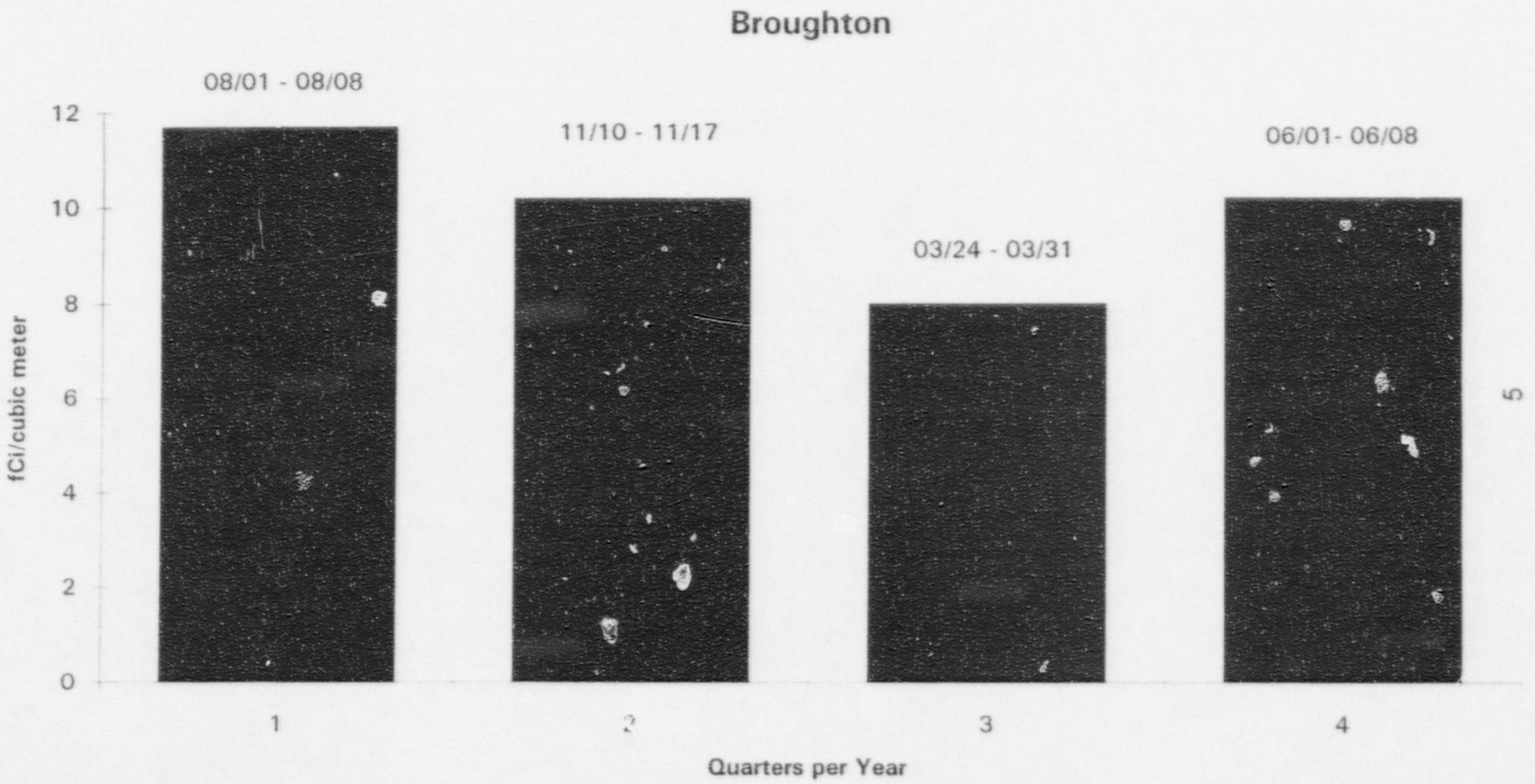

FIGURE 2b
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3 (0.037 Bq/M^3)
ALERT LEVEL = 500 fCi/M^3 (0.0185 Bq/M^3)
LLD ~ 1 fCi/M^3 (3.7 X 10^{-5} Bq/M^3)

