ORO-4207-22

TWENTY-SIXTH PROGRESS REPORT OF THE TEXAS A&M UNIVERSITY NUCLEAR SCIENCE CENTER

JANUARY 1, 1989-DECEMBER 31, 1989

CONTRACT DE-AC05-76ER04207

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Per T. Michaels

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

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

Table of Contents

List of Tables and Figures

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-AC05-76ER0)4207 (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

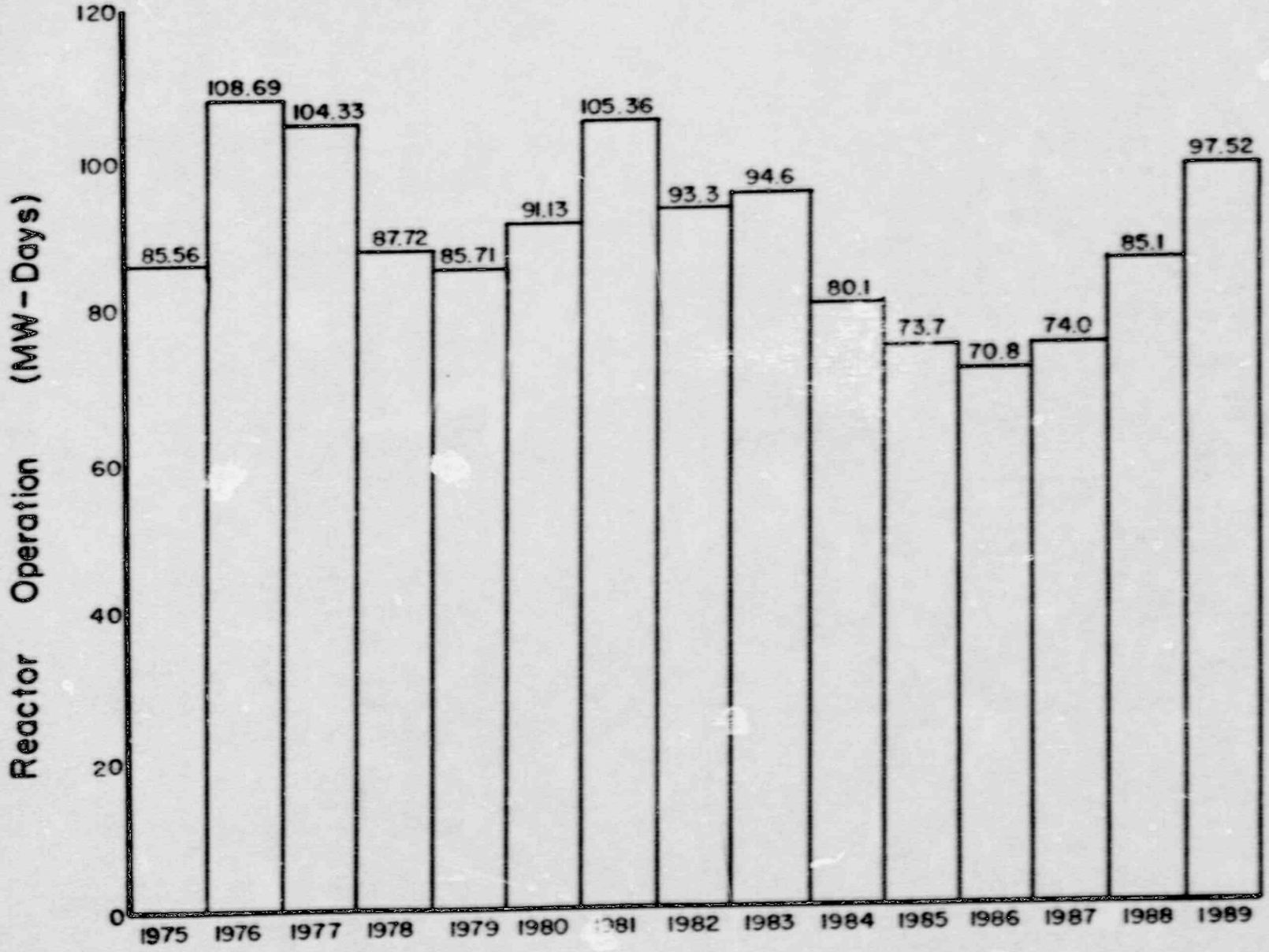

Figure 1. Yearly Reactor Operation

TABLE I

REACTOR UTILIZATION SUMMARY

	1989 Annual Total
*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. Senor	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
S. Brown
P. McKay
A. Showler
J. Nguyen

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

Department	Course No.	Instructor	No. of Students and Purpose
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 Okalahoma -- 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 parrafin, 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 strapes. 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 turnover 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 Opeations
+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)

