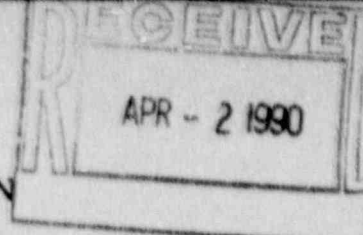
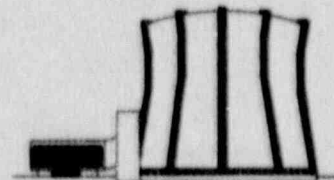


TEXAS ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY  
COLLEGE STATION, TEXAS 77843-3575



30 March 1990



NUCLEAR SCIENCE CENTER  
409/845-7551

Mr. Robert D. Martin  
Regional Administrator  
U.S. Nuclear Regulatory Commission  
Region IV  
611 Ryan Plaza Drive, Suite 1000  
Arlington, Texas 76011

Dear Mr. Martin:

In accordance with the reporting requirements of Technical Specification 6.6.1 for the Texas A&M University Nuclear Science Center Reactor we hereby submit three copies of our annual report for the period of January 1, 1989 - December 31, 1989.

Sincerely,

Donald E. Feltz  
Director

DEF/ym

Enclosures

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PDR ADOCK 05000128  
R PNU

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U.S. ATOMIC ENERGY COMMISSION  
UNIVERSITY-TYPE CONTRACTOR'S RECOMMENDATION FOR  
DISPOSITION OF SCIENTIFIC AND TECHNICAL DOCUMENT

(See Instructions on Reverse Side)

1. AEC REPORT NO.

ORO-4207-22

2. TITLE

Twenty-Sixth Progress Report of the  
Texas Engineering Experiment Station,

3. TYPE OF DOCUMENT (Check one):

Texas A&M University System,  
Nuclear Science Center

- ☐ a. Scientific and technical report  
☐ b. Conference paper not to be published in a journal:

Title of conference \_\_\_\_\_

Date of conference \_\_\_\_\_

Exact location of conference \_\_\_\_\_

Sponsoring organization \_\_\_\_\_

- ☒ c. Other (Specify) Facility Annual Progress Report (1989)  
USNRC License R-83, Docket No. 50-128

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Donald E. Feltz, Director

Organization

Nuclear Science Center  
Texas Engineering Experiment Station  
Texas A&M University System

Signature

*Donald E. Feltz*

Date

30 March 1990

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☐ c. Patent clearance not required.

U. S. ATOMIC ENERGY COMMISSION  
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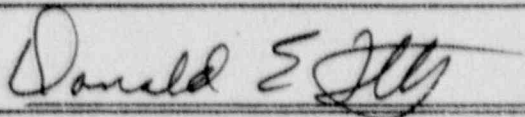
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Donald E. Feltz, Director

Organization

Nuclear Science Center  
Texas Engineering Experiment Station  
Texas A&M University System

Signature



Date

30 March 1990

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RECOMMENDATION:

B. PATENT CLEARANCE:

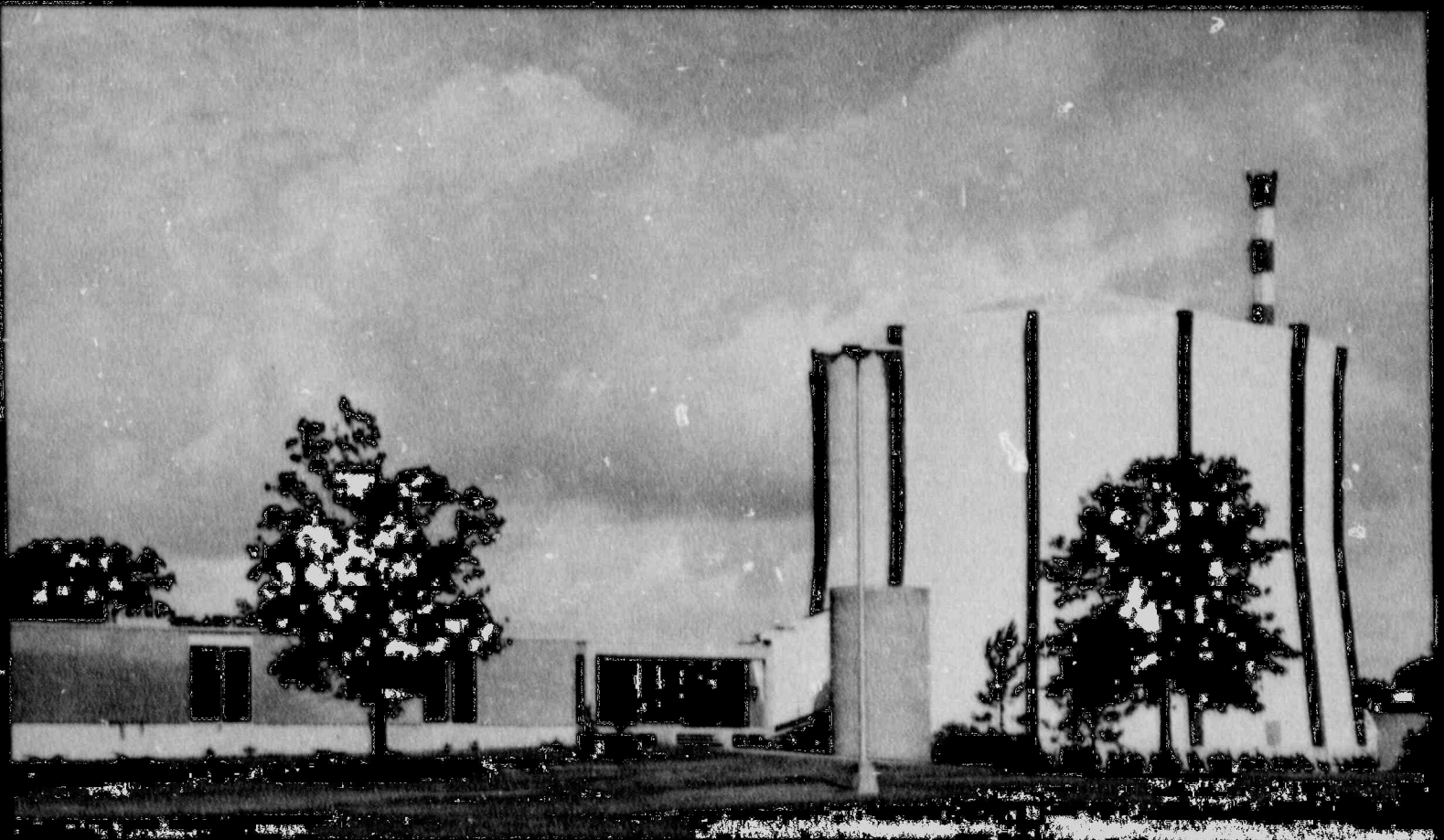
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☐ c. Patent clearance not required.



TWENTY-SIXTH PROGRESS REPORT  
OF THE  
TEXAS A&M UNIVERSITY  
NUCLEAR SCIENCE CENTER  
JANUARY 1, 1989-DECEMBER 31, 1989  
CONTRACT DE-ACO5-76ER04207



NUCLEAR SCIENCE CENTER  
TEXAS ENGINEERING EXPERIMENT STATION  
ENGINEERING PROGRAM  
TEXAS A&M UNIVERSITY SYSTEM  
COLLEGE STATION, TEXAS

4004100054 938



T W E N T Y - S I X T H   P R O G R E S S   R E P O R T

of

TEXAS ENGINEERING EXPERIMENT STATION  
TEXAS A&M UNIVERSITY SYSTEM  
NUCLEAR SCIENCE CENTER

Facility License No. R-83  
Docket No. 50-128

January 1, 1989 - December 31, 1989

Prepared by

The Nuclear Science Center Staff

Submitted to

U.S. Nuclear Regulatory Commission

and

U.S. Department of Energy

and

The Texas A&M University System

By

D. E. Feltz, Director  
Nuclear Science Center  
Texas Engineering Experiment Station  
College Station, Texas

March, 1990

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## I. INTRODUCTION

The Nuclear Science Center is operated by the Texas Engineering Experiment Station as a service to the Texas A&M University System and the State of Texas. The facility is available to the University, organizations and individuals. The facility operating license, R-83 issued by the U.S. Nuclear Regulatory Commission, currently extends through March, 2003.

This report has been prepared by the staff of the Nuclear Science Center of the Texas Engineering Experiment Station to satisfy the reporting requirements of Technical Specification 6.6.1 to the facility operating license R-83 and of U.S. DOE Contract #DE-AC05-76ERO4207 (formerly EY-76-C-05-4207) and 10CFR50.59. The report covers the period from January 1, 1989 through December 31, 1989.

Total operating hours of the reactor increased over 1988 values. The total experiment hours were approximately the same as 1988 with a decrease in sample irradiation hours. Beam port and irradiation experiments continued to increase and there was a decrease in irradiation cell experiment hours compared to 1988. These changes in utilization were due primarily to the characteristics of the experiments performed. Commercial utilization and the number of tours increased.

Core VIII-A, which has been operational since March 1986, was used throughout 1989. Pulse operations were continued at a low level in 1989 with a total of 40 pulses (\$61.48 total pulse reactivity) executed. As in the previous few years, pulsing operations were restricted mostly to calibrations and laboratory demonstrations.

There were no changes made to the site area during this reporting period and no changes were made to the security or emergency systems.

## II. REACTOR UTILIZATION

### A. Utilization Summary

Utilization of the NSCR for the 1989 calendar year is illustrated by Figure I and Table I. Figure I shows the annual totals for reactor operation for the years 1975 through 1989. During the present reporting period the NSCR was utilized by over 500 students (including 48 researchers) and 29 faculty and staff members representing 15 departments at Texas A&M University. In addition, more than 180 faculty and students from 15 other educational institutions used the facilities and 3,729 visitors were registered during 1989. A total of 19 non-educational organizations utilized the NSCR during the year for their commercial and research applications.

During twenty-eight years of operation, the NSC has provided services to 46 departments at Texas A&M University, 114 other colleges and universities, 103 industrial organizations, and 25 governmental and medical organizations (see Appendix III and IV for listings).

### B. Utilization by the Texas A&M University System

During 1989 the following personnel from various departments at Texas A&M University used the NSCR for research. Appendix I describes some of the projects completed.

#### Animal Science

Faculty: Dr. W. C. Ellis, Professor  
Dr. L. W. Greene, Associate Professor

Students: S. Rodriguez  
S. Martin  
G. Stout

#### Center for Chemical Characterization and Analysis (CCCA)

Staff: Dr. E. Schweikert, Professor  
Dr. D. James, Research Chemist  
M. Raulerson, Technician  
T. Woods, Technician

Students: J. Speed  
I. Ewa  
B. Grazmann  
M. Inman



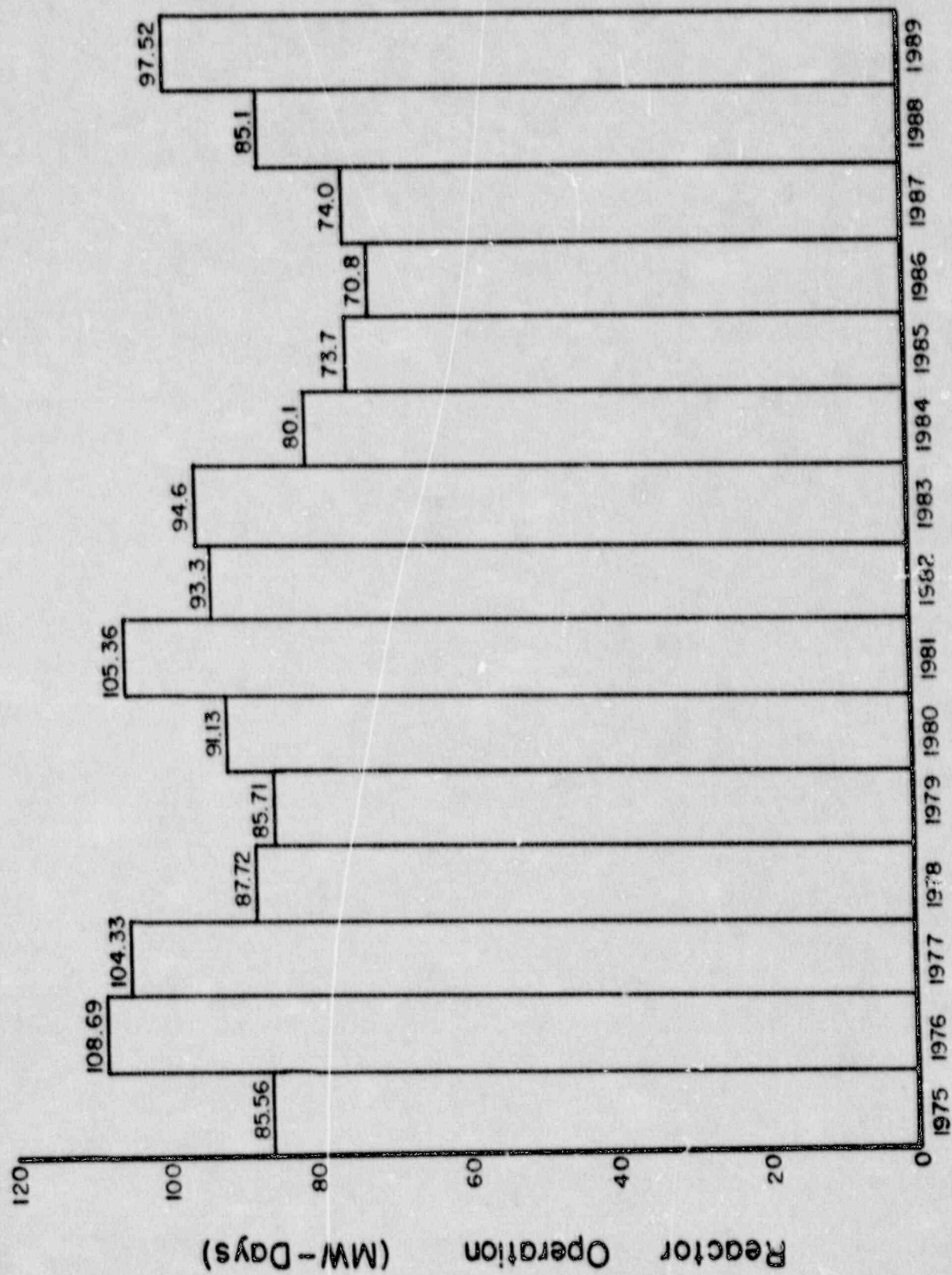


Figure 1. Yearly Reactor Operation

TABLE I  
REACTOR UTILIZATION SUMMARY

	<u>1989 Annual Total</u>
*Number of Days Reactor Operated	240
Reactor Operation (MW-Days)	97.52
Number of Hours at Steady State	2433.017
Average Number of Operating Hours Per Week	48.66
Total Number of Pulses	39
Total Pulse Reactivity Insertion	\$61.48
Number of Irradiations	625
Number of Samples Irradiated	10,401
Sample Irradiation Hours	59,559.151
Average Number of Irradiations per Operating Day	2.604
Irradiation Experiment-Hours	7926.192
Beam Port Experiment-Hours	421.754
Irradiation Cell Experiment Hours	33.735
Total Experiment Hours	8381.681
Fraction of Utilization Attributable to Commercial Work	.37
Number of Visitors	3729

\*Note: 50 Weeks of Operation Available

The NSCR was converted in August 1968 from the use of MTR plate fuel to TRIGA fuel with pulsing capability. Since the conversion both Standard TRIGA and FLIP TRIGA fuels have been used and at present the NSCR core has a full FLIP TRIGA loading. Since the initial use of TRIGA fuel the total energy produced by operations is 1,925.225 Mw-Days.