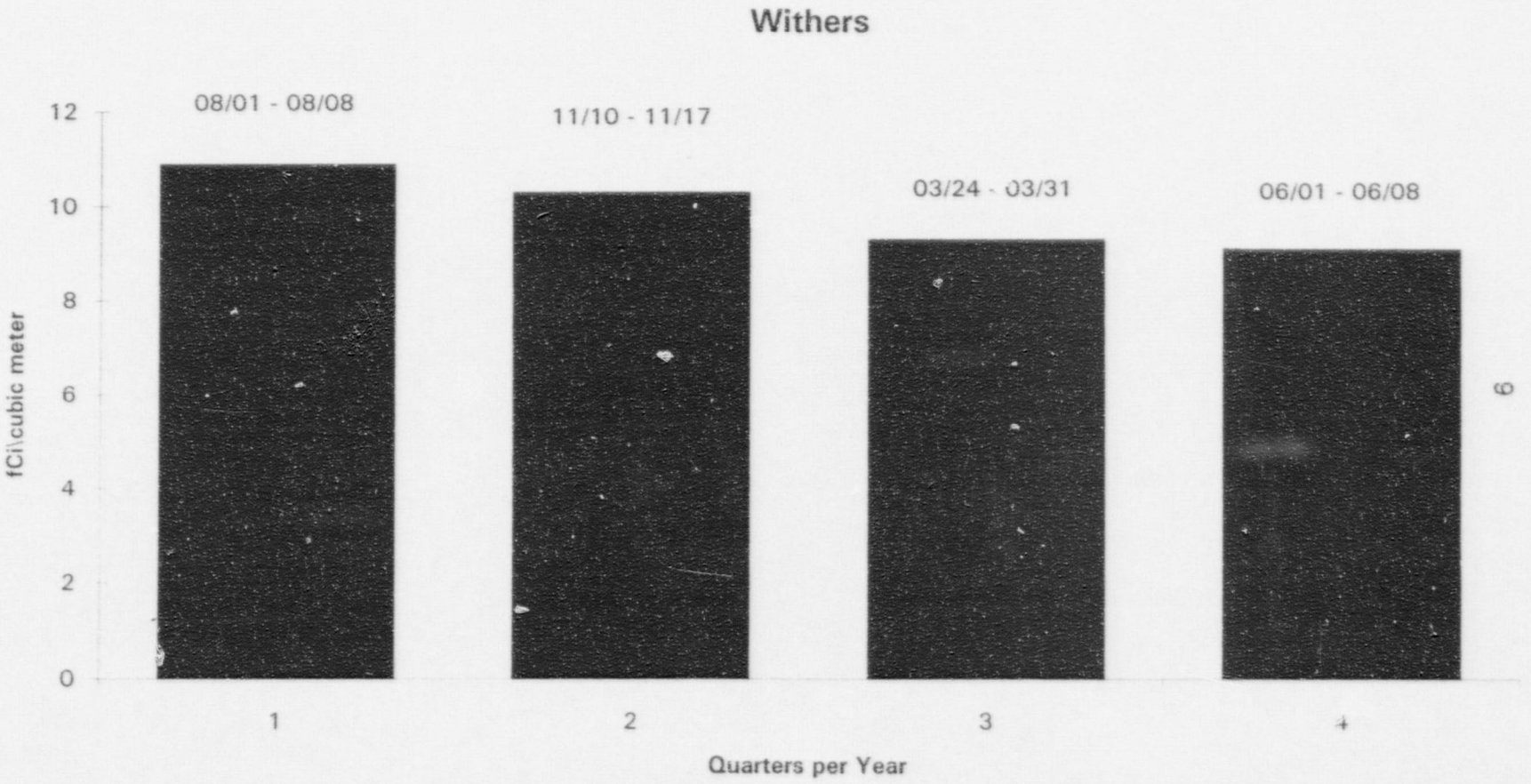

FIGURE 2c
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3 (0.037 Bq/M^3)
ALERT LEVEL = 500 fCi/M^3 (0.0185 Bq/M^3)
LLD – 1 fCi/M^3 (3.7 X 10^{-5} Bq/M^3)