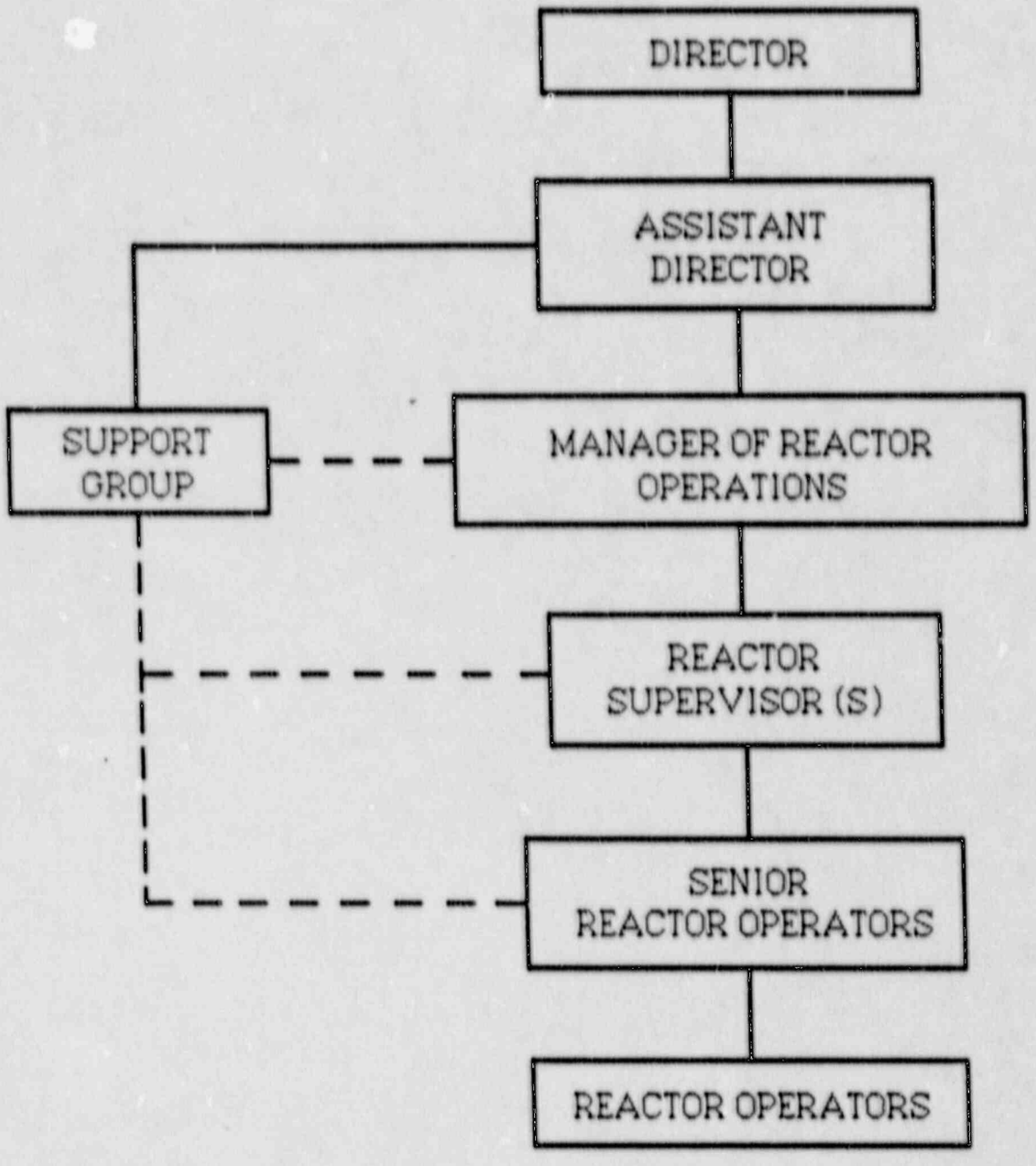

Figure 2 Nuclear Science Center
Reactor Operations Organization Chart

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. Kenefick, 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 University

Nuclear 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. Rozgonyi -- 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 [illegible] 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 CRETACEAUS/TERTIARY BOUNDARY

Personnel

Dr. N. Carter -- Professor
A. Huffman -- Graduate Assistant
T. Oldham -- Graduate Assistgant

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

B. Other Universities

