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

Department of Nuclear Engineering
Campus Box 7909
Raleigh, NC 27695-7909

919.515.7294
919.513.1276 (fax)
URL:www.ne.ncsu.edu/NRP/reactor_program.html

27 August 2003

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 2002 through 30 June 2003. Please feel free to contact me at (919) 515-4601 if you have any questions or comments.

Sincerely,

Gerald D. Wicks

Gerald D. Wicks
Acting Associate Director
Nuclear Reactor Program

A020

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

copy w/attachments:

Dr. Nino A. Masnari, Dean
College of Engineering

Dr. D. Keith Cassel, Chairman
Radiation Safety Committee

Dr. Ayman I. Hawari, Chairman
Reactor Safety and Audit Committee

Dr. Paul J. Turinsky, Head
Department of Nuclear Engineering

Dr. Ayman I. Hawari, Director
Nuclear Reactor Program

Mr. David Rainer, Associate Vice Chancellor
Environmental Health and Public Safety

Ms. Amy C. Orders
Radiation Safety Officer

Mr. Stephen J. Bilyj
Reactor Operations Manager

Mr. Mark Poirier
ANI/MAELU

Mr. Daniel Hughes
Nuclear Regulatory Commission

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 July 2002 - 30 June 2003

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 mostly routine during this reporting period. During the months of January through March there was a slight increase in unaccounted water loss from the primary cooling system. Actions required by Special Procedure 5.10 "Primary Water Inventory" were followed and reactor operations were not impacted. No official notification was required by the facility license to the NRC. Unaccounted primary water loss rates were not detectable twelve weeks later. Contractors with expertise in locating small leaks have been contacted to provide assistance if needed. One part-time reactor operator received her license in November 2002. The Reactor Health Physicist is currently serving as the interim Associate Director.

(i) (1) Reactor Operating Experience:

The NCSU PULSTAR Reactor has been utilized for the following:

• Teaching and Short Courses	192.9 hours
• Faculty and Graduate Student Research	103.9
• Isotope Production	0.2
• Neutron Activation Analysis	473.9
• Beam Tube and Irradiation Facilities	113.7
• Nuclear Training (Utilities)	0.0
• PULSTAR Reactor Training	30.8
• Reactor Cal/Measurements, Surveillance & Ops	47.5
• Reactor Health Physics Surveillance	21.4
• Reactor Sharing	70.9
TOTAL	1,055.2 hours

Last reporting period: 1,517.0 hours

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

- Teaching Laboratories, Short Courses, and Research
  core thermal power measurements
  dynamic reactivity measurements
  axial power and peaking factor measurements (flux mapping)
  reactor power determination using photodiode arrays

neutron diffusion length in graphite by foil activation
neutron fluence and spectral measurements
neutron transmutation doping of silicon
in-core detector certification
radiation damage determination to fiber optic material
accelerated lifetime testing for nuclear detectors

- Neutron Activation Analysis
  cereal/grain
  animal feed
  food samples
  fish and laboratory animal tissue
  human hair and nails
  urine and excrement
  sediment/soil/rocks
  water
  dyes
  polymers and plastics
  textiles
  crude oil
  silicon crystals
  carbon fiber samples recovered from Shuttle Columbia

(ii) Changes in Performance Characteristics Related to Reactor Safety:

None

(iii) Results of Surveillance, Tests, and Inspections:

The reactor surveillance program has revealed no significant or unexpected trends in reactor systems performance during this reporting period. The Reactor Safety and Audit Committee (RSAC) performed its annual audit for the facility and determined that all phases of operation and supporting documents were in compliance.

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

6.7.4.b Total Energy Output:

13.2 Megawatt·days

Reactor was Critical:

556.2 hours

Cumulative Total Energy Output Since Initial Criticality:

936.1 Megawatt·days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

1. Emergency Shutdowns - none

2. Unscheduled Shutdowns - none

6.7.4.d Corrective and Preventative Maintenance:

Preventative maintenance, tests and calibrations are scheduled, performed and tracked utilizing the PULSTAR Surveillance File System. Each major component of the Reactor Safety System defined in Section 3.3, and all surveillance required by Section 4 of the Technical Specifications are monitored by this file system to ensure that maintenance and calibrations are performed in a timely manner. All historical data relating to those components, in addition to many other sub-systems, are maintained in these files.

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

1. Design Changes (DC)

   a. DC 02-3 replaces a 30 year old SCRAM logic and magnet power supply.

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

   a. PC 2-02 was Revision 32 to the PULSTAR Operations Manual incorporating changes required by DC 02-3 described in 1.a above. Also, typographical errors were corrected.

   b. PC 3-02 was Revision 1 to Security Procedure 6.0.

   c. MC 02-6 was Revision 3 to Special Procedure 5.10 "Primary Water Inventory" making data entry more intuitive on the approved spreadsheet.

   d. MC 02-7 was Revision 8 to Emergency Procedure 2 "Off-site Notification" providing clarification for responsibility when completing forms and updated Authentication Code List.

   e. MC 02-8 was Revision 12 to Emergency Procedure 1 "Emergency Plan Activation, Response, and Action" updating building evacuation notice, alternate Emergency Coordinator and call out list.

   f. MC 03-1 was Revision 33 to the PULSTAR Operations Manual changing the sequence in the preoperational checklist to ensure that certain steps will not be inadvertently missed.

Summary:
Procedures were written or revised covering the calibration of installed equipment, reactor operations, surveillance, security, 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 02	0	0	0	0	0
01 Oct - 31 Dec 02	1	9	2,840	1.5E4	7
01 Jan - 31 Mar 03	1	13	3,420	9.92E4	3
01 Apr - 30 Jun 03	3	8	3,120	0	8

(6) 18 μCi of tritium was released during this reporting period.