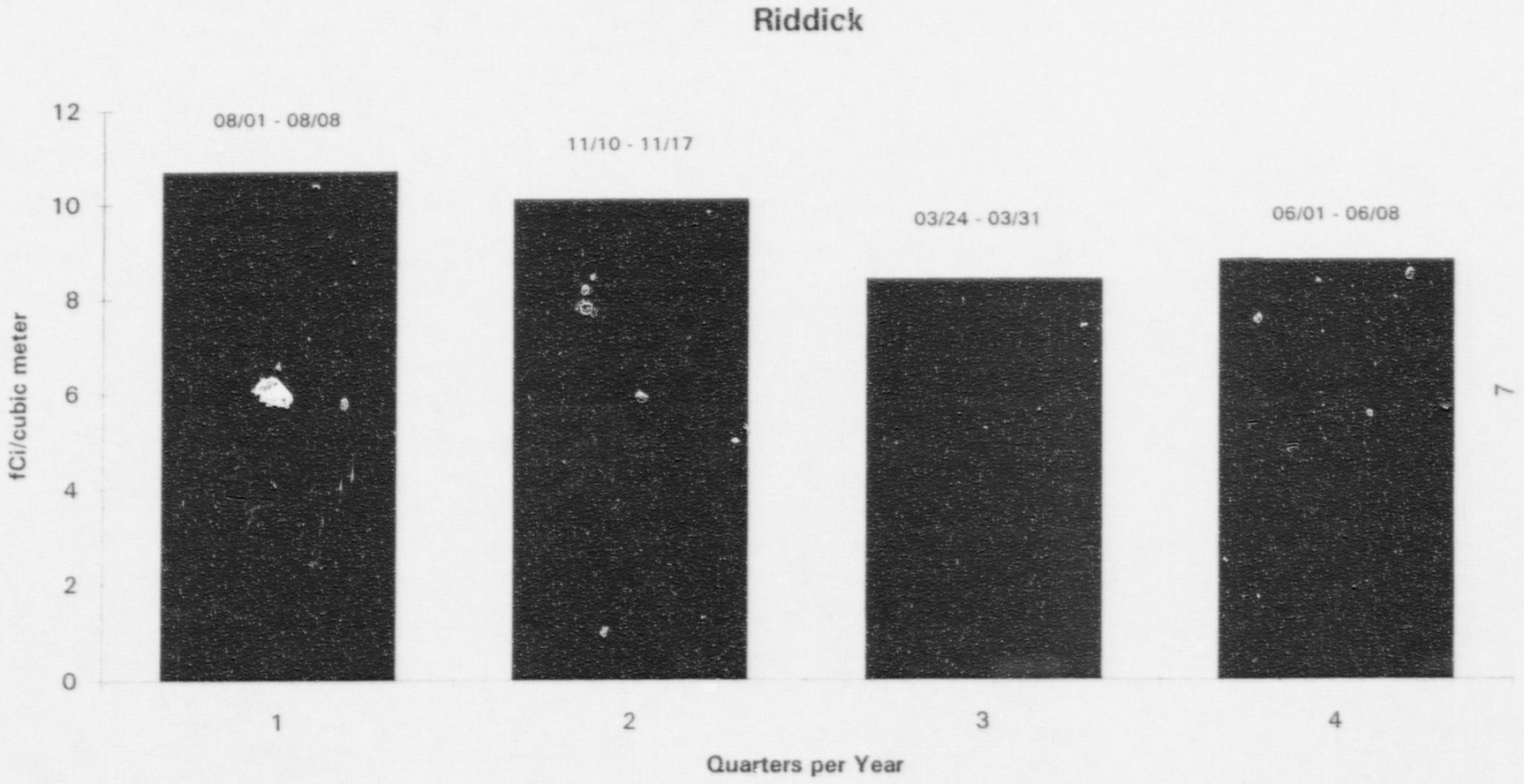

FIGURE 2d
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3 (0.037 Bq/M^3)
ALERT LEVEL = 500 fCi/M^3 (0.0185 Bq/M^3)
LLD - 1 fCi/M^3 (3.7 X 10^{-5} Bq/M^3)