Chemistry Department

Faculty: Dr. M. W. Rowe, Professor  
 Dr. R. Zingaro, Professor  
 Dr. T. R. Hughbanks, Assistant Professor

Students: J. Russ  
 C. Brumlik

Electrical Engineering

Faculty: Dr. D. Parker

Student: S. Lee

Geology Department

Faculty: Dr. T. Tieh, Professor  
 V. Harder, Lecturer

Student: M. Denham

Geophysics Department

Faculty: Dr. N. Carter, Professor

Students: A. Huffman  
 T. Oldham

Mechanical Engineering Department

Faculty: Dr. D. Bray, Associate Professor

Student: P. Junghans

Nuclear Engineering Department

Faculty: Dr. J. W. Poston, Professor and Head  
 Dr. R. R. Hart, Professor  
 Dr. D. W. James, Associate Professor  
 Dr. M. E. McLain, Associate Professor  
 Dr. T. A. Parish, Associate Professor  
 Dr. J. A. Reuscher, Professor

Students:	L. Foster	S. Hayes
	P. Lee	R. Frymire
	S. Midgett	S. Menon
	J. Wright	A. Velasquez
	S. Narrow	P. Tissot
	I. Carron	M. Nguyen
	K. Miller	M. Mallet
	A. Lambert	S. Sloan
	C. Beard	J. Rennie
	J. Pruitt	T. Bagwell
	D. Senior	C. Oxley



Nuclear Science Center

Staff: J. Krohn, Assistant Director and Manager  
of Technical Services  
N. Khalil, Research Associate  
G. Stasny, Reactor Supervisor  
D. Deere, Research Associate  
J. Petesch, Reactor Supervisor  
C. Meyer, Health Physicist

Oceanography Department

Faculty and Staff: Dr. P. Boothe, Asst. Research Scientist

Petroleum Engineering

Faculty: Dr. W. Von Gonten

Student: K. Zoeller

Physics Department

Faculty: Dr. J. A. McIntyre, Professor

Students: R. Seidel

Range Science

Faculty: Dr. R. Knight

Student: R. Lyons

Radiological Safety Office

Staff: Dr. M. E. McLain, Radiological Safety  
Officer  
J. Simek, Assistant Radiological Safety  
Officer  
C. Meyer, Senior Health Physicist

Veterinary Physiology and Pharmacology

Faculty: Dr. D. Hightower, Professor  
M. Chambers, Vet. Clin. Assoc.

In addition to the research performed by the above personnel, the NSCR was used as an educational aid in numerous courses at Texas A&M. Table II lists the academic courses utilizing the reactor and their use.

C. Utilization by Other Educational Institutions

In addition to Texas A&M University, services were provided to the following educational institutions through the Department of Energy Reactor Sharing Program. A description of some of the projects utilizing the reactor is presented in Appendix I.

Baylor University -- Waco, Texas

Faculty: Dr. Ken-Hsi Wang, Professor of Physics

Students: Physics Class

East Texas State University -- Commerce, Texas

Faculty: Dr. Razniak

Louisiana State University -- Baton Rouge, Louisiana

Faculty: Dr. Ron Knaus

Students:	D. Von Gent	A. Showler
	S. Brown	J. Nguyen
	P. McKay	

Louisiana Tech -- Ruston, Louisiana

Faculty: Dr. R. Thompson

McLennan Community College -- Waco, Texas

Faculty: Mr. Don Tatum, Instructor of Physics

Students: Physics Class

McNeese State -- Lake Charles, Louisiana

Faculty: Dr. J. Beck

TABLE II  
Academic Use of the Reactor

<u>Department</u>	<u>Course No.</u>	<u>Instructor</u>	<u>No. of Students and Purpose</u>
Building Construction	336	Woods	40-Tour
Environmental Health	331	Kingery	23-Tour
Nuclear Engineering	101	Davis	13-Tour
	402	James	12-Tour/Demo
	405	Schlapper	15-Lab/Class
	479	Schlapper	15-Tour
	606	Reuscher	19-Lab/Class
Oceanography	640	Boothe	10-Tour



Miami University -- Oxford, Ohio

Faculty: Dr. K. Crowley

Student: J. Corrigan

Southern Methodist University -- Dallas, Texas

Faculty: Dr. S. Kelley

Sul Ross State University -- Alpine, Texas

Faculty: Dr. D. Nelson  
Dr. J. Richerson

Students: K. Nelson

Texas State Technical Institute -- Waco, Texas

Faculty: Mr. R. Wheet, Instructor  
Ms. G. Martini

Students: Nuclear Technology Classes

University of New Hampshire -- Durham, New Hampshire

Faculty: A. Conners  
J. Macri

University of Oklahoma -- Norman, Oklahoma

Faculty: Dr. B. Weaver

Students: J. Aquilar  
P. Anderson

University of Southwestern Louisiana -- Lafayette, Louisiana

Faculty: Dr. J. Meriwether

University of Texas -- Austin, Texas

Faculty: Dr. J. Kyle  
Dr. F. Iskander  
T. Bergman  
K. Milliken  
P. Schmidt

Student: B. Coel

University of Texas -- El Paso, Texas

Faculty: E. Anthony

Public and Private School Tours

No. of Students

A&M Consolidated -- College Station, TX	79
Bammel High School -- Houston, TX	40
Bryan/College Station Science Teachers	58
Buckholts High School -- Buckholts, TX	23
Conroe Home School -- Conroe, TX	56
Centerville High School -- Centerville, TX	17
Cy Fair High School -- Houston, TX	21
Del Valle High School -- Austin, TX	38
East Texas State University -- Commerce, TX	13
Engineering Program for Minorities -- TAMU	36
Hardin Jefferson High School -- Sour Lake, TX	23
Honors Program -- TAMU	95
Jane Long Jr. High -- Bryan, TX	36
Jeff Davis High School -- Houston, TX	26
Jersey Village High School -- Houston, TX	75
Jets Chapters -- Needville & San Antonio, TX	75
Lamar School -- Bryan, TX	135
Lumberton High School -- Lumberton, TX	34
McCullough High School -- Woodlands, TX	37
Moody High School -- Moody, TX	23
Pearsall High School -- Pearsall, TX	8
Queen City High School -- Queen City, TX	11
Rockdale High School -- Rockdale, TX	40
Sharpstown High School -- Houston, TX	41
Stephen F. Austin University -- Nacogdoches, TX	36
Teague High School -- Houston, TX	36
Tyler Jr. College -- Tyler, TX	31
Wells Middle School -- Houston, TX	44
Woodville High School -- Livingston, TX	27

D. Utilization by Non-University Institutions

AAE/BCS Traders -- Globe, Arizona

Experimenter: D. Williams

Amber Engineering -- Goleta, California

Experimenter: C. Woolaway

Brown and Associates -- College Station, Texas

Experimenter: J. Fares

Texas Instruments -- Dallas, Texas

Experimenters: C. Blackburn

Tracerco, Inc. -- Houston, Texas

Experimenters: R. Gilman  
D. Bucior

TRW-EDS -- Redondo Beach, California

Experimenters: D. Randall  
T. Lunn

Tru-Tec -- LaPorte, Texas

Experimenter: C. Winfield  
J. Landry



### III. FACILITY OPERATIONS

#### A. Facility Improvements

##### New Facility Air Conditioning Units

Two new smaller air conditioning chill water cooling units were installed as replacement of an older unit that could not be repaired.

#### B. Improvements to Reactor Systems and Experimental Facilities

##### Miscellaneous Equipment Control Drawer

This drawer was completely rebuilt with new components and a new face format. The drawer still controls the following devices: lower research level access controls, front gate, C-2 warning devices, cell/pneumatic exhaust fan, water shutter indications, and operator status board.

##### Facility Air Monitor Meters

New FAM meters were installed as replacement of meters in the reactor control room and the reception room. The old meters were hard to find, very expensive, and difficult to calibrate. The new meters are better in all of these respects.

##### New Switches for Reactor Console

Pump switches were replaced and solid state control circuits provided for water system control. These type switches have reduced electronic noise sources considerably. As a result, there have been fewer spurious signals to the reactor instrumentation. A heavy duty reactor console power switch was installed as a replacement to improve reliability.

##### Diffuser Pump and Transient Rod Surge Tank Blowdown Piping Rearrangement

The diffuser pump piping and transient rod blowdown piping were rearranged under the reactor bridge to make room for the new east face irradiator.

##### Additional Rotisserie Irradiation Device Storage

To expand the capacity of rotisserie storage a new rack was installed on the north pool wall. The rack has storage positions for 12 rotisserie irradiation devices.

#### Additional Sump Pump Strainer and Blow Down

A new strainer and strainer blowdown piping were installed parallel to the old sump pump strainer and blowdown. These strainers prevent solids from reaching the liquid waste holdup tanks. The blowdown piping enables the strainers to be cleaned periodically.

#### Self Adjusting Skimmer Head

The old skimmer heads would not work well with different pool levels due to the difficulty in adjusting their heights. A new single skimmer head was designed to be self-adjusting and is working fine.

#### Cross-Connect Valves in the Facility Air Monitoring System

New valves for this system were added upstream of the main flow control panel. These valves allow a cross connect between air sampling locations and detectors. In case a detector normally required for operations is out of service, the appropriate sampling location can be changed to another operable detector.

#### Beam Port #1 Collimator

A series of cylinders of graphite, borated paraffin, lead, boroflex, and concrete were placed inside Beam Port #1 to act as a collimator of neutrons. This creates a narrower and more controllable neutron beam for experiments.

### C. Operational Problems

#### Reportable Occurrence 89-01

##### Adjustment of Linear Channel Compensating Voltage

There was a requirement to adjust the linear channel compensating voltage due to a significant increase in scheduled reactor operating hours. When additional night shift operations were added, the increase in core power history caused the startup gammas to be more significant at low power levels. The compensation voltage was reset and normal readings returned. All required tests were performed and the instrument was returned to normal operation.

#### Beam Port #1 Water Shutter Repair

A down leg of the water shutter was leaking at the union with the beam port piping. The down leg leak was repaired using a saddle at the union. A gasket was used to seal the saddle to the beam port piping. The saddle is held in place against the beam port piping with two stainless steel straps. This design has performed well since installation.

### Failure of Compressed Supply Air Piping

Compressed air supply piping between the demineralizer room and the tunnel area suffered a corrosion stress fracture. Galvanized piping was used for replacement which has a greater resistance against moisture corrosion than the previous used iron piping.

### Control Rod Drive Circuitry Troubleshooting

The control rod drive units exhibited infrequent malfunctions in withdrawal operation and position indication over the year. In each case, the circuitry was either repaired or replaced immediately and operation of the circuitry was tested to ensure it performed in accordance with all previously approved changes and modifications.

### D. Procedural Changes

Changes to the following SOP's were reviewed and approved by the Reactor Safety Board during the reporting period:

#### SOP's

II-C	Reactor Startup
Figure II-C-1(c)	Pre-Startup Checklist
III-I	Scram Circuit Surveillance
III-L	Control Rod Drive Maintenance
Figure III-B-2(a)(b)	Fuel Element Temperature Measuring Channel - Semiannual Maintenance
Figure III-E-2(a)(b)	Safety Power Measuring Channel - Annual Maintenance
Figure III-I-2	Scram Circuit Surveillance - Semiannual Check
IV-C	Pneumatic System Operation
IV-D	Beam Port Experiments
IV-F	Neutron Radiography Beam Port #4
IV-H	Thermal Column Film Irradiator
Figure VI-B-1(a)(b)	Weekly Reactor Maintenance
VII-A3	Reporting Requirements
VII-B4	Daily Facility Air Monitoring Check
VII-B7	Area Radiation Monitors
VII-B14	Personnel Dosimeters
VII-C2	Radioactive Materials Released Off-Site
VII-C3	Radioactive Materials Released to Campus
VII-C6	Radioactive Materials Storage
VII-C7	Radioactive Solid Waste Disposal
VII-C14	Facility Contamination Survey
VII-E1	Radiation Monitoring Devices and Exposure Control Guides
VIII-D	Safeguards Information



### E. Unscheduled Shutdowns

A total of seven unscheduled shutdowns occurred during 1989. The unscheduled shutdowns were caused by the following:

One shutdown caused by equipment failure in a fail-safe mode.  
One shutdown caused by Safety Channel #2 instrumentation spike.  
One shutdown caused by a sticking period meter during startup.  
Four shutdowns due to complete power loss to the facility.

\*There were no shutdowns due to operator error this year.

### F. Reactor Maintenance and Surveillance

1. The Technical Specification requirements for maintenance and surveillance were completed for all required channels as follows:

Fuel Element Temperature Measuring Channel  
Linear Power Channel  
Log Power Channel  
High Power (Safety) Channels  
Facility Air Monitoring Channels  
Area Radiation Monitoring Channels

All control rods were calibrated during annual maintenance performed in January, 1989 with a total rod worth of \$15.75 and a shutdown margin of \$2.73.

The power level (linear) channel was calibrated by the calorimetric method on 1/5/89.

The rod scram time checks resulted in times less than the Technical Specification limit of 1.2 seconds.

Fuel elements requiring inspection were inspected by 5 January 1989.

All other required maintenance as set forth in the Technical Specifications was performed annually, semi-annually, or weekly as required. This was in addition to completion of a pre-startup checklist done daily prior to reactor operation, and other daily checks.

2. The pulse mode is calibrated annually by comparison of flux foils. Operability is verified semi-annually by pulsing for comparison of pulse energy and temperature.

The maximum allowable pulse reactivity insertion is \$2.09 for Core VIII-A as determined by a pulse test program. An administrative limit of \$1.90 is imposed for pulse operations.

3. The reactivity worth for each experiment was measured or estimated as appropriate before performance of the experiment. The most reactive fixed experiment is the Thermal Column coupler with a value of \$1.35.
4. The biennial Emergency Preparedness drill was conducted on April 20, 1989.
5. A review of the NSC security plan and emergency plan was conducted by the NSC staff and the Reactor Safety Board on 2/10/89.
6. A review of the NSC ALARA program was conducted by the NSC staff and the Reactor Safety Board on 2/10/89.

#### IV. FACILITY ADMINISTRATION

##### A. Organization

The organization chart for reactor operations at the Nuclear Science Center is presented in Figure 2. During this reporting period Thom Ives joined the NSC staff filling the position of the Manager of Reactor Operations. James C. Luther was hired as a full-time Reactor Operator in November. The problem of high turn-over among the student operators during the previous years has improved as we presently have two highly qualified licensed individuals who are in their first or second year of college.

During the past year Thom Ives, Sean O'Kelly, and Shane Brightwell received Senior Reactor Operator licenses.

##### B. Personnel

The following is a list of personnel at the Nuclear Science Center for the period of January 1, 1989 - December 31, 1989.