(7) 30 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
2002	01 Jul - 31 Jul	744	0.207
	01 Aug - 31 Aug	744	0.081
	01 Sep - 30 Sep	720	0.139
	01 Oct - 31 Oct	744	0.069
	01 Nov - 30 Nov	720	0.015
	01 Dec - 31 Dec	744	0.022
2003	01 Jan - 31 Jan	744	0.112
	01 Feb - 28 Feb	672	0.147
	01 Mar - 31 Mar	744	0.133
	01 Apr - 30 Apr	720	0.169
	01 May - 31 May	744	0.142
	01 Jun - 30 Jun	720	0.029
	Totals	8,760 hours	1.265 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 1.265 curies.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack during this period was 3.8×10^{-9} μCi/cc . This is below the regulatory limit of 1×10^{-8} μCi/cc given in 10 CFR 20 Appendix B. Dose calculations for the fiscal year were performed using the "COMPLY" code with results 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 - 66 ft^3 (1.87 m^3)
- Total activity of solid waste - 0.25 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 09 Jul 02 and 17 Jan 03.

6.7.4.g Personnel Radiation Exposure Report:

Twenty-seven individuals were monitored for external radiation dose during the reporting period. Collective dose for this reporting period was 1.374 person-rem. Individual doses ranged from 0.009 to 0.136 rem with an average of 0.051 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 40 μrem/h in some areas when the reactor was operating at power. However, external radiation levels were at background levels in routinely occupied spaces.

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

ATTACHMENT A

PULSTAR REACTOR

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JULY 1, 2002 - JUNE 30, 2003

NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY CENTER

RADIATION SAFETY DIVISION

by

Ralton J. Harris
Environmental Health Physicist

TABLE OF CONTENTS

1. INTRODUCTION

The Environmental Radiation Surveillance Program exists to provide routine measurements of the university environment surrounding the PULSTAR Reactor. The specific objectives of this program include:

1) Providing information that assesses the adequacy of the protection of the university community and the public-at-large;

2) Meeting requirements of regulatory agencies;

3) Verifying radionuclide containment in the reactor facility;

4) Meeting legal liability obligations; and

5) Providing public assurance and acceptance.

Table 1:
Environmental Monitoring Programs for the PULSTAR Reactor at North Carolina State University

Sample	Activity Measured	Conducted By	Previous Frequency	Current Frequency	Basis For Measurement
Stack Gases	Gross Gamma	N.E.	Continuous	Continuous	10 CFR 20 T.S. 6.7.4
Stack Particles	Gross Beta Indiv. Gamma Emitters	N.E. N.E.	Monthly	Monthly	10 CFR 20 T.S. 6.7.4
Water from Reactor Facility	Gross Beta Gross Gamma Tritium	N.E. N.E. N.E.	Prior to Discharge (~ Monthly)	Prior to Discharge ~ Monthly	10 CFR 20 T.S. 6.7.4 City of Raleigh Ordinance
Air/Particles at 5 Campus Stations*	Gross Beta Indiv. Gamma Emitters	RSD/EHSC RSD/EHSC	Weekly Weekly	Quarterly	10 CFR 20 10 CFR 20
Air/Dosage at 8 Campus Stations+	TLD Dosimeter	RSD/EHSC	Quarterly	Quarterly	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Indiv. Gamma Emitters	RSD/EHSC RSD/EHSC	Quarterly Quarterly	Quarterly Quarterly	NCSU NCSU
Vegetation NCSU Campus	Gross Beta Gamma	RSD/EHSC RSD/EHSC	Semi-annually	Alternate years Alternate years	NCSU NCSU
Milk Local Dairy	I-131	RSD/EHSC	Monthly	Alternate years	NCSU

Abbreviations Used in Table:
N.E. = Nuclear Engineering/Reactor Facility; RSD/EHSC = Radiation Safety Division.
*These 5 stations include:
Withers, Riddick, Broughton, Hill Library and Environmental Health & Safety Center.

+These 8 stations include: the PULSTAR stack, a control station (EHSC) and the 5 air sampling stations, and North Hall.

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

Air monitoring is performed continually for one week during each of four (4) quarters during the year. The data shows the normal fluctuations in gross beta activity levels expected during the year. Figures 2a through 2e show bar graphs of gross beta activity (fCi/cubic meter *vs.* sampling quarters per year). The highest gross beta activity observed was 21.6 $fCiM^{-3}$ at the Riddick Hall station during the week of 09/16/02 to 09/23/02. The annual campus average was 12.3 $fCiM^{-3}$.