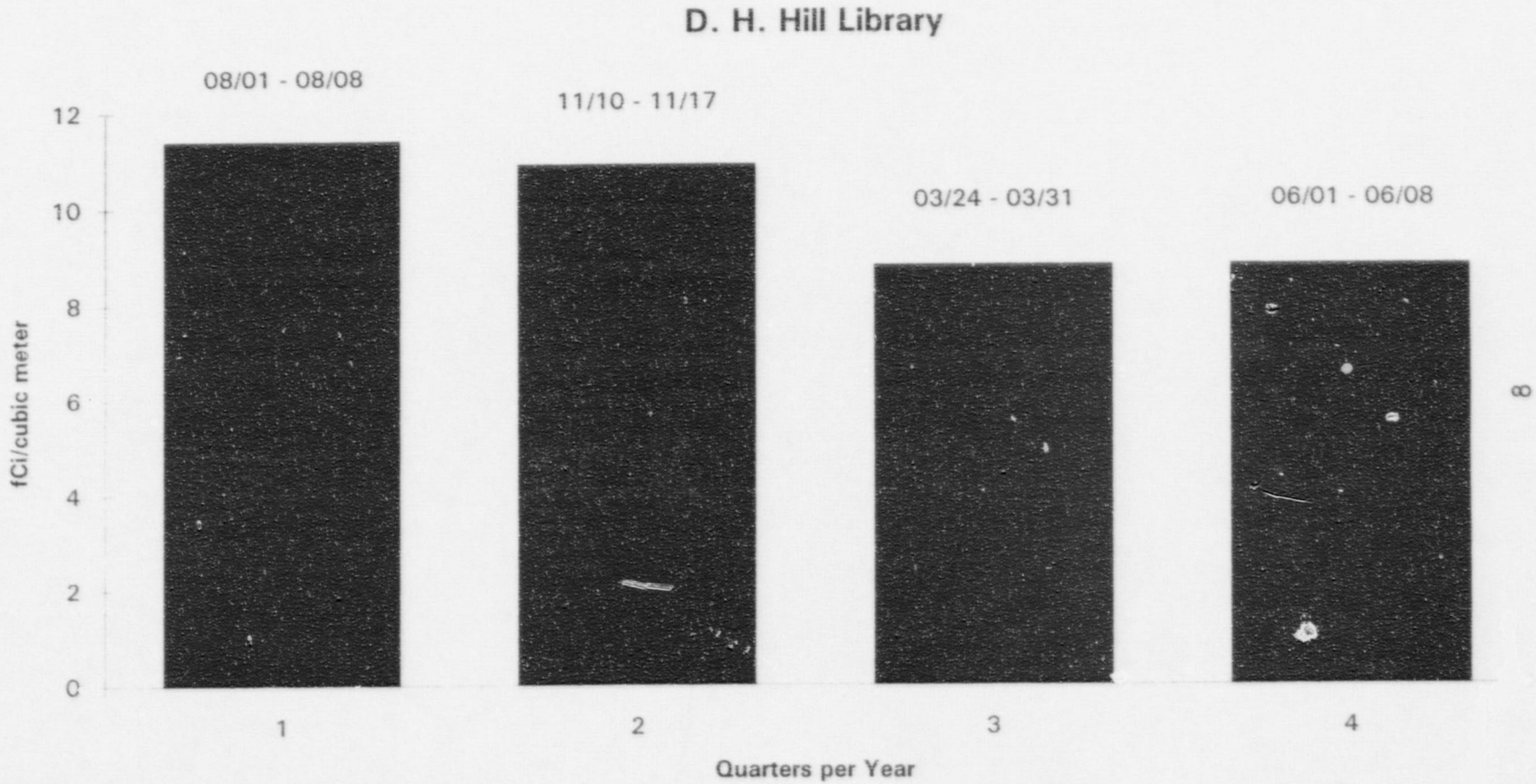

FIGURE 2e
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3 (0.037 Bq/M^3)
ALERT LEVEL = 500 fCi/M^3 (0.0185 Bq/M^3)
LLD ~ 1 fCi/M^3 (3.7 X 10^{-5} Bq/M^3)