Louisiana 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 Institutions

M. 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.

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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, "Mineralogical 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 Minerology in an Unoxidized Roll Front in the Jackson Group, South Texas", M. S. Thesis in Geology, Texas A&M University, 1978.

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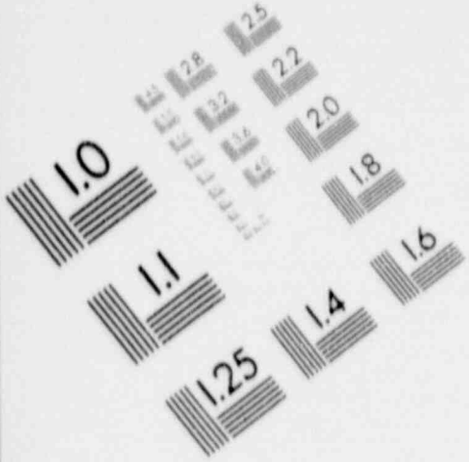
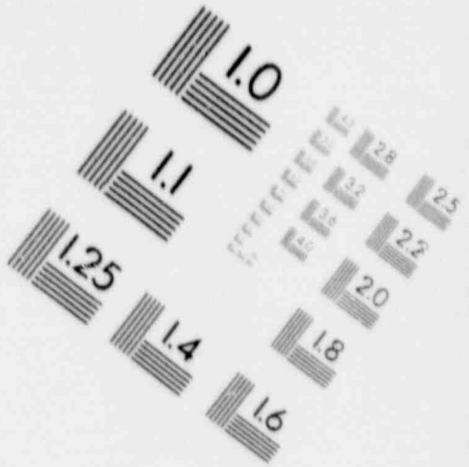
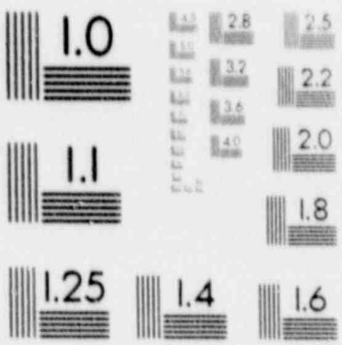
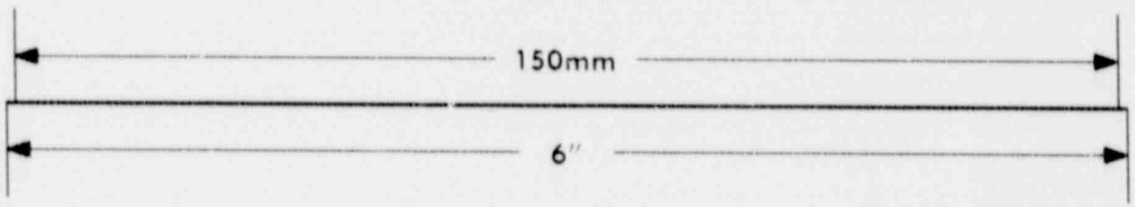
2