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

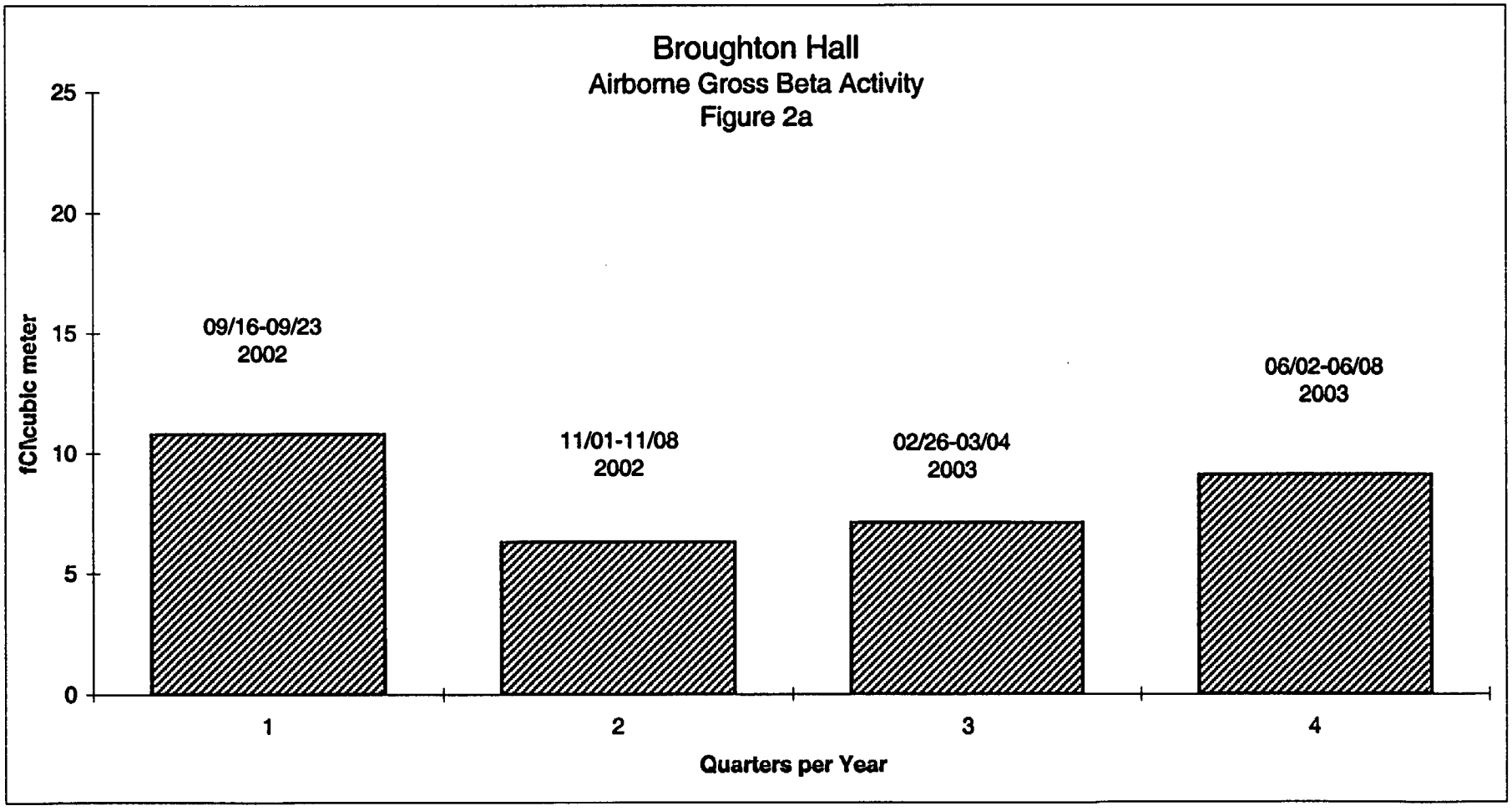
SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
*DAVID CLARK LABS	WEST	500	-18
LIBRARY	NORTHWEST	192	+11
RIDDICK	SOUTHEAST	99	-14
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL	NORTHEAST	402	-4

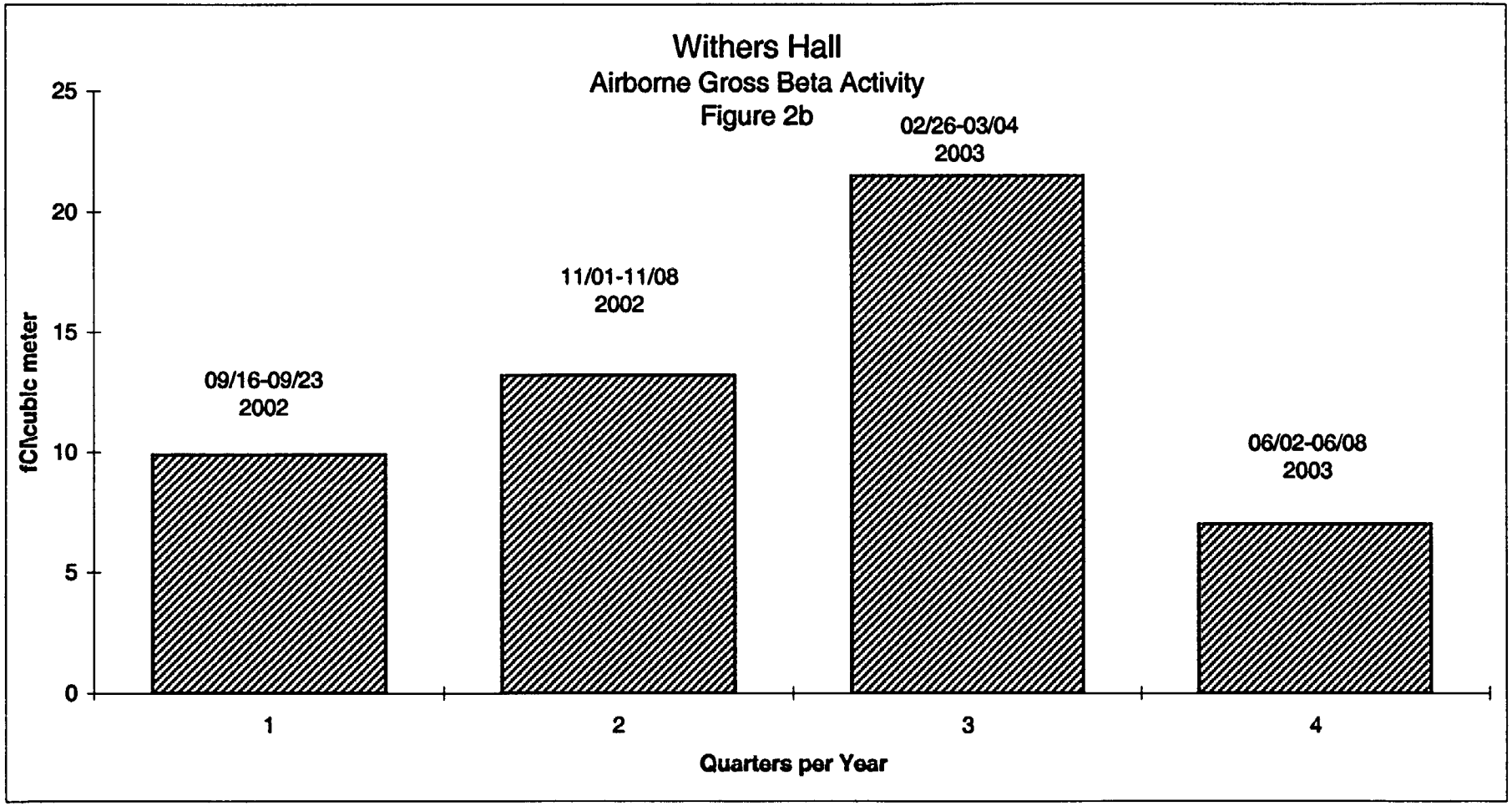
[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