##### Facility Administration and Reactor Operations Staff

+Brightwell, D. S.	- Reactor Operator
+Feltz, D. E.	- Director
+Ives, T. W.	- Manager of Reactor Operations
+Krohn, J. L.	- Assistant Director
Luther, J. C.	- Reactor Operator (Trainee)
+O'Kelly, D. S.	- Senior Reactor Operator
+Petesch, J. E.	- Reactor Supervisor
Reuscher, J. A.	- Professor, and Director, Nuclear Research Reactor Programs
+Stasny, G. S.	- Reactor Supervisor
*Stowers, M. W.	- Reactor Operator (Terminated)



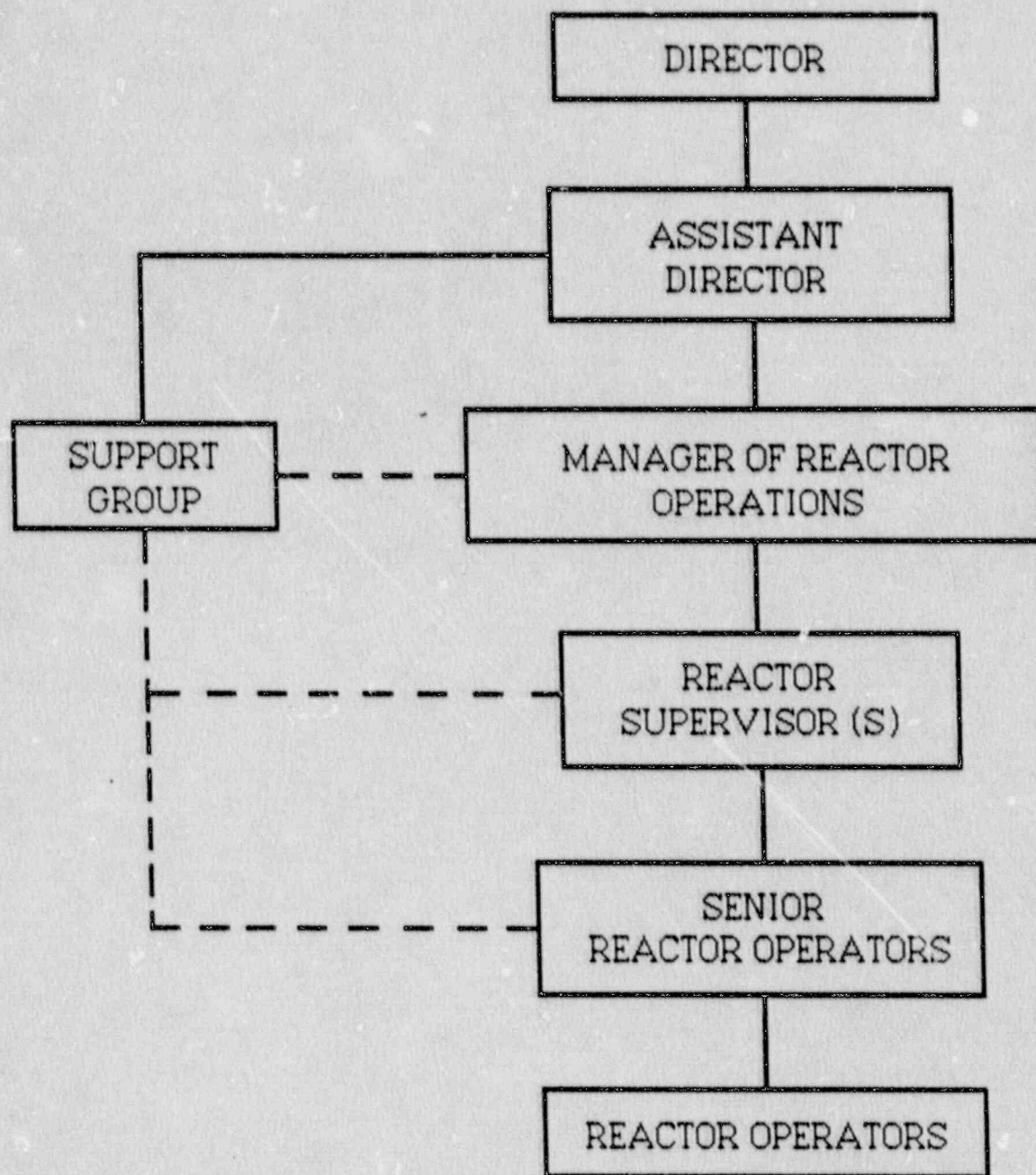


Figure 2 Nuclear Science Center  
Reactor Operations Organization Chart

Technical Service and Maintenance

Allen, R.	- Student Worker I
Beeler, J.	- Student Technician
*Deere, D. C.	- Engineering Research Associate (Terminated)
*Fisher, T. H.	- Scientific Instrument Maker II
Horn, C. R.	- Mechanical Equipment Foreman
Kensing, M.	- Student Worker I (Terminated)
+Khalil, N. S.	- Engineering Research Associate (Terminated)
Lively, T.	- Student Worker I
Restivo, A. L.	- Engineering Research Associate
Steffek, R.	- Student Worker I
Tier, M.	- Draftsman

\*Licensed Reactor Operator  
+Licensed Senior Reactor Operator

Clerical

Killingsworth, S. B.	- Receptionist
Mitchell, Yvonne	- Secretary
Ribardo, Joy	- Bookkeeper

Health Physics Staff

Cannell, B. K.	- Health Physics Technician
Meyer, C. M.	- Senior Health Physicist (Terminated)
Rodriguez, L.	- Health Physicist (Terminated)

C. Reactor Safety Board

Committee Composition

Chairman

F. Jennings, Director, Office of University Research  
(January 1, 1989 - December 31, 1989)

Voting Members

R. Green, Assistant Professor, Small Animal Clinic  
(January 1, 1989 - September 1, 1989) (Terminated)

R. R. Hart, Professor, Nuclear Engineering  
(January 1, 1989 - December 31, 1989)

J. Hiebert, Professor, Physics  
(January 1, 1989 - September 1, 1989) (Terminated)

R. Keneflick, Professor, Physics  
(April 1, 1989 - December 31, 1989)

R. Koppa, Professor, Industrial Engineering  
(January 1, 1989 - December 31, 1989)

E. L. Morris, Professor, Veterinary Medicine  
(September 1, 1989 - December 31, 1989)

G. Schlapper, Associate Professor, Nuclear Engineering  
(September 1, 1989 - December 31, 1989)

E. A. Schweikert, Professor, Chemistry  
(January 1, 1989 - December 31, 1989)

Ex-Officio Members

D. E. Feltz, Director, Nuclear Science Center  
(January 1, 1989 - December 31, 1989)

M. McLain, Professor and University Radiological Safety Officer  
(January 1, 1989 - December 31, 1989)

J. W. Poston, Head, Nuclear Engineering  
(January 1, 1989 - December 31, 1989)



Meeting Frequency

The Reactor Safety Board (RSB) met on the following dates during the calendar year 1989: 2/15/89, 3/30/89, 8/3/89, and 8/30/89.

RSB Audits

During the reporting period RSB audits of NSC activities were conducted on the following dates: 1/9/89, 4/7/89, 7/21/89 and 10/23/89.



APPENDIX I

Description of Projects Utilizing the NSCR

## DESCRIPTION OF PROJECTS UTILIZING THE NSCR

A. Texas A&M UniversityNuclear Engineering

## DAMAGE STUDIES OF INFRARED DETECTOR MATERIAL

## Personnel

Dr. Ron R. Hart -- Professor  
Kevin Seager -- Graduate Assistant

This study investigated damage caused to infrared detector materials by exposure to neutrons. The work included studies of charged particle channeling and the effects of neutron radiation on this channeling.

## NOBLE GAS FISSION PRODUCT GENERATION

## Personnel

Dr. M. McLain -- Professor  
P. Lee -- Graduate Assistant

A small device containing uranium, was irradiated and an inert gas was used to sweep out noble gas fission products to an exposure chamber for dosimetry measurement studies.

## NUCLEAR ENGINEERING GRADUATE LAB IN REACTOR EXPERIMENTATION

## Personnel

Dr. J. A. Reuscher -- Professor  
NE 606 Graduate Students (19 students)

Several experiments were performed at the NSC during the lab course. Each student participated in a control rod calibration lab, a subcritical multiplication lab, a power calibration lab and a reactor pulsing lab. Other experiments performed included core flux mapping, neutron radiography, and neutron activation analysis.

## NEUTRON DEPTH PROFILE EXPERIMENT

## Personnel

Dr. J. A. Reuscher -- Professor  
N. Khalil -- Graduate Assistant

A neutron depth profile apparatus was designed, built and installed at Beam Port #1. This device uses a charged particle detector to measure the alpha particle emission from a sample containing trace amounts of boron. The alpha particle energy spectrum is used to determine the depth profile of the boron in the sample. Experimental results using the device compared exactly with data obtained by the National Institute of Standards and Technology (NIST) on the same sample of borosilicate glass. NIST obtained data during a 15 minute beam exposure and our apparatus required 5 hours.

## REAL-TIME NEUTRON RADIOGRAPHY

## Personnel

Dr. J. A. Reuscher -- Professor  
John Wright -- Graduate Assistant  
Scott Midgett -- Graduate Assistant

A real-time neutron radiography system was developed and installed at Beam Port #4. This system uses a ZnS(LiF) scintillating screen to obtain images of samples placed in the neutron beam. The screen low-level light emission is intensified by a relay optics unit and collected by a monochrome CCD television camera. The TV image is digitized at a rate of 30 frames/second by an IBM PC/AT with image capture and processing boards. The neutron radiography image is displayed on a high resolution CRT. Numerous image enhancement options are available using digital filtering or false color displays. The system shows good resolution for small holes (0.020-inch) in a cadmium plate or standard film quality indicators. The system is being used to image operating heat pipes, bubble flows in liquids, the melting of metallic samples, moisture content measurements in zeolite and other research areas.



## NUCLEAR ENGINEERING UNDERGRADUATE LAB

## Personnel

Dr. G. A. Schlapper -- Professor  
NE 405 Students

Several experiments were performed at the NSC during the lab course. Each student performed a reactor startup and participated in a control rod calibration lab and a subcritical multiplication lab.

## RADIOISOTOPE PRODUCTION FOR LABORATORY EXPERIMENTS

## Personnel

Dr. John Poston -- Professor and Head  
Dr. Milton McLain -- Radiation Safety Officer  
Dr. Dennis James -- Assistant Professor  
Graduate and Undergraduate Students in various classes

Several laboratory classes took advantage of the NSC to produce short-lived radioisotopes for use in lab experiments ranging from half-life measurements to detector operation and calibration.

## TOURS OF THE NSC

## Personnel

Dr. K. L. Peddicord -- Assistant Director, TEES  
Dr. R. G. Cochran -- Professor  
Dr. G. A. Schlapper -- Associate Professor  
Graduate and Undergraduate Students in various classes

Various classes toured the NSC during the year as "field trips". The tours ranged from introductory views for freshman students to in depth studies of the facility air monitoring system for a graduate health physics class.

Animal Science

## DYNAMICS OF RUMINANT DIGESTION AND NUTRITION

## Personnel

Dr. W. C. Ellis -- Professor  
Mark Hill -- Graduate Assistant  
Steve Martin -- Graduate Assistant

A continuation of investigations aimed at measuring the contributing dynamic processes in cattle fed a number of different roughage and roughage/chemical treatments. The results are to be integrated into models of the animal's intake and digestive system. The work involves activation analysis of elemental markers added to individual meals of the animals in the study.



Range Science

## NUTRITIONAL STATUS OF FREE-RANGING CATTLE

## Personnel

Dr. J. W. Stuth -- Professor  
Robert Lyons -- Graduate Assistant

This research is designed to develop calibration equations for near infrared spectroscopy to predict diet quality and forage intake of free-ranging cattle. The calibration required a chemical analysis and determination of forage intake by use of stable markers. NAA was used to perform these analyses.

Oceanography

## DISTRIBUTION OF BARIUM IN SEDIMENTS ON THE TEXAS-LOUISIANA CONTINENTAL SHELF AND SLOPE

## Personnel

Dr. B. J. Presley -- Professor  
Dr. P. N. Boothe -- Assistant Research Scientist  
Four Graduate Students

This continuing project studied fine-grain sediment transport on the continental shelf using barium sulfate which is released during oil drilling operations. The determination of barium levels at various locations on the shelf and slope by activation analysis allows a model of the transport processes taking place to be formulated. These processes are important to understand in view of the increased off-shore drilling expected during the rest of this century.

Physics

## CONSTRUCTION OF A POSITRON TOMOGRAPH

## Personnel

Dr. J. A. McIntyre -- Professor  
R. A. Seidel -- Graduate Student

Work continued on the construction and testing of a positron emission tomography system for clinical imaging. The NSC provided the positron sources, activated copper samples, for this system.

Veterinary Physiology and Pharmacology

## SM-153 EDTMP BONE THERAPY AGENT

## Personnel

Dr. Dan Hightower, D.V.M. -- Professor  
Mark Chambers -- Graduate Assistant  
Androy Kankov -- Graduate Assistant

Initial irradiations of samarium oxide were performed to study the feasibility of producing EDTMP Bone Therapy sources. The initial studies included calibrations and preliminary studies with animals.

Chemistry

## INAA OF GEOLOGIC SAMPLES

## Personnel

Dr. M. Rowe -- Professor

Various geologic samples were analyzed using the instrumental neutron activation analysis technique to determine the elemental concentration of the samples.

## MIXED FIELD IRRADIATION OF COAL SAMPLES

## Personnel

Dr. J. Zoeller -- Coal and Lignite Research Lab  
Dr. T. Rozganyi -- Department of Petroleum Engineering

This project involved exposing coal and lignite samples to gamma radiation in an attempt to increase oxidation of sulfur and chlorine and thus improve the efficiency of standard removal techniques.

Geology

## OCCURRENCE OF URANIUM IN HYDROCARBON RESERVOIR ROCKS

## Personnel

Dr. T. Tieh -- Professor  
M. Denham -- Graduate Assistant

Fission tracks were induced using neutrons to investigate occurrence of uranium to determine if uranium concentrates in certain phases during diagenesis and hydrocarbon migration.

## FISSION TRACK AGE DETERMINATIONS FROM FLOURITE

## Personnel

Dr. V. Harder -- Lecturer

This work is aimed at determining the burial depth of sediments by finding the flourite fission track ages of these sediments.

Geophysics

## TRACE ELEMENT GEOCHEMISTRY ACROSS THE CRETACEOUS/TERTIARY BOUNDARY

## Personnel

Dr. N. Carter -- Professor

A. Huffman -- Graduate Assistant

T. Oldham -- Graduate Assistant

Neutron activation analysis was performed on deep sea and volcanic rock samples to study trace-element signatures across the Cretaceous-Tertiary boundary and determine the cause for a major extinction 66 million years ago.

B. Other UniversitiesLouisiana State University

## FIRE ANT TERRITORIALITY

## Personnel

Dr. Ron Knaus -- Professor, LSU Nuclear Science Center

Dr. T. E. Reagan -- Professor, Entomology

Allen Showler -- Graduate Student

This continued study investigated fire ant territoriality in a producing sugar cane field as determined by NAA performed at the NSC on the ants which had been tagged with Dy and Sm.



## TRANSMISSION OF EQUINE DISEASES

## Personnel

Dr. R. M. Knaus -- Professor, Nuclear Science

Animals were injected with Na-24 produced at the Texas A&M Nuclear Science Center, to study mechanical transmission of equine infectious diseases.