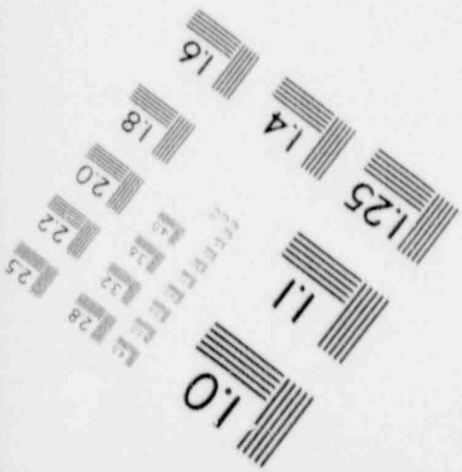
IMAGE EVALUATION TEST TARGET (MT-3)

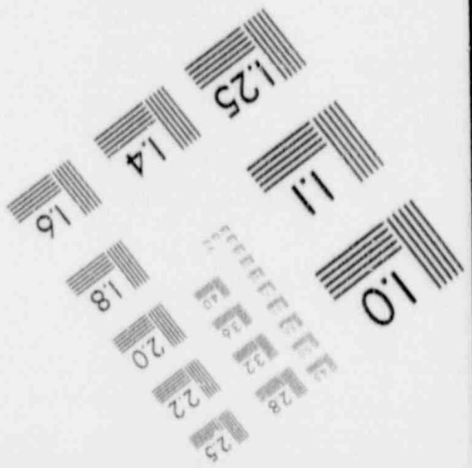












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(716) 265-1600

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

Educational Institutions (Cont'd)

North Park College and Theological Seminary
North Shore Community College
North Texas State University
Oregon State University
Pan American University
Potomac State College
Prairie View A&M University
Rice University
Sam Houston State University
San Antonio College
San Bernadino Valley College
Somerset Community College
South Dakota School of Mines
South Dakota State University
Southeast Missouri State College
Southern Methodist University
Southwestern State College
Southwest Texas State College
Southwest Theological Seminary
State College of Arkansas
State University College, N.Y.
State University of Ohio
Stephen F. Austin College
Sue Bennett College
Sul Ross State University
Taft College
Tarleton State College
Temple University
Thames Valley State Tech. College
Tennessee Tech University
Texas Eastern University
Texas Southmost College
Texas State Tech. Institute - Harlingen
Texas State Tech. Institute - Waco
Texas Tech University
Texas Women's University
University of Alaska
University of Arizona
University of Arkansas
University of Calif. at Los Angeles
University of Corpus Christi
University of Genova
University of Houston
University of New Hampshire
University of Oklahoma
University of Pittsburgh
University of Southern Louisiana
University of Texas - Arlington
University of Texas - Austin
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.
Amber Engineering
American Hoechst Corporation
Andrychuk Gemstones
Atomic Energy Industrial
Avery Oil Company
Babcock and Wilcox Company
Balcones Research
Bell Helicopter
Bendix Corporation
Bio Assay Lab - Bio Nuclear
Broz Labs
Cardinal Survey
Celanese Company
Chemtrol, Inc.
Comfaco
Core Laboratories
Diamond Alkali Company
Dow Chemical Company
D. W. Mueller, Consultant
Eastern Whipstock
Ebasco
E.I. DuPont DeNemours and Co.
Electric Reliability Council Texas
Engineers/Designers, Inc.
Estrada, Inc.
E-Systems, Inc.
Exxon Oil & Refining
Exxon Production Research
Exxon Research and Development
General Electric Company
General Nuclear Corporation
Gulf Nuclear, Inc.
Gulf Research
Gulf Science and Technology
Gulf States Utilities Company
Halliburton Services, Inc.
Hastings Radiochemical Works
Houston Area Research Center
Houston Lighting and Power Co.
Hughes Aircraft Company
Hughes Research Labs
Independent Exploration Company
Institute of Research and Instrumentation
Isotex
Jet Research Center, Inc.
Kansas Gas and Electric Company
K. W. Brown & Associates
Lane Well Company
LGL, Ltd.
Lloyd Barber and Associates
Medical Arts
Mission Engineering
Mobil Oil Company
Monsanto, Inc.
Morris Engineering Company