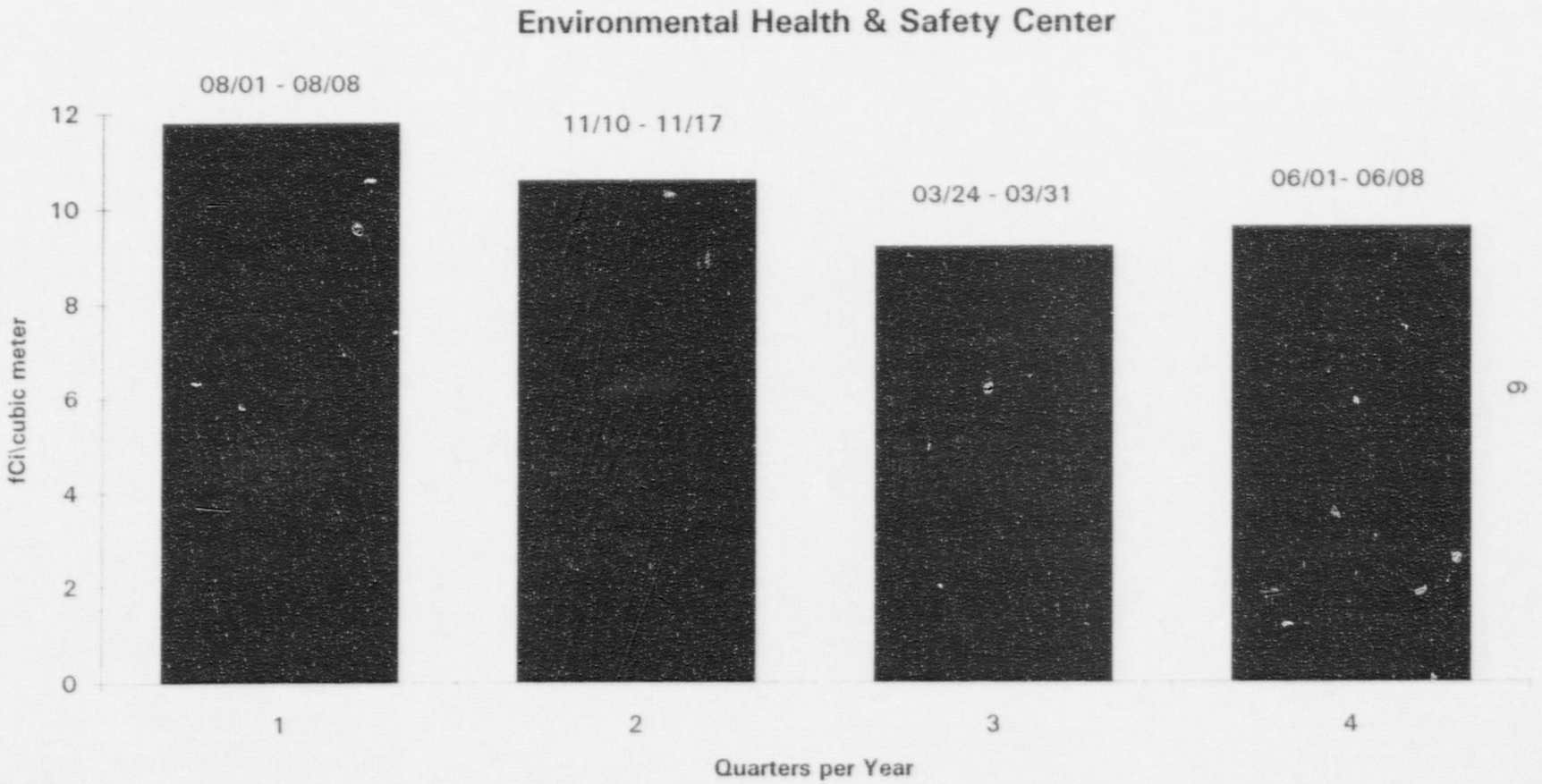

TABLE 2.3 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi M^{-3}).