Sam Houston State University

## NEUTRON TRANSMUTATION DOPING OF SILICON AND GaAs SAMPLES

## Personnel

Dr. B. Covington -- Professor, Division of Physics and Chemistry

This continued study was performed to identify shallow impurities and to observe the effects of annealing on the centers created by fast neutrons in Si and GaAs.

Sul Ross State University

## ANALYSIS OF GEOLOGIC SAMPLES FROM VARIOUS SITES IN TEXAS

## Personnel

Dr. Dennis Nelson -- Associate Professor and Chairman, Geology

Dr. G. David Mattison -- Associate Professor, Geology

Dr. David Rohs -- Assistant Professor, Geology

Eight Graduate and Five Undergraduate Students

These continued studies include the determination of trace element contents of various rock and mineral samples from a variety of sites in Texas. The samples are irradiated at the NSC and the analysis performed at Sul Ross. Several projects are ongoing at any one time with various combinations of faculty, graduate and undergraduate students. Many of the results from these studies are incorporated into theses, papers and presentations at geologic society meetings.

Texas State Technical Institute

## Personnel

William Kester -- Chairman, Nuclear Technology, Waco

Richard Wheet -- Chairman, Nuclear Technology, Waco



During 1989, approximately 50 students participated in health physics training which included items from shipping and release regulations to an introduction to reactor physics and neutron activation analysis. The training provided the students with hands-on experience to supplement their classroom instructions in the Health Physics Technician program.

Southern Methodist University

FISSION-TRACK ETCH STUDIES

Personnel

Dr. S. Kelley -- Professor, Geology  
Dr. K. Damm -- Visiting Professor  
C. McKinney -- Graduate Assistant

Fission-track etching was performed for three different projects. One was used to study fission tracks produced in zircon crystal lattices. Another project studied uranium absorption in fossilized teeth to help in dating the fossils. The last project was used to date samples and determine the cooling history during the Cenozoic uplift of the Central Andes mountains.

McNeese State University

DISTRIBUTION OF TRACE METALS IN LOUISIANA STATE SEDIMENTS

Personnel

Dr. J. Beck -- Professor, Chemistry  
K. Stacks -- Graduate Assistant  
K. Martin -- Graduate Assistant

Neutron activation analyses were carried out on lake sediment samples to study the presence of pollution by heavy metal concentration.

Miami University

FISSION-TRACK ANALYSIS OF GEOLOGICAL MATERIALS

Personnel

Dr. K. Crowley -- Professor

Fission-track age by induced U-238 fissions was determined to study annealing processes.

University of Oklahoma

## RARE EARTH CONCENTRATIONS IN IGNEOUS ROCKS AND SHALES

## Personnel

Dr. B. Weaver -- Professor, Geology  
 P. Anderson -- Graduate Assistant

Rare earth concentrations were determined by neutron activation analysis to study the geochemistry of igneous rocks and shales.

## TOURS AND NEUTRON ACTIVATION ANALYSIS DEMONSTRATIONS

Groups from various institutions toured the Texas A&M Nuclear Science Center facilities and saw neutron activation analysis demonstrations. Some of the associated group chaperones and their institutions are listed below.

L. C. Hall, Geography, Stephen F. Austin University  
 D. Tatum, McLennan Community College  
 K. H. Wang, Physics, Baylor University

C. Non-University InstitutionsM. D. Anderson Hospital

## PRODUCTION OF RADIOISOTOPES FOR RESEARCH AND TREATMENT

## Personnel

Jack Cundiff -- M. D. Anderson

The NSC produces radioisotopes for use in medical research and treatment at the M. D. Anderson Hospital and Tumor Center in Houston. Several different isotopes and forms have been produced for various types of uses at the hospital.

The Methodist Hospital of Houston

## DEVELOPMENT OF A TREATMENT FOR RHUMETOID ARTHRITIS

## Personnel

Dr. Bill Cole -- Nuclear Medicine, Methodist Hospital  
 John Krohn -- Nuclear Science Center

This continuing project was aimed at developing an alternative to surgery as treatment for rhumetoid arthritis. The work was based on similar work done at Harvard Medical School and involves the injection of radioisotopes to destroy the affected cells instead of the usual surgical removal. The efforts conducted in 1989 included continued patient treatments at Methodist Hospital in Houston and clinical evaluation of treatment effectiveness.

Texas Instruments

## NEUTRON ACTIVATION ANALYSIS OF SEMICONDUCTOR MATERIALS

## Personnel

Bruce Gnade -- Texas Instruments

Cheryl Blackburn -- Texas Instruments

This long-term project involves the irradiation of semiconductor materials supplied by Texas Instruments at the Nuclear Science Center and subsequent analysis by TI personnel. The analysis results are used in quality assurance and product development.

## RADIOISOTOPE PRODUCTION

The NSC produced a wide variety of radioisotopes for a number of commercial users. These isotopes were produced for a variety of projects including well logging, gamma radiography, and tracer studies. Some of the more commonly produced isotopes were: Co-60, Ir-192, Fe-59, Br-82, Ar-41, and Na-24. Some of the companies supplied were: Gulf Nuclear Corp., Tracerco, Inc., Teledyne Isotopes, Radiation Consultants and Tru-Tec.



APPENDIX II

Publications, Theses and Papers Involving Use  
of NSC Facilities From 1976 to Date



Publications, Theses and Papers Involving the Use of NSC  
Facilities From 1978 to Date

1. R. R. Hart and L. D. Albert, "Measurement of P-31 Concentrations Produced by Neutron Transmutation Doping of Silicon", International Conference on Neutron Transmutation Doping, University of Missouri, April 1978.
2. D. Wootan, "Measurement of Neutron Flux in Thermal Rotisserie", M.S. Thesis in Nuclear Engineering, Texas A&M University, 1978.
3. W. Huang and J. Catham, "Uranium in Lignite: I. Geological Occurrence in Texas", Tenth International Congress on Sedimentology, Volume 1, 1978.
4. W. Huang and S. Parks, "Uranium Resources in Some Tertiary Sediments of Texas Gulf Coastal Plain: I Geologic Occurrence in the Lower Miocene Sediments", Tenth International Congress on Sedimentology, Volume 1, 1978.
5. W. Huang and K. Pickett, "Factors Controlling In-Situ Leaching of Uranium from Sandstone and Lignite Deposits in South Texas", Proceedings of Uranium Mining Technology, Update 78, Reno, Nevada, November 1978.
6. B. J. Presley, R. Pflaum and J. Trefry, "Fallout and Natural Radionuclides in Mississippi Delta Sediments", Environmental Oceanographic Science, Vol. 59, No. 4, April 1978.
7. P. H. Fishman, "Minerological Analysis and Uranium Distribution of the Sediments from the Upper Jackson Formation, Karnes County, Texas", M. S. Thesis in Geology, Texas A&M University, 1978.
8. E. M. Prasse, "Uranium and Its Relationship to Host Rock Mineralogy in an Unoxidized Roll Front in the Jackson Group, South Texas", M. S. Thesis in Geology, Texas A&M University, 1978.
9. W. C. Ellis, J. H. Mathis and C. E. Lescano, "Quantitating Ruminant Turnover", Fed. Proc., Vol. 38, 1979.
10. C. E. Lescano and W. C. Ellis, "An Evaluation of Lanthanides as Particulate Matter Markers", American Society of Animal Science (abstract), Tucson, Arizona, 1979.
11. S. W. Bachinski and R. B. Scott, "Rare-Earth and Other Trace Elements Contents and the Origin of Mineetes", Geochim. Cosmochim. Acta, Vol. 43, 93, 1979.

12. R. B. Scott, D. G. Temple and P. Peron, "Nature of Hydrothermal Exchange Between Oceanic Crust and Seawater at 26°N Lat., Mid-Atlantic Ridge", Benthic Boundary Layer Processes, IOGC Symposium on the Benthic Boundary Layer, 1979.
13. L. J. Tiezzi and R. B. Scott, "Crystal Fractionation in a Cumulate Gabbro, Mid-Atlantic Ridge, 26°N Lat.", J. of Geophys. Research, 1979.
14. P. J. McGoldrick, R. R. Keays and R. B. Scott, "Thallium: A Sensitive Indicator of Rock/Seawater Interaction of Sulfur Saturation of Silicate Melts", Geochim. Cosmochim. Acta, 1979.
15. G. Zakoriadze, R. B. Scott and D. H. Lilly, "Petrology and Geochemistry of the Palao-Kyushu Remnant Arc, Site 448, DSDP Leg 59", Trans. Amer. Geophys. Union, Vol. 50, 94, 1979.
16. R. B. Scott, "Petrology and Geochemistry of Ocean Plateaus", TAMU Symposium on Ocean Plateaus, 1979.
17. A. Clearfield and L. Kullberg, "On the Mechanism of Ion-Exchange in Zirconium Phosphates: An Equilibrium Study of Sodium-Potassium-Hydrogen Exchange on Crystallizing Zirconium Phosphates", J. of Inorganic and Nucl. Chem., 1979.
18. O. F. Zeck, R. A. Ferrieri, C. A. Copp, G. P. Gennaro and Y. N. Tang, "Gas Phase Recoil Phosphorous Reactions IV - Effect of Moderators on Abstraction Reactions", J. of Inorganic and Nucl. Chem., 41, 1979.
19. J. R. Catham, "A Study of Uranium Distribution in an Upper Jackson Lignite - Sandstone Ore Body, South Texas", M. S. Thesis in Geology, Texas A&M University, 1979.
20. S. L. Parks, "Distribution and Possible Mechanism of Uranium Accumulation in the Catahoula Tuff, Live Oak County, Texas", M. S. Thesis in Geology, Texas A&M University, 1979.
21. M. E. Miller, "Uranium Roll Front Study in the Upper Jackson Group, Alascosa County, Texas", M. S. Thesis in Geology, Texas A&M University, 1979.
22. W. C. Ellis, J. H. Matis and C. E. Lescano, "A Method for Determining In-Vivo Rates of Particle Size Degradation, Genesis, and Passage from the Rumen", Proc. of 15th Conference on Rumen Function, 1979.
23. W. C. Ellis, J. H. Matis and C. E. Lescano, "Sites Contributing to Compartmental Flow for Forage Residues", Ann. Res. Vet., 1979.



24. C. E. Lescano, "Determination of Grazed Forage Voluntary Intake", Ph.D. Dissertation in Animal Nutrition, Texas A&M University, 1979.
25. K. Pond, "Effect of Monensin on Intake Digestibility, Gastrointestinal Fill and Flow in Cattle Grazing Coastal Bermuda Pasture", M. S. Thesis in Animal Nutrition, Texas A&M University, 1979.
26. H. Loza, "Effect of Protein Deficiency on Forage Intake and Digestibility", M. S. Thesis in Animal Nutrition, Texas A&M University, 1979.
27. V. L. Tenhet, "Penetration Mechanism and Distribution Gradients of Sodium-Tripoly-Phosphate in Peeled and Deveined Shrimp", M. S. Thesis in Animal Science, Texas A&M University, 1979.
28. W. C. Ellis and H. Lippke, "A Continuous Infusion and Pulse Dose Marker Method for Determining Fecal Output", Proceeding of Southern Pasture and Forage Crop Improvement Conference, Nashville, Tennessee, May 1980.
29. D. S. Delaney, "Effects of Monensin on Intake, Digestibility, and Turnover of Organic Matter and Bacterial Protein in Grazing Cattle", M. S. Thesis in Animal Science, Texas A&M University, 1980.
30. J. P. Telford, "Factors Affecting Intake and Digestibility of Grazed Forages", Ph.D. Dissertation in Animal Science, Texas A&M University, 1980.
31. E. E. Siefert, K. L. Loh, R. A. Ferrieri and Y. N. Tang, "Formation of 1-Silacyclopenta-2,4-diene Through Recoil Silicon Atom Reactions", J. Amer. Chem. Soc., 102, 1980.
32. M. W. Rowe, E. W. Filberth and H. J. Shaeffer, "Uranium in Huero and Guadalupe Mountain Indian Ceramics", Archaeometry, Great Britian, 1980.
33. E. B. Ledger, T. T. Tieh and M. W. Rowe, "Delayed Neutron Activation Determination of Uranium in Thirteen French Rock Reference Samples", Geostandards Newsletter, 1980.
34. T. T. Tieh, E. B. Ledger and M. W. Rowe, "Release of Uranium from Granitic Rocks During In Situ Weathering and Initial Erosion (Central Texas)", Chemical Geology, 1980.
35. J. P. Taft, J. D. Randall and K. Walker, "Core Modification of the Texas A&M Nuclear Science Center Reactor for Improved Commercial Utilization", presented at the Seventh TRIGA User's Conference, San Diego, California, March 1980.



36. E. F. Bates, R. D. Neff and J. D. Randall, "Organization and Management of Health Physics Support for a Research Reactor", presented at the Seventh TRIGA User's Conference, San Diego, California, March 1980.
37. K. L. Walker, "Analysis of Uranium in Ore Samples by Delayed Neutron Activation Analysis", Radiochemical and Radioanalytical Letters, October 1980.
38. E. E. Siefert, K. L. Loh, R. A. Ferrieri and Y. N. Tang, "Fluoride Atom Shift in 1,2-Difluoroethyl Radicals", J.C.S. Chem. Comm., 814, 1980.
39. E. B. Ledger, T. T. Tieh and M. W. Rowe, "Delayed Neutron Activation Determination of Uranium in Twelve Rock Reference Standards", Geostandards Newsletter, 4, 1980.
40. K. R. Pond and W. C. Ellis, "Effects of Monensin on Fecal Output and Voluntary Intake of Grazed Coastal Bermudagrass", Beef Cattle Research in Texas, 1981.
41. W. C. Ellis, J. H. Matis and K. R. Pond, "Effect of Monensin on Gastrointestinal Fill and Turnover of Undigested Forage Residues in Animals Grazing Coastal Bermuda", Beef Cattle Research in Texas, 1981.
42. D. S. Delaney, K. R. Pond, C. E. Lescano and W. C. Ellis, "Comparison of Fecal Output as Estimated by Two Marker Methods", Beef Cattle Research in Texas, 1981.
43. D. S. Delaney and W. C. Ellis, "Effect of Monensin on Rumen Microbial Turnover", Beef Cattle Research in Texas, 1981.
44. D. Hightower, "Whole Body Counting", Southwest Chapter of Society of Nuclear Medicine, 1981.
45. J. Watson and B. Covington, "Neutron Transmutation Doped Silicon", American Association of Physics Teachers, 1981.
46. L. Kullberg and A. Clearfield, "Mechanism of Ion Exchange in Zirconium Phosphates - 32: Thermodynamics of Alkali Metal Ion Exchange on Amorphous ZrP", J. Phys. Chem., 1981.
47. L. Kullberg and A. Clearfield, "Mechanism of Ion Exchange in Zirconium Phosphates - 32: Thermodynamics of Alkali Metal Ion Exchange on Crystalline ZrP", J. Phys. Chem., 1981.
48. D. Nelson, W. McDonough and D. Mattison, "Trace Element Geochemistry of the Sawtooth Mountain Syenites, Transpecos Magmatic Belt of West Texas", Trans Pecos Volcanism Symposium, 1981.