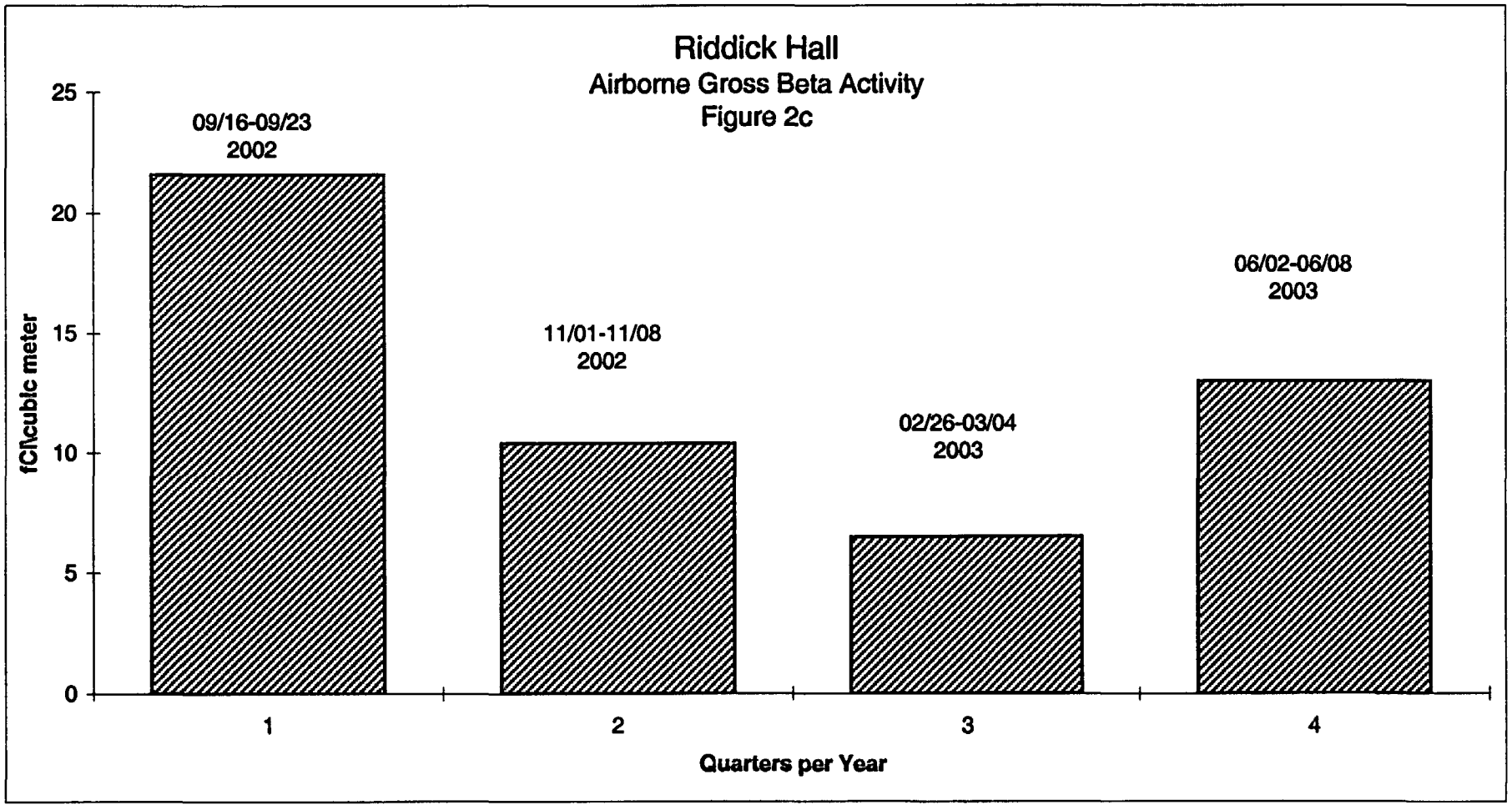
*The station at David Clark Labs was relocated to the EH & S Center in January 1996, however a TLD monitor is maintained at David Clark Labs for the State of N.C. Division of Radiation Protection.