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 March 1997. The next data will be supplied in 1999.

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
1998	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 LLD values in Table 4.2 are for the second quarter of 1997.

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

*LLDα ~ 0.3 pCi liter^{-1} LLDβ ~ 0.4 pCi liter^{-1}

		pCi liter^{-1}	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
THIRD QUARTER 1997	ON	< 0.3	1.9 ± 0.6
	OFF	< 0.3	2.4 ± 0.6
FOURTH QUARTER 1997	ON	< 0.3	2.9 ± 0.8
	OFF	< 0.3	2.3 ± 0.6
FIRST QUARTER 1998	ON	< 0.3	2.6 ± 0.5
	OFF	< 0.3	2.6 ± 0.5
SECOND QUARTER 1998	ON	< 0.3	2.4 ± 0.6
	OFF	< 0.3	2.4 ± 0.6

*LLD VALUES ARE DETERMINED QUARTERLY

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 2ND QUARTER OF 1997

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 1999.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ±2σ)
1998	NORTH CAMPUS	No data
1998	SOUTH CAMPUS	No data
1998	EAST CAMPUS	No data
1998	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

*LLD VALUES ARE FOR THE 1ST QUARTER OF 1997

6. THERMOLUMINESCENT DOSIMETERS (TLDs) (TABLE 6.1)

TLD analysis is contracted to Thermo Nutech for determination of ambient gamma exposures. The dosimeters are LiF and have a manufacturer-stated sensitivity of 0.5 ± 0.15 mR (90% C.L.). Exposures are integrated over a three-month period at each of the five air monitor stations listed in Table 2.1 and also at the top of 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 Safety Center. Table 6.1 gives the data for these seven (7) monitoring locations.

The gross exposures are given along with the transit exposure reading. The net exposures are lower than those typically expected in this area of North Carolina(i.e., is ~ 18 - 20 mR per quarter year), and lower than those observed in past years on the NCSU campus. The contractor does not believe that the unexplained lower-than-usual exposure readings are due to any processing errors.

TABLE 6.1	ENVIRONMENTAL TLD EXPOSURES (mR/QUARTER YEAR)								
DATE	TRANSIT	WITHERS	RIDDICK	BROUGHTON	DH HILL	EH&S	PULSTAR STACK	CONTROL	NORTH
1997									
06/30-10/16	35	37	34	35	37	36	33	36	36
10/16-12/31	39	38	38	40	37	42		38	38
1998									
01/01-03/31	43	42	43	43	47	43	43	43	42
04/01-06/30	Data not yet available from the contractor								
***1997**	This data was not previously available from the contractor for inclusion in the 1996-97 report								
04/17-06/30	37	37	37	36	37	38	38	38	37

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory (ERSL) of the Radiation Protection Division has participated in the U.S. DOE Environmental Measurements Laboratory Quality Assurance Division Program (QAP 47) 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 47 were developed from the percentiles of data distributions for the years 1991-1996.

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 15th and 85th 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 5th and 15th percentile and between the 85th and 95th percentile. In other words, the middle 90% of all reported values are acceptable, while the outer 5th-15th (10%) and 85th-95th percentiles (10%) are in the warning area. The not acceptable criteria, "N", is established at less than the 5th percentile and greater than the 95th 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 1997

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	1.550	0.060	1.490	0.090	1.040
Gross Beta	2.800	0.060	3.000	0.140	0.930

QAP 47 Statistical Summary

Radio-nuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Gross Alpha	1.490	0.090	1.097	1.070	0.206	67
Gross Beta	3.000	0.140	1.048	1.035	0.145	72