49. E. E. Siefert, S. D. Witt and Y. N. Tang, "Reactions of Monomeric Difluorosilylene with Ethylene", J.C.S. Chem. Comm., 1981.
50. Y. N. Tang, "Unusual Compounds Synthesized via Nuclear Recoil Methods", Advances in Chemistry Series, No. 197, 1981.
51. E. J. Parma, "Gamma Abundance of Silicon-31", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1981.
52. L. R. Theriot and L. Daley, "Matrix Effect in Atomic Absorption Determination of Copper in Fraction I Protein: Possible Role of Copper in Light Sensitive Control of Ribulose Biphosphate Carboxylase Activity", Texas Journal of Science, December 1981.
53. W. C. Ellis, C. E. Lescano, R. Teeter and F. N. Owne, "Solute and Particulate Flow Markers", Proceedings of Symposium on Ruminant Protein Nutrition, Oklahoma State University, 1982.
54. J. P. Telford and W. C. Ellis, "Duration of Grazing Effects on Gastrointestinal Fill, Turnover, Digestibility and Voluntary Intake of Grazed Oak Pasture", Beef Cattle Research in Texas, 1982.
55. K. R. Pond, "The Fragmentation and Flow of Forage Residues Through the Gastrointestinal Tract of Cattle", Ph.D. Dissertation in Animal Science, Texas A&M University, 1982.
56. K. R. Pond, A. G. Deswyen, J. H. Matis and W. C. Ellis, "Chromium-mordanted and Rare Earth Marker Fiber for Particulate Flow Measurement", Beef Cattle Research in Texas, 1982.
57. K. R. Pond, A. G. Deswyen, J. H. Matis and W. C. Ellis, "Rate of Passage Measurements as Affected by Dosing at Beginning or End of a Meal", Beef Cattle Research in Texas, 1982.
58. K. R. Pond, A. G. Deswyen, J. H. Matis and W. C. Ellis, "Marker Technique - A Two Marker, Two Dose Method for Estimating Fecal Output, Fill and Flow", Beef Cattle Research in Texas, 1982.
59. M. S. Mohan, R. A. Zingaro, R. D. Macfarlane and K. J. Irgolic, "Characterization of Uranium-Rich Organic Material Obtained from a South Texas Lignite", Pittsburgh Energy Technology Center, May 1982.
60. D. Casserly, M. Vecchiono, R. Maples, R. Ilg, D. Gaston, D. Weston and L. Dervoan, "Biological Attributes of the West Hackberry Brine Disposal Site", Oceans 82, 4, 1982.



61. G. L. Grout and C. L. Webre, "Quick Separation of Manganese from Brine Solutions", Radiochemical and Radioanalytical Letters, 51, 1982.
62. J. Watson and B. Covington, "Annealing Studies of Transmutation Doped Silicon", presented at Texas Academy of Science Meeting in San Angelo, Texas, March 1982.
63. J. Watson and B. Covington, "Annealing Study of Transmutation Doped Silicon: Boron", Proceedings of the Fourth International NTD Conference, Washington, D. C., 1982.
64. R. K. Dokka, "Implications of Fission Track Ages from the Kaplan Geothermal Geopressure Zone, Vermilion Parish, Louisiana", Transactions of Gulf Coast Association of Geological Societies, Vol. 32, 1982.
65. W. F. McDonough, D. O. Nelson and G. D. Mattison, "Major and Trace Element Variation in a Dynamically Evolving Silicon Magma Chamber", Trans-Pecos Volcanism, March 1982.
66. J. H. Schieffer, G. D. Mattison and D. O. Nelson, "The Mineralogy and Geochemistry of the Igneous Rocks of the Terlingua District, Brewster County, Texas", Trans-Pecos Volcanism, March 1982.
67. J. H. Schieffer and G. D. Mattison, "Nature and Origin of Alkaline and Calcic Veinlets in Xenoliths from the Terlingua District, West Texas", Geological Society of America, 1982.
68. C. Conrad, "Uranium in the Oatman Creek Granite and Its Economic Impact", M. S. Thesis in Geology, Sul Ross State, 1982.
69. W. Schaftenaar, "Uranium in Igneous Rock of the Central Davis Mountains of West Texas", M. S. Thesis in Geology, Sul Ross State, 1982.
70. H. Deigl and D. E. Feltz, "Antiquity, Man and Machine", presented at the Eighth TRIGA User's Conference, Idaho Falls, Idaho, March 1982.
71. R. D. Rogers and J. D. Randall, "In-Pool Neutron Radiography of Damaged FLIP Fuel", presented at the Eighth TRIGA User's Conference, Idaho Falls, Idaho, March 1982.
72. C. W. Beasley, "Perfusion Measurement with Rubidium-81 to Krypton-81m Ratio", Ph.D. Dissertation in Veterinary Physiology and Pharmacology, TAMU, 1982.



73. M. C. Brady, "Radiation Field Measurements in the TAMU Nuclear Science Center Irradiation Cell", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1982.
74. E. J. Parma and R. R. Hart, "Measurements of the Gamma Abundance of Si-31", Proceedings of the Fourth International Conference on Neutron Transmutation Doping of Semiconductors, Gaithersburg, Maryland, June 1982.
75. M. H. Young and R. R. Hart, "Neutron Transmutation Doping of p-Type Czochralski-Grown GaAs", Proceedings of the Fourth International Conference on Neutron Transmutation Doping of Semiconductors, Gaithersburg, Maryland, June 1982.
76. K. R. Pond, W. C. Ellis and J. H. Matis, "Digesta Flow Through the Ruminant's Digestive Tract", Beef Cattle Research in Texas, 1983.
77. K. R. Pond, W. C. Ellis, W. D. James and M. G. Otte, "Analysis of Multiple Markers Used in Nutrition Research", Beef Cattle Research in Texas, 1983.
78. K. L. Welch, "Fluence Monitor Calibration of the Multiple Rotisserie Irradiation Device for Neutron Transmutation Doping", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1983.
79. L. Pgoniski, A. N. Hanna and O. Suschny, "Report on Inter-comparisons S-14, S-15, S-16 of the Determination of Uranium and Thorium in Thorium Ores", IAEA Report IAEA/RL/101, 1983.
80. J. H. Schieffer, and D. O. Nelson, "Petrology and Geochemistry of Megacrysts, Xenoliths and Their Host Basalts from the Terlingua Mercury District of West Texas", Geological Soc. of America, Abstracts with Program, Vol. 13, 1983.
81. D. O. Nelson, K. L. Ott and R. D. Tolley, "Geochemistry of Cibolo Creek I: Evaluation of Element Distribution in Stream Sediments", Earth Sciences, 1983.
82. R. L. Rudnick, "Geochemistry and Tectonic Affinities of a Proterozoic Bimodal Igneous Suite, West Texas", Geology, 1983.
83. W. G. McDonough, "The Geochemistry and Petrology of a Trachyte Comendite Suite from the Oligocene Paisano Volcano, West Texas", M. S. Thesis in Geology, Sul Ross State, 1983.
84. M. C. Kennicutt II, W. L. Kenny-Kennicutt, B. J. Presley and F. Fenner, "The Use of Pyrolysis and Barium Distributions to Assess the Areal Extent of Drilling Fluids in Surficial Marine Sediments", Environ. Geol., 4, 1983.

85. B. J. Presley and D. D. Sheu, "Orea Basin: Recent Deep-Sea Black Mud", Annual Meeting of the Geological Society of America, Indianapolis, Indiana, 1983.
86. M. Whiteacre, "Sorber Performance Data on the Recovery of Strategic Elements from Seawater", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1983.
87. F. R. Best and M. Whiteacre, "Sorber Performance Data on the Recovery of Strategic Elements from Seawater", International Meeting on Recovery of Uranium from Seawater, Tokyo, Japan, 1983.
88. F. R. Best, "Interpretation and Analysis of Sorber Performance Data on Recovery of Uranium from Seawater - II", International Meeting on Recovery of Uranium from Seawater, Tokyo, Japan, 1983.
89. W. D. James, "Multiple Stable Isotope Markers Used in Nutrition Research", Annual American Nuclear Society Meeting, Detroit, Michigan, 1983.
90. M.S. Akanni, V. O. Ogugbuaja and W. D. James, "Trace Element Content of Magnetohydrodynamic Coal Combustion Effluents", J. of Radioanalytical Chem., Vol. 79, No. 2, 1983.
91. R. L. Budnick, "Petrology and Geochemistry of the Carrizo Mountain Group", Geology, Spring 1983.
92. T. H. Simpkins, "The Geology and Geochemistry of the Aguachili Mountain Fluorspar-Beryllium District", presented at The Geologic Society of America Meeting, Fall 1983.
93. G. A. Schlapper, R. D. Neff, D. R. Davis and P. S. Sandel, "Measurement of Routinely Encountered Neutron Doses in Research Facilities", Radiation Protection Management, 1983.
94. N. Khalil, "A Test of the Efficiency of the Raw Water Stirring System Installed in Liquid Waste Holdup Tank 1", NSC Technical Report No. 44, 1983.
95. D. G. Goodman, "Motor Driven Flux Wire Counter", NSC Technical Report No. 45, 1983.
96. J. O'Donnell, "Determination of the Neutron Flux in the TAMU Nuclear Science Center Reactor During Pulse and Steady-State Operation", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1983.



97. D. S. Followill, "Determination of Exchangeable Potassium in the Canine by Means of Whole-Body Counting", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1983.
98. M. S. Mohan and R. A. Zingaro, "Trace Element Characterization of Deep Basin Lignites of Texas", Final Report to Texas Energy and Natural Resources Advisory Council, 1983.
99. W. A. Ilger, "A Study of Uranium in South Texas Lignite", M. S. Thesis in Chemistry, Texas A&M University, 1983.
100. L. S. Daley, "ESR of Transition Metal 'Chromophores' in RuBP Case Supporting Neutron Activation and Optical Data Concepts of UV Light Activation Through Transition Metal Chromophores", Blue Light Syndrome, Springer-Verlag, 1984.
101. J. D. Ilger, W. A. Ilger, M. S. Mohan and R. A. Zingaro, "Characterization of Uranium in a South Texas Lignite", Eleventh Annual Meeting of Federation of Analytical Chemistry and Spectroscopy Societies, Philadelphia, September 1984.
102. W. C. Ellis, J. H. Matis, K. R. Pond, C. E. Lescano and J. P. Telford, "Dietary Influences on Flow Rate and Digestive Capacity", Proceedings of Symposium on Herbivore Nutrition in the Sub-Tropics and Tropics, Johannesburg, South Africa, 1984.
103. L. D. Roth, W. C. Ellis and F. M. Rouquette, Jr., "Sward Attributes and Nutritive Value of Coastal Bermudagrass as Influenced by Grazing Pressure", Proceedings of Forage and Grasslands Conference, Houston, Texas, 1984.
104. R. V. Machem, "Effects of Physiological Status, Supplementation and Monensin on Forage Intake, Digestibility and Digesta Turn-over", M. S. Thesis in Animal Science, Texas A&M University, 1984.
105. L. R. Roth, "Effects of Grazing Upon Sward Attributes and Utilization of Coastal Bermudagrass by Cattle", M. S. Thesis in Animal Science, Texas A&M University, 1984.
106. M. Whiteacre, "Experimental Determination of Elemental Recovery from Natural Seawater Achieved by Ion Exchange Resins", Master of Engineering project report, Texas A&M University, 1984.
107. M. H. Tobey, H. J. Shafer and M. W. Rowe, "Trace Element Investigations of Mayan Chert from Belize", International Symposium on Archaeometry, May, 1984.
108. M. H. Tobey, E. O. Nielsen and M. W. Rowe, "Elemental Analysis of Etruscan Ceramics from Murlo, Italy", International Symposium on Archaeometry, May 1984.



109. M. Charles, "The Application of a Scintillation Flask Technique for the Measurement of Radon Emanation", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1984.
110. Y. C. Gonzalez, "Aerosol Dilution and Dispersion at the Nuclear Science Center Confinement Building", M. S. Thesis in Health Physics, Texas A&M University, 1984.
111. C. H. Poynton, R. S. Tilbury, J. G. Head, S. Tindle, K. A. Dicke, L. Peters and C. L. Reading, "Boron Slow Neutron Capture with Colloidal Cobalt Boride Conjugated to Monoclonal Antibody", Conference on Advances in the Application of Mono-Clonal Antibodies in Clinical Oncology, London, U.K., June 1984.
112. V. O. Ogugbuaja, "Bioaccumulation of Trace Elements from Coal Fly Ash in Rats", Ph.D. Dissertation in Chemistry, Texas A&M University, 1984.
113. T. E. Clevenger, E. J. Hinderberger, D. A. Yates and W. D. James, "Analysis for Trace Elements in Magnetohydrodynamic (MHD) Pilot Plant Effluents", Environmental Science and Technology, 18, 1984.
114. W. D. James, F. F. Arnold, K. R. Pond, M. D. Glascock and T. G. Spalding, "Application of Prompt Gamma Activation Analysis and Neutron Activation Analysis to the Use of Samarium as an Intestinal Marker", J. of Radioanalytical Chem., 83, 1984.
115. W. F. McDonough and D. O. Nelson, "Geochemical Constraints on Magma Processes in a Peralkaline System: The Paisano Volcano, West Texas", Geochim. Cosmochim. Acta, Vol. 48, 1984.
116. D. O. Nelson, K. L. Nelson and G. D. Mattison, "Reconnaissance Geochemistry of Rocks of the Trans-Pecos Magmatic Belt", Geological Soc. of America Abstracts, Vol. 16, No. 2, 1984.
117. D. O. Nelson, K. L. Nelson and G. D. Mattison, "Implications of Trace Element and Isotopic Composition for the Origins of Silicic Rocks of the East-Central Trans-Pecos Magmatic Belt of West Texas", Geological Soc. of America Abstracts, Vol. 16, No. 4, 1984.
118. R. T. Perry., W. B. Wilson and T. A. Parish, "A 14-MeV Neutron Source", Sixth Topical Meeting on the Technology of Fusion Energy, San Francisco, California, March 1984.
119. G. A. Schlapper, D. C. Kay, R. D. Neff and P. S. Sandel, "Dose Equivalent Measurements in an Area of Reduced Shielding at the Texas A&M Variable Energy Cyclotron", Radiation Protection Management, July 1984.

120. J. G. Pina-Jordan, "Measurement and Modeling of Uranium and Strategic Element Sorption by Amidoxime Resins in Natural Seawater", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1985.
121. K. D. Seager, "Acceptor and Donor Production in  $Hg_{1-x}Cd_xTe$  by NTD", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1985.
122. M. Schuller, "An Investigation of Aqueous Slurries as Fusion Reactor Blankets", Ph.D. Dissertation in Nuclear Engineering, Texas A&M University, 1985.
123. Y. R. Contreras and G. A. Schlapper, "Aerosol Dilution and Dispersion in a Nuclear Research Facility", Radiation Protection Management, July 1985.
124. K. L. Nelson, "Combined Elemental and Isotopic Evaluation of a Deep-Water Carbonate: Implications for a Dynamic Diagenetic Model", Geological Soc. of America Abstracts, Vol. 17, No. 7, September 1985.
125. K. L. Nelson, "Combined Elemental and Isotopic Evaluation of a Deep-Water Carbonate: Implications for a Dynamic Diagenetic Model", M. S. Thesis in Geology, Sul Ross State, 1985.
126. G. D. Mattison, "Mineralogy and Petrology of the Sheep Canyon Basalts, Trans-Pecos Volcanic Field, West Texas", Geological Soc. of America Abstracts, Vol. 17, No. 3, 1985.
127. D. O. Nelson and K. L. Nelson, "Geochemical Comparison of Alkaline Volcanism in Oceanic and Continental Settings: Clarion Island Versus the Eastern Trans-Pecos Magmatic Province", Geological Soc. of America Abstracts, Vol. 17, No. 3, 1985.
128. G. M. Vasquez, P. S. Sandel and G. A. Schlapper, "Development of the Scintillation Flask Technique for the Measurement of Indoor Radon-222 Concentrations", presented at the Mid-Year Symposium of the Health Physics Soc., Colorado Springs, Colorado, January, 1985.
129. G. M. Vasquez, "Development of the Scintillation Flask Technique for the Measurement of Indoor Radon-222 Concentrations", M. S. Thesis in Health Physics, Texas A&M University, 1985.
130. P. N. Boothe and W. D. James, "Neutron Activation Analysis of Barium in Marine Sediments from the North Central Gulf of Mexico", J. Trace and Microprobe Techniques, 3, 1985.