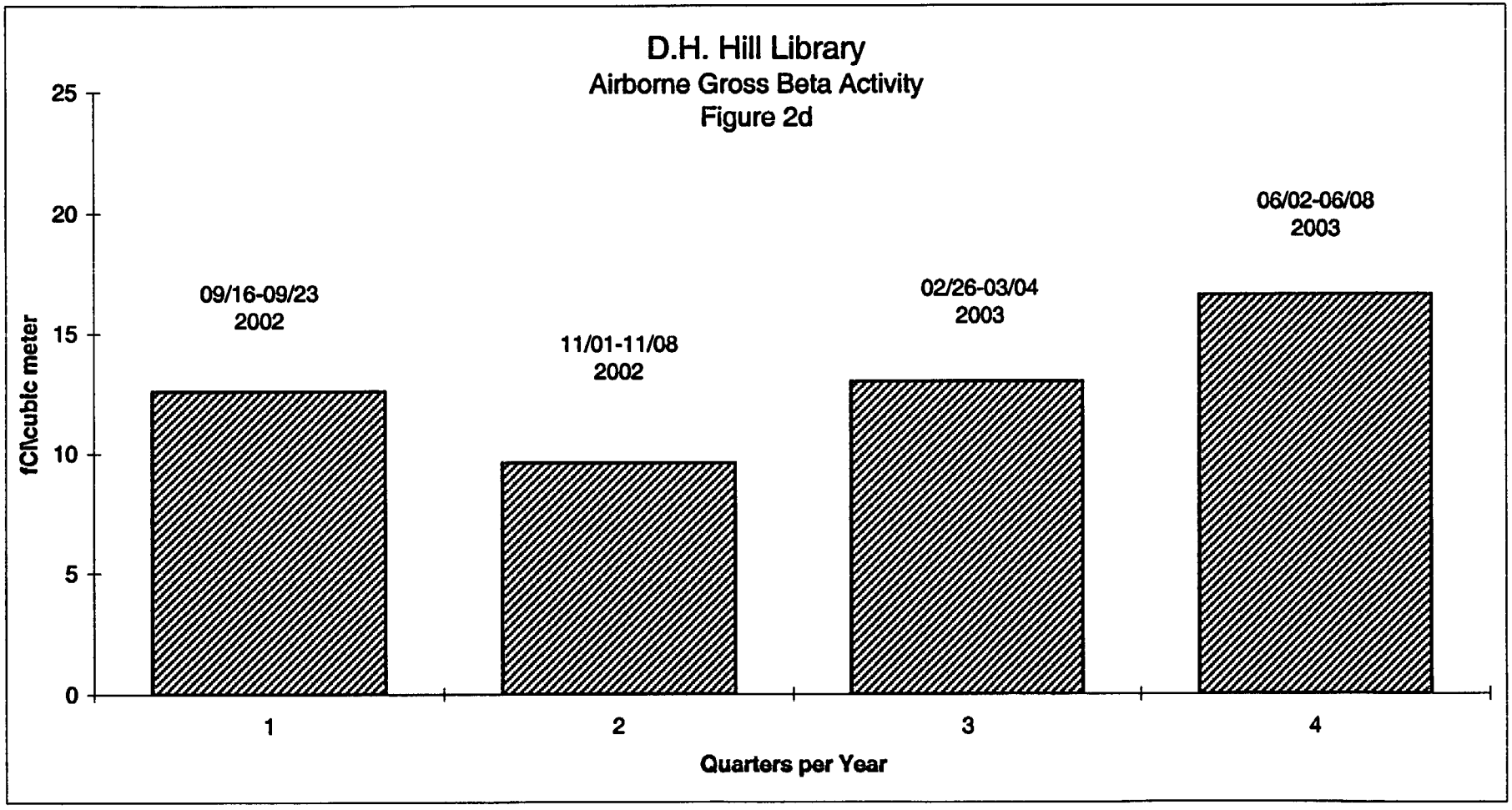
A wind rose is included in Appendix 2 to indicate the prevailing wind direction trends for the years 1996-2003.

Table 2.2 Aerially Transported Gamma Activity				LLD values fCi/cubic meter					
					NUCLIDES				
SAMPLING PERIOD	**Co-57**	**Co-60**	**Nb-95**	**Zr-95**	**Ru-103**	**Ru-106**	**Cs-137**	**Ce-141**	**Ce-144**
2002									
09/16 - 09/23	0.21	0.44	0.29	0.46	0.27	2.25	0.33	0.36	1.21
11/01 - 11/08	0.21	0.44	0.28	0.48	0.28	2.48	0.35	0.34	1.28
2003									
02/26-03/04	0.17	0.37	0.32	0.53	0.32	2.49	0.23	0.42	1.42
06/02-06/08	0.17	0.31	0.31	0.51	0.36	2.43	0.26	0.38	1.41


Broughton Hall
Airborne Gross Beta Activity
Figure 2a
fCi/cubic meter
25
20
15
10
5
0
09/16-09/23
2002
11/01-11/08
2002
02/26-03/04
2003
06/02-06/08
2003
1
2
3
4
Quarters per Year


Withers Hall
Airborne Gross Beta Activity
Figure 2b
fCi/cubic meter
25
20
15
10
5
0
09/16-09/23
2002
11/01-11/08
2002
02/26-03/04
2003
06/02-06/08
2003
1
2
3
4
Quarters per Year


Riddick Hall
Airborne Gross Beta Activity
Figure 2c
fCi/cubic meter
25
20
15
10
5
0
09/16-09/23
2002
11/01-11/08
2002
02/26-03/04
2003
06/02-06/08
2003
1
2
3
4
Quarters per Year


D.H. Hill Library
Airborne Gross Beta Activity
Figure 2d
fCi\cubic meter
25
20
15
10
5
0
09/16-09/23
2002
11/01-11/08
2002
02/26-03/04
2003
06/02-06/08
2003
1
2
3
4
Quarters per Year

