The University of Texas at Austin

Nuclear Engineering Teaching Laboratory

2000

Annual Report

NRC Docket 50-602

DOE Contract No. DE-AC07-ER03919

EXECUTIVE SUMMARY

There was a significant increase in reactor and facility usage during this reporting period. The Nuclear Engineering Teaching Laboratory (NETL) facility continues to support the academic and research missions of The University of Texas but has begun to provide these support functions to other institutions. Experimenters from Canada and Mexico requested the support of the faculty and staff of the Nuclear Engineering Program during 2000 and these collaborations will continue into the future. The environmental research and analysis services performed by the NETL during this past year supported the U.S. Army, the Amarillo National Resource Center and the State of Texas.

Work continued towards the construction and testing of a reactor-based slow-positron beam at the NETL. This project is supported by the State of Texas Advanced Technology Program and is a collaborative project with The University of Texas at Arlington. When complete, it will be one of a few, intense, slow variable-energy positron beams in the world.

The following is a partial list of NETL funded research and services provided for the reporting period. Descriptions of some individual projects are found in Section 2 of the Annual Report. Complete project descriptions are available at the NETL.

- Radiation Damage and Microstructual Changes of Stainless Steels Due to Long Term Irradiation by Alpha Particles
- Neutron Imaging System for Materials Characterization Research at the University of Texas Reactor
- University Reactor Sharing (IL, VT, NH, TX, LA)
- Investigations of Plutonium Waste Streams in a MOX Facility
- Investigations of Lead and Heavy Metals Contaminated Surface Soils from PANTEX Firing Ranges
- Determination of Cs-137 in Soils at Fort Hood for monitoring soil erosion
- Determination of Trace Elements in Archaeological Materials by Neutron Activation Analysis
- Air Filter Analysis for Heavy Metals for Vermont Environmental Monitoring

FORWARD

The mission of the Nuclear Engineering Teaching Laboratory at The University of Texas at Austin is to:

Support the teaching and research mission of the University of Texas and the greater scientific community by the application of advanced radiation engineering and science.

This objective is achieved by carrying out a well-balanced program of education, research, and service. The focus of all of these activities is the new TRIGA research reactor, the first new U.S. University reactor in 20 years.

The NETL research reactor supports hands-on education in reactor physics and nuclear science. In addition, the reactor can be used in laboratory course work by students in non-nuclear fields such as physics, chemistry, and biology. It may also be used in education programs for nuclear power plant personnel, secondary schools students and teachers, and the general public.

The NETL research reactor benefits a wide range of on-campus and off-campus users, including academic, medical, industrial, and government organizations. The principal services offered by our reactor involve material irradiation, trace element detection, material analysis, and radiographic analysis of objects and processes. Such services establish beneficial links to off-campus users, expose faculty and students to multidisiplinary research and commercial applications of nuclear science, and earn revenues to help support Nuclear Engineering activities.

Carl Beard, Director
Nuclear Engineering Teaching Laboratory

Chapter 1

1.0 NUCLEAR ENGINEERING TEACHING LABORATORY

1.1 Introduction

Purpose of the Report

The Nuclear Engineering Teaching Laboratory (NETL) at The University of Texas at Austin prepares an annual report of program activities. Information in this report provides an introduction to the education, research, and service programs of the NETL. A TRIGA nuclear reactor is the major experimental facility at the Laboratory. The reactor operates at power levels up to 1100 kilowatts or with pulse reactivity insertions up to 2.2% $\Delta k/k$.

Figure 1-1 NETL - Nuclear Engineering Teaching Laboratory

The annual reports also satisfy requirements of the University Fuel Assistance Program, U.S. Department of Energy (DOE) [contract number DE-AC07-ER03919, Amendment A015; C85-110742 Task Order 2, Mod. 1], and the licensing agency, the U.S. Nuclear Regulatory Commission (NRC) [docket number 50-602]. This annual report covers the period from January 1, 2000 to December 31, 2000.

Availability of the Facility

The NETL facility serves a multipurpose role. The use of NETL by faculty, staff, and students in the College of Engineering is the Laboratory's primary function. In addition, the development and application of nuclear methods are done to assist researchers from other universities, industry, and government. NETL provides services to industry, government and other laboratories for the testing and evaluation of materials. Public education through tours and demonstrations is also a routine function of the laboratory operation.

Operating Regulations

Licensing of activities at NETL involve both Federal and State agencies. The nuclear reactor is subject to the terms and specifications of Nuclear Regulatory Commission (NRC) License R-129, a class 104c research reactor license. Another NRC license, SNM-180, for special nuclear material, provides for the use of a subcritical assembly with neutron sources. Both licenses are responsibilities of the NETL. For general use of radioisotopes the university maintains a broad license with the State of Texas, L00485. Functions of the broad license are the responsibility of the University Office of Environmental Health and Safety.