QAP 47 Control Limits by Matrix

Radio-nuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Gross Alpha	0.45	0.80	1.34	1.57
Gross Beta	0.50	0.80	1.48	1.77

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

TABLE 7.1b
MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 September 1997
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
Ce144	16.410	1.660	19.120	0.700	0.860
Co57	10.950	0.430	12.640	0.430	0.860
Co60	8.370	0.560	10.730	1.090	0.782
Cs134	25.200	0.690	28.170	0.730	0.890
Cs137	6.540	0.530	7.310	0.250	0.890
Mn54	6.340	0.570	6.720	0.270	0.940
Sb125	14.750	1.340	16.120	0.790	0.910

QAP 47 Statistical Summary

Radio-nuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Ce144	19.120	0.700	0.870	0.860	0.121	81
Co57	12.640	0.430	0.918	0.900	0.121	91
Co60	10.730	1.090	0.919	0.900	0.094	93
Cs134	28.170	0.730	0.898	0.890	0.089	92
Cs137	7.310	0.250	0.957	0.955	0.109	98
Mn54	6.720	0.270	0.988	0.980	0.113	92
Sb125	16.120	0.790	0.976	0.990	0.160	88

QAP 47 Control Limits by Matrix

Radio-nuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Ce144	0.58	0.66	1.10	1.26
Co57	0.62	0.69	1.10	1.28
Co60	0.75	0.82	1.10	1.27
Cs134	0.73	0.81	1.11	1.22
Cs137	0.72	0.82	1.11	1.33
Mn54	0.76	0.83	1.11	1.32
Sb125	0.58	0.81	1.14	1.36

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

TABLE 7.1c
MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 September 1997

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	23.430	1.380	23.300	1.200	1.010
Cs134	66.150	0.790	66.000	2.600	1.000
Cs137	34.910	0.700	34.300	1.700	1.020
Mn54	39.210	1.650	37.800	1.900	1.040

QAP 47 Statistical Summary

Radio-nuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Co60	23.300	1.200	1.019	1.010	0.057	91
Cs134	66.000	2.600	1.049	1.040	0.073	93
Cs137	34.300	1.700	1.050	1.040	0.082	97
Mn54	37.800	1.900	1.067	1.070	0.075	91

QAP 47 Control Limits by Matrix

Radio-nuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Co60	0.80	0.90	1.13	1.18
Cs134	0.89	0.90	1.16	1.25
Cs137	0.80	0.90	1.18	1.27
Mn54	0.80	0.90	1.16	1.22

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 (e.g., Be-7) 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 = $\bar{x}$

$$\bar{x} = \frac{\sum_{i=1}^{N} X_i}{N} = \frac{9360}{3} = 3120 \text{ pCi/liter}$$

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 = $\bar{R}$

$R = d_2\sigma$ 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

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

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

$= (1556 - 604.4) \div 3$

$\sigma_R = 317.2$ 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 $$x = \frac{r - \bar{R}}{\sigma_R}$$

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

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*Rosentein, M., and A. S. Goldin, "Statistical Techniques for Quality Control of Environmental Radioassay," AQCS Report Stat-1, U.S. Department of Health Education and Welfare, PHS, November 1964.

**From table "Factors for Computing Control Limits," Handbook of Tables for Probability and Statistics, 2nd Edition, The Chemical Rubber Co., Cleveland, Ohio, 1968, p. 454.

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

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

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

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

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

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

$$w + x = 0.30$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

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

$$= 3120 - 3273$$

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

Standard error of the mean = σ_m

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

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

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

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

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

$$ND = -0.7$$

Control limit = CL

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

Warning limit = WL

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

Experimental sigma (all laboratories) = s_t

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

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

s_t = 149 pCi/liter

Grand Average = GA

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

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

GA = 3290 pCi/liter

Normalized deviation from the grand average = ND'

Deviation of the mean from the grand average = D'

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

= 3120 - 3290

D' = -170 pCi/liter

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

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

ND' = - 0.8