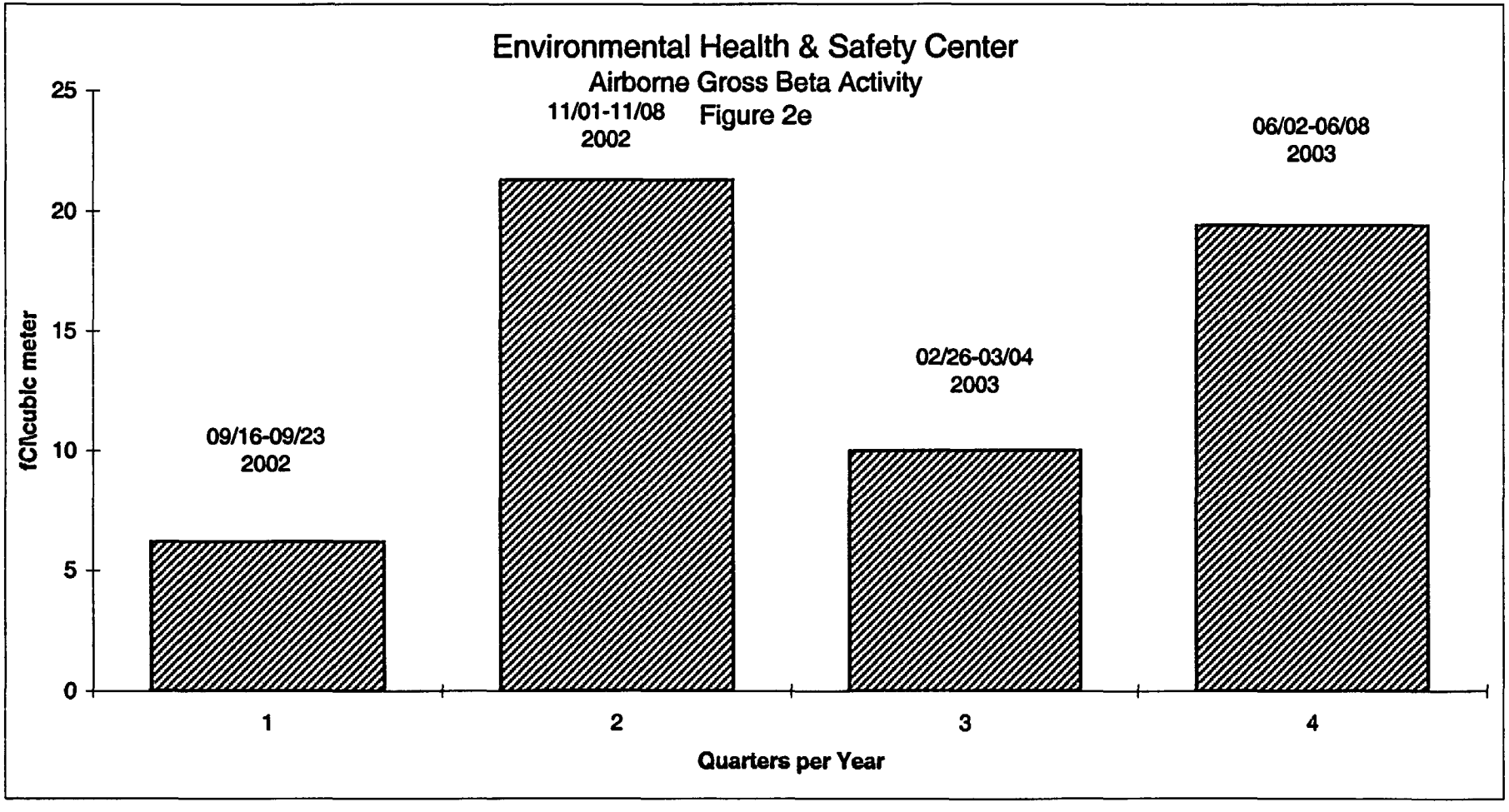

Environmental Health & Safety Center
Airborne Gross Beta Activity
Figure 2e
11/01-11/08
2002
06/02-06/08
2003
02/26-03/04
2003
09/16-09/23
2002
fCi\cubic meter
25
20
15
10
5
0
1
2
3
4
Quarters per Year

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	14.7 ; 3.1*
Cs-137	5×10^5	10	2
Ce-144	2×10^5	100	0
Ru-106	2×10^5	30	0
I-131	1×10^5	10	0

* These data represent a range of annual average values measured in North Carolina. Data courtesy of Dale Dusenbury of the N.C. Division of Radiation Protection.

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

3. MILK (TABLES 3.1A and 3.1B)

Milk samples are collected in alternate years from the Campus Creamery and the Lake Wheeler Road Dairy and analyzed for I-131. Data given for the years 2003 and 2001 shows that no I-131 activity was detected. The next sample collection will be in 2005.

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
June 2003	< 3	< 3

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

	pCi Liter^{-1}	
DATE	Campus Creamery	Lake Wheeler
May 2001	< 3	< 3

4. SURFACE WATER (TABLES 4.1 AND 4.2)

Table 4.1 gives the gross alpha and beta activities for water from Rocky Branch at points where it enters (ON) and exits (OFF) the campus. The LLD value for gross alpha and beta activities is ~ 0.4 pCi Liter^{-1}. For gross alpha activity the Alert Level is 5 pCi Liter^{-1} and the Regulatory Limit is 15 pCi Liter^{-1}. For gross beta activity the Alert Level is 5 pCi Liter^{-1} and the Regulatory Limit is 50 pCi Liter^{-1}. Samples with gross alpha or beta activities exceeding these Alert Levels would require gamma analysis to identify the radionuclides present. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 4.2 were detected.