131. W. D. James, V. O. Ogugbuaja, M. D. Glascock and R. C. Attig, "Partitioning of Trace Elements in MHD Coal Combustion Effluents", Proceedings of the Fifth International Conf. on Nuclear Methods in Environ. and Energy Research, 1985.
132. C. M. Meyer, "Improved Assessment of Population Doses and Risk Factors for a Nuclear Power Plant Under Accident Conditions", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1985.
133. J. H. Kleck, "Determination of Radiation Absorbed Dose to the Kidneys of Rhesus Monkeys from Radiolabelled Orthoiodohippuran", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1985.
134. D. L. Mayfield, "A Calibration and Evaluation of Eberline Instrument Corporation's SPING-4 Radiological Air Monitor", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1985.
135. R. Yupari, "Three-dimensional Neutronics Calculations for the Texas A&M TRIGA Reactor", M. S. Thesis in Nuclear Engineering, Texas A&M University, 1985.
136. R. D. Rogers, "Modification and Verification of the "SPOOFA" Computer Code for Use at the Texas A&M University Nuclear Science Center", M. E. Project in Nuclear Engineering, Texas A&M University, 1985.
137. H. C. Cheung and A. Clearfield, "The Oxidative Dehydrogenation of Cyclohexene Catalyzed by  $\text{ZrCu}(\text{PO}_4)_2$ ", Journal of Catalysis, Vol. 98, 1986.
138. T. Feeley and E. Morris, "Petrologic Similarities of Eocene Quartz-Olivine Basaltic Andesites, Oregon and Montana", Geological Soc. of America Abstracts, Vol. 18, No. 6, 1986.
139. E. Morris and G. Nelson, "Petrologic and Age Relations in Granite Mountain Syenite", Geological Soc. of America Abstracts, Vol. 18, No. 3, 1986.
140. D. O. Nelson and D. Gerlach, "Sr, Nd, and Pb Isotopic Compositions of Rocks of Clarion Island, East-Central Pacific Ocean", Geological Soc. of America Abstracts, Vol. 18, No. 6, 1986.
141. B. Sanza, "Measurement of Neutron Spectra for Determining Dose Equivalent Rates at the Texas A&M University Nuclear Science Center", M.S. Thesis in Nuclear Engineering, Texas A&M University, 1986.



142. C. Meyer and G. Schlapper, "A Comparison of Dose Calculation Methodologies for Airborne Releases from Nuclear Power Plants", Radiation Protection Management, April 1986.
143. J. Randall, "Development of a Generic Job Task List for Research Reactor Operators and Senior Reactor Operators", presented at the Tenth TRIGA User's Conference, College Station, Texas, April 1986.
144. R. Yupari, R. Perry and T. Parish, "Three Dimensional Neutronics Calculation for the TAMU Nuclear Science Center TRIGA Reactor Using Bold Venture", presented at the Tenth TRIGA User's Conference, College Station, Texas, April 1986.
145. J. L. Krohn, D. E. Feltz and N. Khalil, "Software Development for Research Reactors", presented at the Tenth TRIGA User's Conference, College Station, Texas, April 1986.
146. S. Na, R. Perry and T. Parish, "Spectroscopy System for Use With a Fusion Plate Installed on the TAMU Reactor", presented at the Tenth TRIGA User's Conference, College Station, Texas, April 1986.
147. P. N. Boothe, B. J. Presley, "Long-term Fate of Drilling Mud Barite on the Texas-Louisiana Continental Shelf and Slope", AGU/ASLO Meeting, New Orleans, Louisiana, January 1986.
148. K. L. Nelson, D. O. Nelson, D. Shucker and B. Brister, "Physical Evidence for Open-System Evolution of the Trans-Pecos Magmatic Province", Geological Society of America Abstracts, Vol. 18, No. 6, 1986.
149. D. E. Feltz, "The Conversion of TRIGA Research Reactors from High-Enriched Uranium to Low-Enriched Uranium Fuel: Owner/Operator View", Trans. American Nuclear Society, Vol. 52, June 1986.
150. R. Knaus, "Neutron Activation Analysis of Very Recent Accumulations in Wetlands Bordering the Northern Gulf of Mexico", presented at the Annual American Chemical Society Meeting, New Orleans, Louisiana, September 1987.
151. W. D. James, P. N. Boothe, "Ocean Sediment Analysis by NAA", Proceedings of ANS Topical Conference on Methods and Application of Radioanalytical Chemistry, Kona, Hawaii, April 1987.
152. D. B. McCarthy, W. C. Ellis, and R. Worley, "Digestion of Fiber in Segments of the Bovine Gastrointestinal Tract", Journal of Animal Science, Vol. 65, Supplement 1, 1987.

153. K. N. Grigsby, F. M. Rouquette, Jr., W. C. Ellis, D. P. Hutcheson and G. T. King, "Source and Level of Protein Supplement on Performance of Calves Grazing Bermuda Grass Pastures", Journal of Animal Science, Vol. 65, Supplement 1, 1987.
154. M. J. Wylie, M. C. Calhoun, A. Lastovica, W. C. Ellis and J. H. Matis, "Turnover of Dietary Residues Through Successive Anatomical Segments of the Lamb's Gastrointestinal Tract", Journal of Animal Science, Vol. 65, Supplement 1, 1987.
155. E. Rivera-Villarreal, W. C. Ellis and J. H. Matis, "Flow of Masticated Particles From the Rumen Upper Digesta Strata of Cattle", Journal of Animal Science, Vol. 65, Supplement 1, 1987.
156. E. Rivera-Villarreal and W. C. Ellis, "Effects of Ammoniation of Bermuda Hays on Particle Size Reduction and Outflow in Cattle", Journal of Animal Science, Vol. 65, Supplement 1, 1987.
157. M. C. Wells, P. N. Boothe and B. J. Presley, "Iridium in Marine Biota", AGU Meeting, 1987.
158. D. O. Nelson, K. L. Nelson and R. S. Miner, "Geochemistry of Plutons in the Eastern Trans-Pecos Magmatic Province", Geological Society of American Abstracts, Vol. 19, No. 3, 1987.
159. R. L. Ward, D. O. Nelson and K. L. Nelson, "Trace Element and Oxygen Isotope Evidence for the Origin of Quartz-Trachytes and Rhyolite, Northern Davis Mountains, West Texas", Geological Society of America Abstracts, Vol. 19, No. 5, 1987.
160. J. L. Krohn, "Radiation Effects Testing Capabilities of the Texas A&M Nuclear Science Center", presented at 4th Symposium on Space Nuclear Power Systems, Albuquerque, New Mexico, January, 1987.
161. M. C. Wells, P. N. Boothe and B. J. Presley, "Iridium in Marine Biota", AGU Fall Meeting Transactions 1988.
162. W. D. James and P. N. Boothe, "Evaluation of Gamma Lines for NAA", American Nuclear Society Annual Meeting, San Diego Transactions 1988.
163. W. D. James and P. N. Boothe, "Ocean-Sediment Analysis by NAA", Journal of Radioanalytical and Nuclear Chemistry 123/1, 295 1988.

164. W. C. Ellis, J. H. Matis and D. Poppi, "Use of Age-Dependent Compartmental Models to Estimate Particulate Flow in Ruminants", *Journal of Animal Science*, 66/1, 479 1988.
165. M. E. Denham and T. T. Tieh, "Distribution and Occurrence of Uranium in Reservoir Rocks", *American Association of Petroleum Geologists*, 72/2 1988.
166. E. Rivera-Villareal, "Forage and Animal Response to Ammoniations of Coastal Bermuda-grass Hays of Different Maturities", Ph.D. Dissertation, Texas A&M University, 1988.
167. P. Lee, "Dosimetry of Noble Fission Gas Products", Ph. D. Dissertation, Texas A&M University, 1988.
168. K. Crowley and S. Kuhlman, "Apatite Thermochemistry of the Western Canadian Shield: Implications for the Origin of the Williston Basin", *Geophysical Research Letters*, 15/3, 221 1988.
169. B. C. Covington and M. O. Manasreh, "Fourier-Transform Infra-Red Absorption Studies of Intracenter Transitions in the EL2 Level in Semi-Insulating Bulk GaAs grown with the Liquid-Encapsulated Czochpalski Technique", *Physical Review*, 35/5, 2524 1988.
170. B. C. Covington, et al., "Electron Paramagnetic Resonance of Isolated As Antisite Defect in Neutron-Transmutation Doped GaAs", *Solid State Comm.*, 65, 1267 1988.
171. J. L. Krohn, T. H. Fisher, "Modification of the NSCR Control Rod System Utilizing Optically Sensed Rod Position Indication", Eleventh TRIGA Owner/User Conference, AFRRI, Bethesda, Maryland, April, 1988.
172. D. E. Feltz, "Installation and Operation of a D<sub>2</sub>O Moderated Rotisserie Irradiation Device for the NSCR", Eleventh TRIGA Owner/User Conference, AFRRI, Bethesda, Maryland, April, 1988.
173. J. W. Davis, "Two-Dimensional Neutronics Analysis of the TAMU Nuclear Science Center Reactor Using Transport and Diffusion Theory Based Codes, M.S. Thesis in Nuclear Engineering, Texas A&M University, 1988.
174. M. E. Denham and T. T. Tieh, "Uranium as an Indicator of Fluid Migration During Late-Stage Diagenesis", *Geological Society of America*, Vol. 20, No. 7, 1988.



175. A. R. Tripp, "Geochemistry of Arsenic and Antimony in Galveston Bay, Texas", M. S. Thesis in Oceanography, Texas A&M University, 1988.
176. A. T. Showler, R. M. Knaus and T. E. Reagan, "Foraging Territoriality of the Imported Fire Ant, *Solenopsis invicta* Buren, in Sugarcane as Determined by Neutron Activation Analysis", *Insectes Sociaux*, Paris, Vol. 36, No. 3, 1989.
177. R. M. Knaus and D. L. Van Gent, "Accretion and Canal Impacts in a Rapidly Subsiding Wetland III A New Soil Horizon Marker Method for Measuring Recent Accretion", *Estuaries*, Vol. 12, No. 4, 1989.
178. P. N. Boothe and B. J. Presley, "Trends in Sediment Trace Element Concentrations Around Six Petroleum Drilling Platforms in the Northwestern Gulf of Mexico", in *Drilling Wastes*, Engelhardt, Ray & Gillon eds., Elsevier Science Publishers, London, 1989.
179. J. D. Corrigan and K. D. Crowley, "Thermal History of Sites 717 and 718, ODP Leg 116, Central Indian Ocean: Constraints from Numerical Simulations and Apatite Fission-Track Data", Geological Society of America Annual Meeting, 1989.
180. K. D. Crowley, "Phanerozoic Thermal History of Michigan Basin and Southern Canadian Shield from Apatite Fission-Track Analysis", *Journal of Geophysical Research*, 1989.
181. J. D. Corrigan and K. D. Crowley, "Fission-Track Analysis of Detrital Apatites from Holes 717 and 718, ODP Leg 116, Central Indian Ocean", *Proceeding of the Ocean Drilling Program*, 1989.
182. N. S. Khalil, "Design, Installation and Implementation of a Neutron Depth Profiling Facility at the Texas A&M Nuclear Science Center", M.S. Thesis in Nuclear Engineering, Texas A&M University, 1989.
183. T. L. Salamanca, "Ultrasonic Measurement of Residual Stress in Steels Using Critically Refracted Longitudinal Waves", Ph.D., Dissertation in Mechanical Engineering, Texas A&M University, 1989.
184. G. R. Shelton, "Neutronics Evaluation of the Replacement Fuel for the Nuclear Science Center TRIGA Reactor", M.S. Thesis in Nuclear Engineering, Texas A&M University, May, 1989.
185. J. M. Vukovics, "Stress Analysis on NSC BeO-UO<sub>2</sub> Fuel Element Using ANSYS, M.E. in Nuclear Engineering, Texas A&M University, December, 1989.
186. R. Parthasarathy, "Reduced Enrichment Neutronics Evaluation for Texas A&M Nuclear Science Center Reactor", M.S. Thesis in Nuclear Engineering, Texas A&M University, August, 1989.

### APPENDIX III

A Listing of Educational Institutions, Industrial, Government  
and Medical Organizations That Have Utilized the  
Facilities and Services of the NSC

## Educational Institutions

Abraham Baldwin College	Fort Valley State College
Alfred State College	Galveston College
Arapahoe Junior College	Grayson County College
Arkansas State University	Grove City College
Arkansas Tech University	Hastings College
Auburn University	Henderson County Junior College
Austin College	Hill Junior College
Ball State Teachers College	Howard Payne College
Baylor School of Medicine	Iowa State University
Baylor University	Kent State University
Bemidgi State College	Lamar University
Blinn College	Laredo Junior College
Bluefield College	Lock Haven State College
Bryan High School	Longwood College
California State College	Louisiana State University
California State Poly. College	Louisiana Tech University
Catholic College for Women	Mary Hardin Baylor College
Chadran State College	Massachusetts Institute of Tech.
Cheyney State College	McLennan Community College
Clarion State College	McNeese State University
Columbus College	Miami University
Community College of the Finger Lakes	Milwaukee Institute of Technology
Defiance College	Moody College
Denison University	Nebraska Wesleyan University
Eastern Kentucky University	New Mexico State University
East Texas University	New Mexico Institute of Mining and Technology



## Educational Institutions (Cont'd)

North Park College and Theological Seminary	Taft College
North Shore Community College	Tarleton State College
North Texas State University	Temple University
Oregon State University	Thames Valley State Tech. College
Pan American University	Tennessee Tech University
Potomac State College	Texas Eastern University
Prairie View A&M University	Texas Southmost College
Rice University	Texas State Tech. Institute - Harlingen
Sam Houston State University	Texas State Tech. Institute - Waco
San Antonio College	Texas Tech University
San Bernadino Valley College	Texas Women's University
Somerset Community College	University of Alaska
South Dakota School of Mines	University of Arizona
South Dakota State University	University of Arkansas
Southeast Missouri State College	University of Calif. at Los Angeles
Southern Methodist University	University of Corpus Christi
Southwestern State College	University of Genova
Southwest Texas State College	University of Houston
Southwest Theological Seminary	University of New Hampshire
State College of Arkansas	University of Oklahoma
State University College, N.Y.	University of Pittsburgh
State University of Ohio	University of Southern Louisiana
Stephen F. Austin College	University of Texas - Arlington
Sue Bennett College	University of Texas - Austin
Sul Ross State University	University of Texas - Dallas
	University of Texas - El Paso

## Educational Institutions (Cont'd)

UT Medical School - San Antonio  
UT System Cancer Center  
University of Texas - Tyler  
University of Washington  
University of Wisconsin  
Victoria College