Industrial Organizations (Cont'd)

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

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 E-11 µCi/cc. Total radioactivity released for the year was 1.06 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 E-07 µCi/cc as measured in the central exhaust stack with no dilution factors applied. Applying the dilution factor of 5.0 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* (µCi/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	≤ 4.2 E-11	≤ 2.57 E-04
October	6.31 E12	≤ 6.45 E-11	≤ 4.07 E-04
November	6.12 E12	2.11 E-12	1.29 E-05
December	6.31 E12	≤ 3.04 E-11	≤ 1.92 E-04

Total Volume: 7.43 E13 (cc)

Annual Average Release Concentration*: 3.01 E-10 µCi/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* (µCi/cc)	Average Concentration** (µCi/cc)	Total Radioactivity (Ci)*
January	6.31 E12	≤ 6.03 E-09	≤ 3.02 E-11	≤ 3.81 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	≤ 5.52 E-09	≤ 2.76 E-11	≤ 3.38 E-02
October	6.31 E12	≤ 5.12 E-09	≤ 2.56 E-11	≤ 3.23 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*: ≤ 3.98 E-07 µCi/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^3 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 µCi/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 (μCi)
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^3 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. µCi/cc	MPC µCi/cc	MPC Percent	Activity Curies
Cr-51	7	3.94E+08	1.58 E-05	2E-03	0.79	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 µCi/cc

TABLE 5

Nuclear Science Center
Radioactive Liquid Effluent Releases
Monthly Summary
January 1989

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

Total Number of Releases: 2

Total Volume Released (with dilution): 8.41E+07 ml (2.22 E+04 gal)

Average Concentration (with dilution): 4.21E-05 µCi/cc

Total Radioactivity: 4.13E-04 Curies

TABLE 8

Nuclear Science Center
Radioactive Liquid Effluent Releases
Monthly Summary
April 1989

Isotope	No. of Releases	Volume mL	Conc. µCi/cc	MPC µCi/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 µCi/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. µCi/cc	MPC µCi/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 µCi/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. µCi/cc	MPC µCi/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 µCi/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. µCi/cc	MPC µCi/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	1.081+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 µCi/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. µCi/cc	MPC µCi/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 µCi/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. µCi/cc	MPC µCi/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 µCi/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. µCi/cc	MPC µCi/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 µCi/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. µCi/cc	MPC µCi/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 µCi/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. µCi/cc	MPC µCi/cc	MPC Percent	Activity Curies
Cr-51	1	3.79E+07	2.27 E-06	2E-03	0.13	8.60 E-05
Co-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 µCi/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

Site #	Location	Measured Average Exposure Rate (μR/hr)	Projected Annual Exposure, 1989 (mR)
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 - background (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

V E G E T A T I O N

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

W A T E R

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

M I L K

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

S O I L

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

V E G E T A T I O N

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

W A T E R

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

M I L K

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

S O I L

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

V E G E T A T I O N

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

W A T E R

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

M I L K

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

S O I L

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

V E G E T A T I O N

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

W A T E R

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

M I L K

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

S O I L

Location	Number Samples	(pCi/g)	(pCi/g)
NSC Creek	1	204.9	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 MANREM 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 radiaoctive contamination, improper storage of radiaoctive 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^2.

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