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

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

		pCi Liter^{-1}	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
THIRD QUARTER 2002	ON	< 0.4	2.5 ± 0.7
	OFF	< 0.4	2.8 ± 0.7
FOURTH QUARTER 2002	ON	< 0.4	5.1 ± 0.8
	OFF	< 0.4	1.5 ± 0.6
FIRST QUARTER 2003	ON	2.2 ± 0.5	3.2 ± 0.7
	OFF	< 0.4	3.0 ± 0.7
SECOND QUARTER 2003	ON	< 0.4	2.8 ± 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. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 5.2 were detected. The next sample collection will be in 2005.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ± 2σ)
03/14/2003	NORTH CAMPUS	11.1 ± 0.2
03/14/2003	SOUTH CAMPUS	6.7 ± 0.2
03/14/2003	EAST CAMPUS	2.4 ± 0.1
03/14/2003	WEST CAMPUS	3.0 ± 0.1

TABLE 5.2 LLD VALUES FOR GAMMA EMITTERS IN VEGETATION

NUCLIDE	LLD (pCi gram^{-1})
Co-60	0.01
Zn-65	0.02
Cs-137	0.01
Cs-134	0.01
Sr-85	0.01
Ru-103	0.01
Nb-95	0.01
Zr-95	0.02

6. THERMOLUMINESCENT DOSIMETERS (TLDs) (TABLE 6.1)

TLD analysis is contracted to Landauer, Inc. for determination of ambient gamma exposures. Exposures are integrated over a three-month period at each of the five air monitor stations listed in Table 2.1 and inside the PULSTAR Reactor stack and at North Hall. A control station is located in Room 107 of the Environmental Health & Safety Center. Table 6.1 gives the data for these eight (8) locations.
The exposures (dose equivalents) are reported as millirem per quarter year. Readings which fall below the dosimeters' minimum measurable quantities (i.e., 1 millirem for gamma radiations and 10 millirems for beta radiations) are reported by the contract vendor with the designation "M ". The observed readings are all within the expected range for natural background radiation levels.

Historically, dosimeter readings for D.H. Hill Library monitoring station have often been higher than those for the other campus stations. Pursuant to a recommendation made in the "NCSU PULSTAR 2001 Annual Self Assessment", two additional TLDs have been added to the D.H. Hill Library station to supplement the existing dosimeter. These two additional dosimeters are a routine part of the quarterly monitoring schedule.

TABLE 6.1	ENVIRONMENTAL TLD EXPOSURES (mrem/QUARTER YEAR)							
DATE	WITHERS	RIDDICK	BROUGHTON	DH HILL*	EH&S	PULSTAR STACK	NORTH	CONTROL
2002								
07/01-09/30	M	M	M	M,M,M	M	M	M	M,M
10/01-12/31	M	14	4	13,18,22	9	8	10	M,6
2003								
01/01-03/31	M	8	M	9,15,25	3	M	M	M,M
04/01-06/30	M	5	M	7,13,13	M	M	M	M,2

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

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

The designation "M" is used by the contract vendor for reporting dose equivalents below the minimum measurable quantity which is 1 millirem for gamma radiation and 10 millirem for beta radiation

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory (ERSL) of the Radiation Safety Division has analyzed samples provided by the U.S. DOE Environmental Measurements Laboratory Quality Assurance Division Program (QAP 57) 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-d) 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 57 were developed from the percentiles of data distributions for the years 1997-2002.

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-d), 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 2002

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	EML Value	EML Error	Reported / EML
Gross Alpha	0.277	0.062	0.287	0.029	0.965
Gross Beta	0.912	0.187	0.871	0.087	1.047

QAP 57 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Gross Alpha	0.287	0.029	1.054	1.025	0.143	88
Gross Beta	0.871	0.087	0.921	0.904	0.099	88

QAP 57 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Gross Alpha	0.73	0.84	1.21	1.43
Gross Beta	0.76	0.85	1.21	1.36

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

TABLE 7.1b
MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 September 2002
The sample consists of one 7 cm diameter glass fiber filter which has been spiked with 0.10 gram of solution and dried. The reported values and the known values are given in Bq/filter.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported / EML
Co60	23.168	0.705	23.000	0.059	1.007
Cs137	33.912	1.645	32.500	0.777	1.043
Mn54	53.429	2.216	52.200	1.170	1.024

QAP 57 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Co60	23.000	0.059	1.014	1.013	0.073	131
Cs137	32.500	0.777	1.045	1.038	0.095	134
Mn54	52.200	1.170	1.047	1.040	0.103	129

QAP 57 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Co60	0.80	0.90	1.11	1.26
Cs137	0.80	0.90	1.17	1.32
Mn54	0.80	0.90	1.19	1.35

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

TABLE 7.1c
MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 September 2002

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	EML Value	EML Error	Reported EML
Co60	273.998	8.614	268.670	9.710	1.020
Cs137	77.639	4.170	81.430	4.280	0.953
Cs134	56.137	2.062	60.200	1.860	0.933

QAP 57 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Co60	268.670	9.710	1.022	1.021	0.053	145
Cs137	81.430	4.280	1.032	1.029	0.055	151
Cs134	60.200	1.860	0.977	0.972	0.076	135

QAP 57 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Co60	0.80	0.90	1.10	1.20
Cs137	0.80	0.90	1.12	1.22
Cs134	0.80	0.90	1.14	1.30