West Virginia Institute of Tech.  
Wharton County Junior College  
Winona State College  
Wisconsin State University  
Xavier University

## Industrial Organizations

AAE/BCS Traders, Inc.	Exxon Production Research
Amber Engineering	Exxon Research and Development
American Hoechst Corporation	General Electric Company
Andrychuk Gemstones	General Nuclear Corporation
Atomic Energy Industrial	Gulf Nuclear, Inc.
Avery Oil Company	Gulf Research
Babcock and Wilcox Company	Gulf Science and Technology
Balcones Research	Gulf States Utilities Company
Bell Helicopter	Halliburton Services, Inc.
Bendix Corporation	Hastings Radiochemical Works
Bio Assay Lab - Bio Nuclear	Houston Area Research Center
Broz Labs	Houston Lighting and Power Co.
Cardinal Survey	Hughes Aircraft Company
Celanese Company	Hughes Research Labs
Chemtrol, Inc.	Independent Exploration Company
Comfaco	Institute of Research and Instrumentation
Core Laboratories	Isotex
Diamond Alkali Company	Jet Research Center, Inc.
Dow Chemical Company	Kansas Gas and Electric Company
D. W. Mueller, Consultant	K. W. Brown & Associates
Eastern Whipstock	Lane Well Company
Ebasco	LGL, Ltd.
E.I. DuPont DeNemours and Co.	Lloyd Barber and Associates
Electric Reliability Council Texas	Medical Arts
Engineers/Designers, Inc.	Mission Engineering
Estrada, Inc.	Mobil Oil Company
E-Systems, Inc.	Monsanto, Inc.
Exxon Oil & Refining	Morris Engineering Company



## Industrial Organizations (Cont'd)

NAPKO Corporation	States Marine Lines
North American Aviation	Stoneworks
Nuclear Environmental Eng. Corp.	Technology for Energy Corp.
Nuclear Laboratory Services	Tech-Sil Corporation
Nuclear Sources and Services, Inc.	Teledyne Isotopes, Inc.
Pacific Gas and Electric Co.	Temple Industries
Petro-Tex Chemical Corp.	Tennessee Gas Transmission Co.
Poretics, Inc.	Texaco, Inc.
Pro-Tag Services, Inc.	Texas Instruments, Inc.
Racon	Texas Nuclear Corp.
Radian Corporation	Texas Romec
Radiation Consultants, Inc.	Todd Shipyards Corp.
Ranger Engineering	Traceco Services, Inc.
R/A Services, Inc.	Tracerco, Inc.
Raytheon Corporation	Tracer Labs of Midland
Research Concepts	TRACO, Inc.
Resource Engineering	TRIAD
Rivera Foods	Tru-Tec Corporation
Santa Barbara Research Center	TRW-EDS
Shell Chemical Company	Turbine Lab
Shell Development Co. - Houston	Universal Technology Corp.
Shell Development Co. - Oakland	Westinghouse Electric Co.
Southwest Research Institute	Xomax
Spectronics, Inc.	

## Government and Medical Organizations

Amarillo District Attorney  
Austin Police Department  
Brooks Medical Center  
Bureau of Economic Geology  
Corpus Christi District Attorney  
Dallas County District Attorney  
Denton County District Attorney  
Fort Worth Police Department  
Houston District Attorney  
Houston Police Department  
International Atomic Energy Agency  
Jefferson County District Attorney  
Lawrence Livermore Labs  
M. D. Anderson Tumor Center and Hospital  
National Aeronautics and Space Administration  
North East Radiological Health Lab  
Oklahoma Medical Examiner  
Orange Police Department  
Osage County Oklahoma District Attorney  
TAES Office of State Chemistry  
The Methodist Hospital of Houston  
United States Air Force  
United States Army  
United States Geologic Survey  
Wichita Falls District Attorney

#### APPENDIX IV

Texas A&M University Departments Served by  
the NSC During Twenty Eight Years of Operation



## TAMU Departments and Agencies

Department of Biochemistry and Biophysics  
Department of Nuclear Engineering  
Department of Oceanography  
Department of Physics  
Department of Petroleum Engineering  
Department of Animal Science  
Department of Range Science  
Department of Mechanical Engineering  
Department of Wildlife and Fisheries Sciences  
Department of Chemistry  
Department of Large Animal Veterinary Medicine and Surgery  
Radiological Safety Office  
Cyclotron Institute  
Department of Plant Sciences  
Department of Veterinary Physiology and Pharmacology  
Department of Radiation Biology  
Center for Chemical Characterization and Analysis  
Bioengineering Program, College of Engineering  
Texas Engineering Extension Service, Electronic Training  
Department of Geology  
Department of Forest Science  
Department of Soil and Crop Sciences  
College of Medicine  
Department of Health and Physical Education  
Department of Architecture  
Department of Building Construction  
Department of Industrial Engineering  
Department of Industrial Education  
Department of Aerospace Engineering

## TAMU Departments (Cont'd)

Department of Engineering Technology  
Department of Civil Engineering  
Fireman's Training School  
Department of Archaeology  
Department of Entomology  
Department of Recreation and Parks  
Department of Engineering Design Graphics  
College of Architecture and Environmental Design  
Center for Energy and Mineral Resources  
Department of Horticulture Sciences  
Department of Chemical Engineering  
Department of Geophysics  
Department of Geology  
Texas Agriculture Experiment Station  
Department of Electrical Engineering  
Department of Environmental Health  
Department of "Vet" Public Health

APPENDIX V

Environmental Survey Program, Effluent Release  
Summary and Personnel Exposure Summary



Summary of Health Physics  
Support for the Operation of  
the Nuclear Science Center Reactor  
1989

- Provided health physics monitoring support for processing 667 irradiations.
- Certified 293 shipments of radioactive materials to off-site industry.
- Certified 132 shipments of radioactive materials to other campus laboratories.
- Conducted environmental survey program in cooperation with the Texas State Department of Health. This program consists of in-situ TLD monitors and the collection, analyses and evaluation of soil, water, vegetation, and milk samples.
- Provided personnel monitoring support for 24 persons on a daily basis and 3,729 visitors as required.
- Performed radionuclide identification and determined radioactivity concentrations for 30 releases of radioactive liquid effluents totaling 1.33 E+06 liters (3.513 E+05 gallons) including fresh water diluent.
- Performed surveys of the Nuclear Science Center facilities for radiation levels and radioactive contamination including the collection, analyses, and evaluation of approximately 250 smear samples on a monthly basis.
- Conducted radiation safety training for 100 NSC employees and experimental personnel using NSC facilities.

## EFFLUENT RELEASE SUMMARY

Introduction

Summaries of radioactive effluents released from the Nuclear Science Center for 1989 are included in this Appendix. These data are presented in tabular form and includes atmospheric, liquid and solid waste releases.

Particulate Releases

Radioactive particulates are monitored at the base of the central exhaust stack and summarized on a monthly basis. The annual average release rate was  $1.42 \text{ E-11 } \mu\text{Ci/cc}$ . Total radioactivity released for the year was  $1.06 \text{ E-03 Curies}$ . These data, presented in Table 1, represent output of the Nuclear Science Center Facility Air Monitoring System. The individual particulate monitors in this system detect gross beta and gamma radiations emitted from filtered particulate material.

Gaseous Releases

Argon-41 is the major gaseous effluent produced and released at the Nuclear Science Center. This effluent is measured by counting the Argon-41 photopeak in the gaseous discharges of the central exhaust stack. Total Argon-41 released during 1989 was 2.46 Curies. This results in an annual average release rate of  $3.98 \text{ E-07 } \mu\text{Ci/cc}$  as measured in the central exhaust stack with no dilution factors applied. Applying the dilution factor of  $5.0 \text{ E-03}$  allowed at the site boundary (as determined, SAR, pages 116-119, June 1980) results in radioactivity concentrations of  $<5.0\%$  of the limits specified in 10CFR20, Appendix B, Table II, Column 1. These data are summarized on a monthly basis and presented in Table 2.

TABLE 1  
 Particulate Effluent Releases  
 Annual Summary  
 1989

Month	Exhaust Volume(cc)	Average Concentration* ( $\mu$ Ci/cc)	Radioactivity Released (Ci)
January	6.31 E12	2.5 E-11	1.58 E-04
February	5.70 E12	1.6 E-11	9.12 E-05
March	6.31 E12	2.6 E-11	1.64 E-04
April	6.12 E12	9.0 E-12	5.51 E-05
May	6.31 E12	2.28 E-11	1.44 E-04
June	6.12 E12	2.79 E-11	1.71 E-04
July	6.31 E12	1.4 E-11	8.83 E-05
August	6.31 E12	2.1 E-11	1.33 E-04
September	6.12 E12	$\leq 4.2$ E-11	$\leq 2.57$ E-04
October	6.31 E12	$\leq 6.45$ E-11	$\leq 4.07$ E-04
November	6.12 E12	2.11 E-12	1.29 E-05
December	6.31 E12	$\leq 3.04$ E-11	$\leq 1.92$ E-04

Total Volume: 7.43 E13 (cc)

Annual Average Release Concentration\*: 3.01 E-10  $\mu$ Ci/cc

Total Radioactivity Released: 2.24 E-02 Ci

\*As measured in the central exhaust stack without applying the allowed 200/1 dilution factor between the release point and the approximate boundary of the exclusion area (SAR, pp. 117-119, June 1979).

There were no releases of particulates with half-lives greater than eight days that exceeded 25% of the concentration allowed or recommended.



TABLE 2  
Gaseous Effluent Releases  
Argon-41  
Annual Summary  
1989

Month	Exhaust Volume (cc)	Average Concentration* ( $\mu\text{Ci/cc}$ )	Average Concentration** ( $\mu\text{Ci/cc}$ )	Total Radioactivity (Ci)*
January	6.31 E12	$\leq 6.03 \text{ E-09}$	$\leq 3.02 \text{ E-11}$	$\leq 3.81 \text{ E-02}$
February	5.70 E12	2.6 E-08	1.30 E-10	1.48 E-01
March	6.31 E12	7.67 E-09	3.84 E-11	4.84 E-02
April	6.12 E12	5.04 E-08	2.52 E-10	3.08 E-01
May	6.31 E12	5.04 E-08	2.52 E-10	3.18 E-01
June	6.12 E12	5.19 E-08	2.6 E-10	3.18 E-01
July	6.31 E12	7.73 E-08	3.87 E-10	4.8 E-01
August	6.31 E12	1.51 E-08	7.55 E-11	9.53 E-02
September	6.12 E12	$\leq 5.52 \text{ E-09}$	$\leq 2.76 \text{ E-11}$	$\leq 3.38 \text{ E-02}$
October	6.31 E12	$\leq 5.12 \text{ E-09}$	$\leq 2.56 \text{ E-11}$	$\leq 3.23 \text{ E-02}$
November	6.12 E12	6.38 E-08	3.19 E-10	3.9 E-01
December	6.31 E12	3.86 E-08	1.93 E-10	2.44 E-01

Total Volume: 7.44 E+13 cc

Annual Average Release Concentration\*:  $\leq 3.98 \text{ E-07 } \mu\text{Ci/cc}$

Total Ar-41 Radioactivity Released: 2.46 E+01 Ci

\*As measured in the central exhaust stack

\*\*As determined at 100 meters, approximate boundary of exclusion area, with 200/1 dilution factor (SAR, pp. 117-119, June 1979).

### Solid Radioactive Waste

Approximately 220 ft<sup>3</sup> of uncompacted dry solid waste material was packaged in plastic bags for disposal during 1989. These materials were transferred to the Texas A&M University Office of Radiological Safety, Texas License 6-448, for disposal. This material consisted of laboratory glassware, irradiation containers, decontamination materials, and expendable protective clothing and equipment, e.g., paper, shoe covers, plastic bags and gloves. The total radioactivity summed over all bags was 1.06 E-02 Ci. These data are in Table 3. The transfers were made on 5-31-89 and 12-19-89.

### Liquid Waste Releases

Radioactive liquid effluents are collected in liquid waste holdup tanks prior to release from the confines of the Nuclear Science Center. Sample analyses for radioisotope identification and radioactivity concentrations were determined for each release. There were 38 liquid waste releases totaling 1.33 E+09 ml (3.51 E+05) including diluents from the Nuclear Science Center during 1989. The total radioactivity released for 1989 was 3.23 E-03 Ci with an average concentration of 2.88 E-06  $\mu$ Ci/ml. Summaries of the radioisotope data are presented in Tables 4 through 16. Radioactivity concentrations for each isotope were below the limits specified in 10CFR20, Appendix B, Table II, Column 2.

TABLE 3  
Solid Radioactive Waste Disposal  
Annual Summary  
1989

Radioisotope	Radioactivity ( $\mu$ Ci)
Cd-109	17.65
Ce-141	2228.92
Ce-144	1730.13
Co-57	55.19
Co-60	.037.58
Cr-51	1161.25
Cs-134	21.08
Cs-137	77.30
Eu-152	5.60
Eu-154	9.11
Ir-192	685.62
Mn-54	437.96
Nb-95	799.12
Ru-103	672.003
Sc-46	3.70
Sr-85	91.818
Tm-170	115.54
Zn-65	799.12
Zr-95	124.16

Total Volume: ~ 220 ft<sup>3</sup> contained in plastic bags (uncompacted)

Total Radioactivity: 1.06 E-02 Ci



TABLE 4  
Radioactive Liquid Effluent Releases  
Summary  
1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Cr-51	7	3.94E+08	1.58 E-05	2E-03	7.9	9.19 E-04
Co-60	25	1.1E+09	1.05 E-05	3E-05	35.00	3.28 E-04
Mn-54	29	1.27E+09	2.46 E-05	1E-04	24.6	1.31 E-03
Na-24	7	2.26E+08	1.46 E-05	3E-05	48.7	3.04 E-04
Zn-65	1	5.31E+07	5.8 E-08	1E-04	0.06	3.08 E-06
K-40	1	1.52E+07	3.93 E-07	3E-04	0.13	5.96 E-06
Sb-124	4	1.93E+08	6.86 E-06	2E-05	34.3	3.17 E-04
Ir-192	2	1.05E+08	4.9 E-07	4E-05	1.23	2.58 E-05

Total Number of Releases: 30

Total Volume Including Dilution: 1.33E+09 ml (3.51 E+05 gal)

Total Activity Curies: 3.23E-03

Average Concentration Including Dilution 1.96E-06  $\mu\text{Ci/cc}$

TABLE 5

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
January 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Co-60	1	4.58E+07	4.4 E-07	3E-05	1.47	2.01 E-05
Mn-54	1	4.58E+07	8.8 E-07	1E-04	0.88	4.03 E-05

Total Number of Releases: 1

Total Volume Released (with dilution): 4.58E+07 ml (1.21 E+04 gal)

Average Concentration (with dilution): 1.32E-06  $\mu\text{Ci/cc}$

Total Radioactivity: 6.04E-05 Curies

TABLE 6

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
February 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Co-60	1	5.21E+07	3.8 E-07	3E-05	1.27	1.98 E-05
Mn-54	1	5.21E+07	1.06 E-06	1E-04	1.06	5.52 E-05
Ir-192	1	5.21E+07	2 E-07	4E-05	0.5	1.04 E-05

Total Number of Releases: 1

Total Volume Released (with dilution): 5.21E+07 ml (1.37 E+04 gal)