NETL History

Development of the nuclear engineering program was an effort of both physics and engineering faculty during the late 1950's and early 1960's. The program became part of the Mechanical Engineering Department where it remains to this day. The program installed, operated, and dismantled a TRIGA nuclear reactor at a site on the main campus in the engineering building, Taylor Hall. Reactor initial criticality was August 1963 with the final operation in April 1988. Power at startup was 10 kilowatts (1963) with one power upgrade to 250 kilowatts (1968). The total burnup during a 25 year period from 1963 to 1988 was 26.1 megawatt-days. Pulse capability of the reactor was 1.4% $\Delta k/k$ with a total of 476 pulses during the operating history. Dismantling and decommissioning of the facility were completed in December 1992.

Planning for a new facility, which led to the shutdown of the campus facility, began in October 1983, with construction commencing in December 1986 and continuing until May 1989. The final license was issued in January 1992, and initial criticality occurred on March 12, 1992.

The new facility, including support laboratories, administrative offices, and the reactor is the central location for all NETL activities.

Land use in the area of the NETL site began as an industrial site during the 1940's. Following the 1950's, lease agreements between the University and the Federal government led to the creation of the Balcones Research Center. In the 1990's, the University became owner of the site, and in 1994 the site name was changed to the J.J. Pickle Research Campus.

1.2 NETL Building

J.J. Pickle Research Campus

The J.J. Pickle Research Campus (PRC) is a multidiscipline research campus with a site area of 1.87 square kilometers. Areas of the site consist of two approximately equal east and west tracts of land. An area of about 9000 square meters on the east tract is the location of the NETL building. Sixteen separate research units and at least five other academic research programs, including the NETL facility, have research efforts with locations at the research campus. Adjacent to the NETL site is the Center for Research in Water Resources and Bureau of Economic Geology, which are examples of the diverse research activities on the campus. A Commons Building provides cafeteria service, recreation areas, meeting rooms, and conference facilities. Access to the NETL site is shown in Figure 1-2.

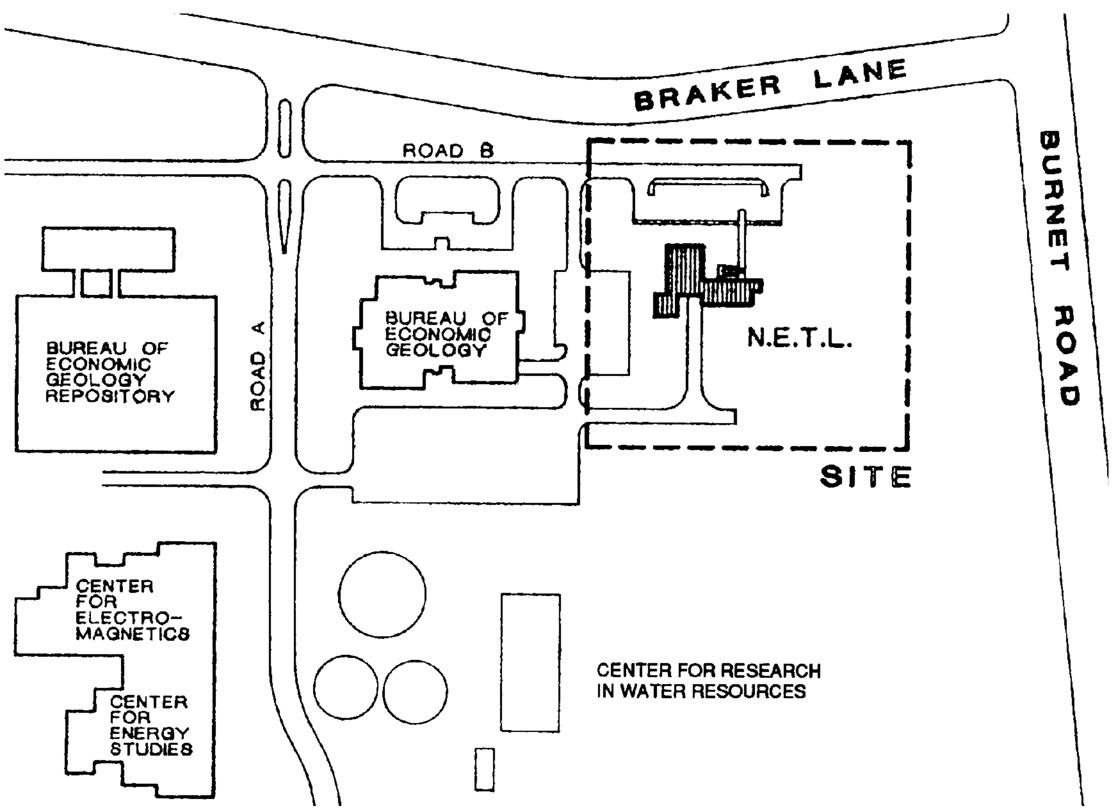


Figure 1-2 NETL Site - J.J. Pickle Research Campus

NETL Building Description

The NETL building is a 1950 sq meter (21,000 sq ft), facility with laboratory and office spaces. Building areas consist of two primary laboratories of 330 sq m (3600 sq ft) and 80 sq m (900 sq ft), eight support laboratories (217 sq m, 2340 sq ft), and six supplemental areas (130 sq m, 1430 sq ft). Conference and office space is allocated to 12 rooms totaling 244 sq m (2570 sq ft). One of the primary laboratories contains the TRIGA reactor pool, biological shield structure, and the neutron beam experiment areas. A second primary laboratory consists of 1.3 meter (4.25 ft) thick walls for use as a general purpose radiation experiment facility. Other areas of the building include support shops, instrument laboratories, measurement laboratories, and material handling laboratories.