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

TABLE 7.1d
GROSS ALPHA AND BETA WATER SAMPLE - INTERCOMPARISON STUDY
01 September 2002

The sample consists of a 4 mL aliquot of ~1 N HCl matrix free solution. The reported values and the known values are given in Bq/Liter.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported / EML
Gross Alpha	207.070	30.495	210.000	21.000	0.986
Gross Beta	901.840	100.555	900.000	90.000	1.002

QAP 57 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Gross Alpha	210.000	21.000	1.032	1.052	0.139	74
Gross Beta	900.000	90.000	0.960	0.944	0.113	92

QAP 57 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Gross Alpha	0.58	0.79	1.13	1.29
Gross Beta	0.61	0.81	1.29	1.43

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 = $\bar{x}$

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

where N = number of results = 3

Experimental sigma = s

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

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

s = 103.9 pCi/liter

Range = r

r = |maximum result - minimum result|

r = |3240 - 3060|

r = 180 pCi/liter

Range Analysis (RNG ANLY)*

Mean range = $\bar{R}$

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

$= (1.693)\ (357)$

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

Control limit = CL

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

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

$= (2.575)\ (604.4)$

CL = 1556 pCi/liter

Standard error of the range = σ_R

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

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

$= (1556 - 604.4) \div 3$

σ_R = 317.2 pCi/liter

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

Define normalized range = $w + x$

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

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

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

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

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

$$= 3120 - 3273$$

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

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

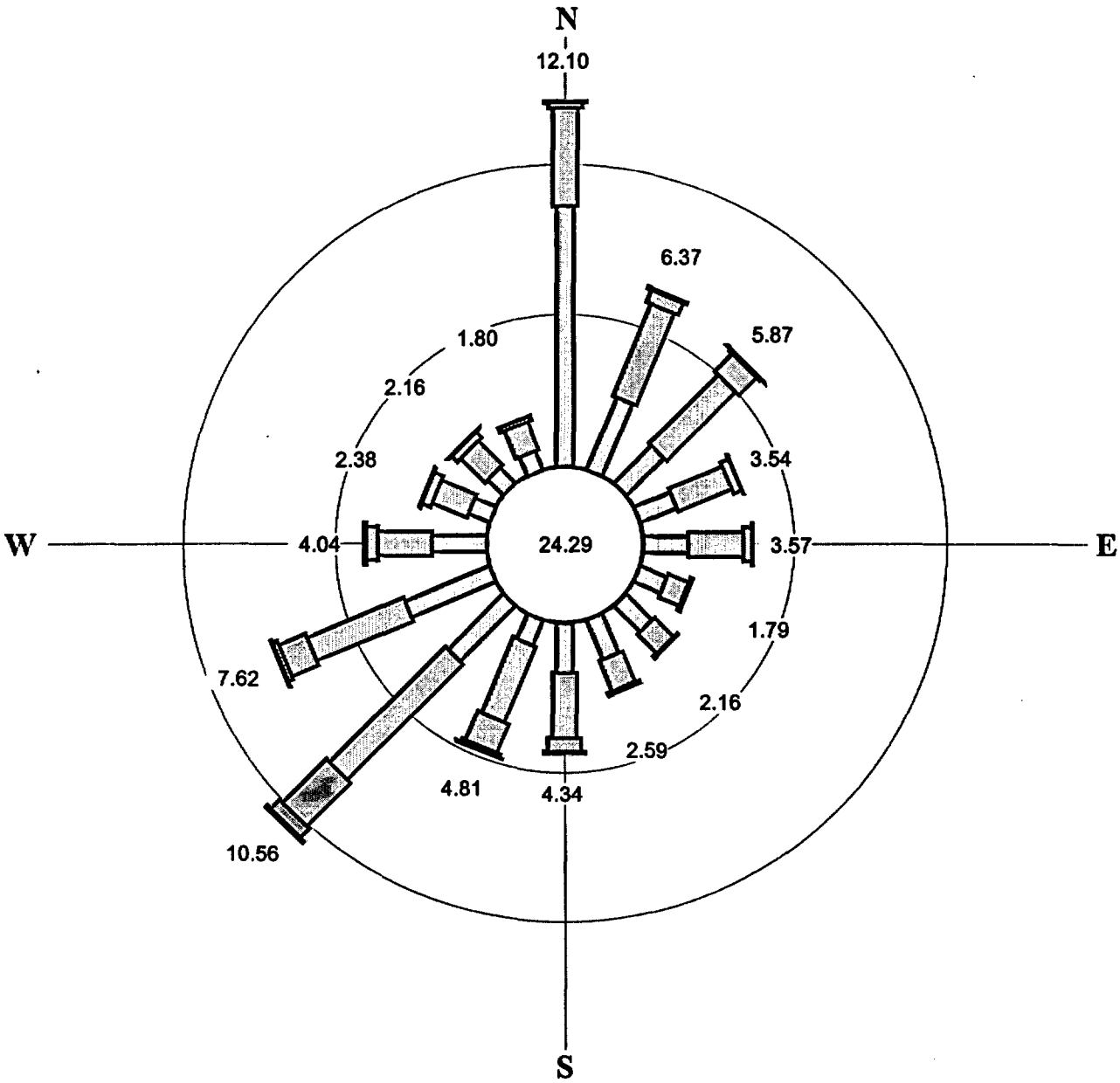
$$ND' = \frac{D'}{\sigma_m}$$

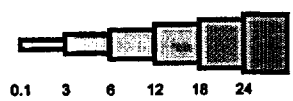
$$= \frac{-170}{206.1}$$

ND' = - 0.8

Appendix 2

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





Wind Speed (Miles Per Hour)

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

Wind Rose Courtesy of Ryan Boyles of the State Climate Office of North Carolina.