Average Concentration (with dilution): 1.64E-06  $\mu\text{Ci/cc}$

Total Radioactivity: 8.55E-05 Curies



TABLE 7

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
March 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Co-60	2	$8.41\text{E}+07$	$1.15\text{ E}-06$	$3\text{E}-05$	3.83	$5.24\text{ E}-05$
Mn-54	2	$8.41\text{E}+07$	$2.94\text{ E}-06$	$1\text{E}-04$	2.94	$1.94\text{ E}-04$
Cr-51	1	$5.38\text{E}+07$	$3.1\text{ E}-06$	$2\text{E}-03$	0.16	$1.66\text{ E}-04$

Total Number of Releases: 2

Total Volume Released (with dilution):  $8.41\text{E}+07$  ml ( $2.22\text{ E}+04$  gal)

Average Concentration (with dilution):  $4.21\text{E}-06\text{ }\mu\text{Ci/cc}$

Total Radioactivity:  $4.13\text{E}-04$  Curies

TABLE 8

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
April 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Co-60	1	5.05E+07	3.18E-07	3E-05	1.06	1.61 E-05
Mn-54	2	9.39E+07	1.31 E-06	1E-04	1.31	6.44 E-05

Total Number of Releases: 2

Total Volume Released (with dilution): 9.39E+07 ml (2.48 E+04 gal)

Average Concentration (with dilution): 8.13E-07  $\mu\text{Ci/cc}$

Total Radioactivity: 8.04E-05 Curies

TABLE 9

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
May 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Co-60	3	1.41E+08	6.28 E-07	3E-05	2.09	2.96 E-05
Mn-54	3	1.41E+08	1.33 E-06	1E-04	1.33	6.22 E-05
Na-24	1	4.42E+07	4.15 E-07	3E-05	1.38	1.84 E-05

Total Number of Releases: 3

Total Volume Released (with dilution): 1.41E+08 ml (3.72 E+04 gal)

Average Concentration (with dilution): 7.87E-07  $\mu\text{Ci/cc}$

Total Radioactivity: 1.11E-04 Curies



TABLE 10

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
June 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Cr-51	1	5.31E+07	1.2 E-06	2E-03	0.06	6.37 E-05
Co-60	2	9.9 E+07	3.81 E-06	3E-05	12.7	2.87 E-05
Mn-54	3	1.53E+08	2.39 E-06	1E-04	2.39	1.25 E-04
Ir-192	1	5.31E+07	2.9 E-07	4E-05	0.73	1.54 E-05

Total Number of Releases: 3

Total Volume Released (with dilution): 1.53E+08 ml (4.04 E+04 gal)

Average Concentration (with dilution): 1.48E-06  $\mu\text{Ci/cc}$

Total Radioactivity: 2.33E-04 Curies

TABLE 11

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
July 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Cr-51	1	5.50E+07	1.1 E-06	2E-03	0.06	6.05 E-05
Co-60	2	1.08E+08	6.71 E-07	3E-05	2.25	3.66 E-05
Mn-54	1	5.5 E+07	4.2 E-07	1E-04	0.42	1.04 E-04

Total Number of Releases: 2

Total Volume Released (with dilution): 1.08E+08 ml (2.85 E+04 gal)

Average Concentration (with dilution): 1.84E-06  $\mu\text{Ci/cc}$

Total Radioactivity: 2.02E-04 Curies

TABLE 12

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
August 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Cr-51	1	5.38E+07	5.5 E-06	2E-03	0.27	2.96 E-04
Co-60	1	5.38E+07	9.7 E-07	3E-05	3.23	5.22 E-05
Mn-54	3	1.39E+08	5.53 E-06	1E-04	5.53	2.92 E-04
Na-24	1	5.38E+07	9.5 E-07	3E-05	3.17	5.11 E-05

Total Number of Releases: 3

Total Volume Released (with dilution): 1.39E+08 ml (3 67 E+04 gal)

Average Concentration (with dilution): 4.31E-06  $\mu\text{Ci/cc}$

Total Radioactivity: 6.91E-04 Curies



TABLE 13

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
September 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Cr-51	3	1.51E+08	4.54 E-06	2E-03	0.23	2.33 E-04
Co-60	6	2.33E+08	1.22 E-06	3E-05	4.07	3.53 E-05
Mn-54	6	2.33E+08	5.49 E-06	1E-04	5.49	2.15 E-04
Na-24	1	1.77E+07	1.9 E-07	3E-05	0.19	3.36 E-06
Sb-124	2	9.79E+07	1.3 E-06	2E-05	6.50	6.19 E-05
Zn-65	1	5.31E+07	5.8 E-08	1E-04	0.06	3.08 E-06

Total Number of Releases: 6

Total Volume Released (with dilution): 2.33E+08 mL (6.16 E+04 gal)

Average Concentration (with dilution): 2.13E-06  $\mu\text{Ci/cc}$

Total Radioactivity: 5.55E-04 Curies

TABLE 14

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
October 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Co-60	2	7.52E+07	1.73 E-07	3E-05	0.58	6.82 E-06
Mn-54	2	7.52E+07	4.34 E-07	1E-04	0.43	1.76 E-05

Total Number of Releases: 2

Total Volume Released (with dilution): 7.52E+07 ml (1.98 E+04 gal)

Average Concentration (with dilution): 3.04E-07  $\mu\text{Ci/cc}$

Total Radioactivity: 3.62E-05 Curies

TABLE 15

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
November 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu\text{Ci/cc}$	MPC $\mu\text{Ci/cc}$	MPC Percent	Activity Curies
Co-60	2	7.21E+07	2.31 E-07	3E-05	0.77	1.01 E-05
Mn-54	2	7.21E+07	6.49 E-07	1E-04	0.65	3.27 E-05
Na-24	1	1.52E+07	5.08 E-08	3E-05	0.17	7.69 E-07
K-40	1	1.52E+07	3.93 E-07	3E-04	0.13	5.96 E-06
Sb-124	1	5.69E+07	2.34 E-06	2E-05	11.70	1.33 E-04

Total Number of Releases: 2

Total Volume Released (with dilution): 7.21E+07 ml (1.90 E+04 gal)

Average Concentration (with dilution): 1.55E-06  $\mu\text{Ci/cc}$

Total Radioactivity: 1.82E-04 Curies



TABLE 16

Nuclear Science Center  
Radioactive Liquid Effluent Releases  
Monthly Summary  
December 1989

Isotope	No. of Releases	Volume mL	Conc. $\mu$ Ci/cc	MPC $\mu$ Ci/cc	MPC Percent	Activity Curies
Cr-51	1	3.79E+07	2.27 E-06	2E-03	0.13	8.60 E-05
Ce-60	2	3.72E+07	4.8 E-07	3E-05	1.60	2.06 E-05
Mn-54	3	1.25E+08	2.81 E-06	1E-04	2.81	1.17 E-04
Na-24	3	9.48E+07	1.3 E-05	3E-05	43.33	2.3 E-04
Sb-124	1	3.79E+07	3.22 E-06	7E-04	0.46	1.22 E-04

Total Number of Releases: 4

Total Volume Released (with dilution): 1.40E+08 ml (3.70 E+04 gal)

Average Concentration (with dilution): 3.14E-06  $\mu$  Ci/cc

Total Radioactivity: 5.76E-04 Curies

## ENVIRONMENTAL SURVEY PROGRAM

Introduction

The environmental survey samples were collected in accordance with the schedules of the cooperative surveillance program between the Texas State Department of Health and the Texas A&M University. These samples were analyzed for gross gamma and beta activities and isotope identification. Data from these samples reflect the continued use of retention facilities and sample analysis for laboratory effluents prior to their release.

The environmental survey program includes the in-situ measurement of integrated radiation exposures at the site boundaries. These measurements are made for a period of approximately 90 days using commercially available thermoluminescent dosimeters (TLD's) of lithium fluoride chips in glass encapsulated bulbs. The dosimeters are provided and processed by Texas Department of Health, Bureau of Radiation Control, Division of Environmental Programs. The state utilizes a background monitor located at a point 5.25 miles west-southwest of the NSC facility. This site for the background measurement is generally at right angles to the prevailing southeasterly winds.

Table 17 lists the average exposure rate above ambient background for a number of locations at the site boundary. The highest exposure point was determined to be at Site #3 (390 mR/yr) which is on the NSC Site Boundary fence west by south-west of the reactor building.

The closest offsite point of extended occupancy is located just beyond the Site Boundary fence directly behind the Site #10 monitoring location. From the data in Table 17, it can be easily shown that those occupants received much less than twice the average local off-site background exposure.

Summaries of the environmental survey program for 1989 are presented in Tables 18-21 for total (sum) gamma or total beta activity as reported to the NSC or as determined by the NSC when data from the state was unavailable.



TABLE 17

Environmental Radiation Monitoring Program  
Radiation Exposures, 1989

<u>Site #</u>	<u>Location</u>	<u>Measured Average Exposure Rate (<math>\mu</math>R/hr)</u>	<u>Projected Annual Exposure, 1989 (mR)</u>
2	104 yd W of reactor building, on SW chain link fence, 1.6 yd SE of W corner	6.7	59
3	86 yd WSW of reactor building, on SW chain link fence, 45 yd SE of W corner	29.7	261
4	68 yd NW of reactor building, on NE chain link fence, 67 yd NE of W corner, near junction of calibration range fence and NE chain link fence	10.5	92
5	75 yd NE of reactor building, 8.3 yd NW of main gate, on NE chain link fence	8.1	71
6	99 yd NNE of reactor building, on NE chain link fence, 1.6 yd SE of N corner	19.8	174
10	63 yd SE of reactor building, on SE chain link fence, 78 yd SW of E corner	7.5	66
11	99 yd E of reactor building, on NE chain link fence, 1.6 yd NW of E corner	7.1	63
14A	5.25 miles WSW of reactor building, at FM 60 bridge over Brazos River, at SW side of bridge, on fence brace of wooden fence at end of access road - back- ground (as of 3/26/87)	5.8*	51*

Monitoring Period for "Measured" data: 4 February 1989 through  
19 October 1989. Fourth quarter data not yet available. "Projected"  
exposures for 1 January 1989 through 31 December 1989.

\*Background values.



TABLE 18  
Environmental Survey Programs  
First Quarter 1989

VEGETATION

Location	Number Samples	Total Activity* (pCi/g)	Activity** (pCi/g)
TAMU Dairy	1	6.4	0.3

WATER

Location	Number Samples	(pCi/ml)	(pCi/ml)
Brazos River	1	≤ MDA	≤ MDA
White Creek	1	0.019	0.019

MILK

Location	Number Samples	(pCi/ml)	(pCi/ml)
TAMU Dairy	1	1.39	≤ MDA

SOIL

Location	Number Samples	(pCi/g)	(pCi/g)
NSC Creek	1	16.1	8.9

\*Total gamma activity including naturally occurring radionuclides

\*\*Excluding naturally occurring radionuclides

TABLE 19  
Environmental Survey Program  
Second Quarter 1989

VEGETATION

Location	Number Samples	Total activity* (pCi/g)	Activity** (pCi/g)
TAMU Dairy	1	32.7	≤ MDA

WATER

Location	Number Samples	(pCi/ml)	(pCi/ml)
Brazos River	1	≤ MDA	≤ MDA
White Creek	1	0.970	≤ MDA

MILK

Location	Number Samples	(pCi/ml)	(pCi/ml)
TAMU Dairy	1	1.8	— MDA

SOIL

Location	Number Samples	(pCi/g)	(pCi/g)
NSC Creek	1	30.7	13.2

\*Total gamma activity

\*\*Excluding naturally occurring radionuclides

TABLE 20  
Environmental Survey Program  
Third Quarter 1989

VEGETATION

Location	Number Samples	Total Activity* (pCi/g)	Activity** (pCi/g)
TAMU Dairy	1	≤ MDA	≤ MDA

WATER

Location	Number Samples	(pCi/ml)	(pCi/ml)
Brazos River	1	≤ MDA	≤ MDA
White Creek	1	≤ MDA	≤ MDA

MILK

Location	Number Samples	(pCi/mL)	(pCi/g)
TAMU Dairy	1	≤ MDA	≤ MDA

SOIL

Location	Number Samples	(pCi/g)	(pCi/g)
NSC Creek	1	40.1	7.1

\*Total gamma activity

\*\*Excluding naturally occurring radionuclides



TABLE 21  
Environmental Survey Program  
Fourth Quarter 1989

VEGETATION

Location	Number Samples	Total Activity* (pCi/g)	Activity** (pCi/g)
TAMU Dairy	1	1.95	0.104

WATER

Location	Number Samples	(pCi/ml)	(pCi/ml)
Brazos River	1	0.376	0.12
White Creek	1	≤ MDA	≤ MDA

MILK

Location	Number Samples	(pCi/ml)	(pCi/ml)
A&M Dairy	1	0.772	≤ MDA

SOIL

Location	Number Samples	(pCi/g)	(pCi/g)
NSC Creek	1	0.04.9	23.9

\*Total gamma activity

\*\*Excluding naturally occurring radionuclides

## PERSONNEL EXPOSURES

Radiation exposures to personnel at the Nuclear Science Center in 1989 were below the limits set forth in 10CFR20.101. The maximum exposure received by any individual for the year was 440 mrem. A total of 3.16 mNREM was received for 1989.

During 1989, 3,745 persons visited the Nuclear Science Center. The maximum exposure to any visitor as determined by issued film badges did not exceed minimum measurable quantities. Dosimetry results were provided by a NVLAP accredited supplier.



## RADIATION AND CONTAMINATION CONTROL PROGRAM

### Introduction

The detection and elimination or control of radiation hazards is an integral part of the Radiation Safety Program at the Nuclear Science Center. The radiation and smear survey programs contribute to the control and elimination of these health hazards. This program is effective in preventing the spread of radioactive contamination, improper storage of radioactive materials, and unwarranted exposures to radiation.

### Radiation Survey

The Nuclear Science Center uses an area radiation monitoring system consisting of ten (10) detector channels located throughout the Reactor and Laboratory Buildings. This system is equipped with alarm settings and remote readouts in the control and reception rooms. Radiation levels and operational checks are recorded on a daily basis. This system functions as a radiation safety monitor for the early detection of radiation hazards. The Nuclear Science Center facilities and site boundaries are surveyed monthly with beta-gamma sensitive instruments. These measurements are taken to determine proper storage and identification of radioactive materials and that visitor and routine work areas are free of radiation hazards. Additionally, radiation monitoring support is provided for the reactor operations and experimenter groups to insure the safe handling of radioactive materials and control of personnel exposures. At the perimeter of the NSC site, radiation levels did not exceed the 500 mrem dose limit during 1989.

### Contamination Survey

The Nuclear Science Center is routinely surveyed for radioactive contamination every month. This program includes the collection, analysis and evaluation of approximately 250 smear samples and the decontamination of areas and materials with removable beta-gamma radioactivities of greater than 1000 dpm/100 cm<sup>2</sup>.



TABLE 22  
Summary of Whole Body Exposures  
1989

Whole Body Exposure Range (Rem)	Number of Persons In Range
No Measurable Exposure	3
Less than 0.100	22
0.100 - 0.249	6
0.250 - 0.499	1
0.500 - 0.749	0
0.750 - 0.999	0
1.000 - 1.999	0
2.000 - 2.999	0
3.000 - 3.999	0
4.000 - 4.999	0
5.000	0
Greater than 5.000	0
Total Number of Individuals Reported:	32