Laboratories, Equipment

The NETL facility makes available several types of radiation facilities and an array of radiation detection equipment. In addition to the reactor, facilities include a subcritical assembly, a gamma irradiator, various radioisotope sources, and several radiation producing machines.

The gamma irradiator is a multicurie cobalt-60 source with a design activity of 10,000 curies. Radioisotopes of cobalt-60, cesium-137, and radium-226 are available in millicurie quantities.

Neutron sources of plutonium-beryllium and californium-252 are available. A subcritical assembly of 20% enriched uranium in a polyethylene moderated cylinder provides an experimental device for laboratory demonstrations of neutron multiplication and neutron flux measurements.

Laboratories provide locations to setup radiation experiments, test instrumentation, prepare materials for irradiation, process radioactive samples and experiment with radiochemical reactions.

A Texas Nuclear 14 MeV neutron generator is functional. It can create a neutron beam of up to one milliamp in steady-state and can also operate in a pulsed mode. Neutron source strength is approximately 10^{11} neutrons per second.

1.3 UT-TRIGA MARK II Research Reactor

The TRIGA Mark II nuclear reactor at the Nuclear Engineering Teaching Laboratory of The University of Texas at Austin is an above-ground, fixed-core research reactor. The nuclear core, containing uranium fuel, is located at the bottom of an 8.2 meter deep water-filled tank surrounded by a concrete shield structure. The highly purified water in the tank serves as the reactor coolant, neutron moderator, and a transparent radiation shield. Visual and physical access to the core is possible at all times. The TRIGA Mark II reactor is a versatile and inherently safe research reactor conceived and developed by General Atomics to meet the requirements of education and research. The UT-TRIGA research reactor provides sufficient power and neutron flux for comprehensive and productive work in many fields including physics, chemistry, engineering, medicine, and metallurgy. The word TRIGA stands for Training, Research, Isotope production, General Atomics.

Reactor Description

Reactor Operation. The UT-TRIGA research reactor can operate continuously at nominal powers up to 1 MW, or in the pulsing mode where typical peak powers of 1500 MW can be achieved for durations of about 10 msec. The UT-TRIGA with its new digital control system provides a unique facility for performing reactor physics experiments as well as reactor operator training. The pulsing operation is particularly useful in the study of reactor kinetics and control. Neutrons produced in the reactor core can be used in a wide variety of research applications including nuclear reaction studies, neutron scattering experiments, and nuclear analytical and irradiation services.

Special neutron facilities include a rotary specimen rack, which is located in the reactor graphite reflector, a pneumatically operated "rabbit" transfer system, which penetrates the reactor core, and a central thimble, which allows samples to be inserted into the peak flux region of the core. Cylindrical voids in the concrete shield structure, called neutron beam ports, allow neutrons to stream out away from the core. Experiments may be done inside the beam ports or outside the concrete shield in the neutron beams.

Nuclear Core. The reactor core is an assembly of about 90 fuel elements surrounded by an annular graphite neutron reflector. Each element consists of a fuel region capped at top and bottom with a graphite section, all contained within a thin-walled stainless steel tube. The fuel region is a metallic alloy of low-enriched uranium evenly distributed in zirconium hydride (UZrH). The physical properties of the TRIGA fuel provide an inherently safe operation. Rapid power transients to high powers are automatically suppressed without using mechanical control; the reactor quickly returns to normal power levels. Pulse operation, which is a normal mode of operation, is a practical demonstration of this inherent safety feature.

Reactor Control. The instrumentation for the UT-TRIGA research reactor is contained in a compact microprocessor-driven control system. This advanced system provides for flexible and efficient operation with precise power and flux control. It also allows permanent retention of all pertinent data. The power level of the UT-TRIGA is controlled by four control rods. Three of these rods, one regulating and two shim, are sealed stainless steel tubes containing powdered boron carbide followed by UZrH. As these rods are withdrawn, boron (a neutron absorber) leaves the core and UZrH (fuel) enters the core, increasing power. The fourth control rod, the transient rod, is a solid cylinder of borated graphite followed by air, clad in aluminum, and operated by pneumatic pressure to permit pulse operation. The sudden ejection of the transient rod produces an immediate burst of power.

Experiment Facilities

The experimental and irradiation facilities of the TRIGA Mark II reactor are extensive and versatile. Experimental tubes can easily be installed in the core region to provide facilities for high-level irradiations or small in-core experiments. Areas outside the core and reflector are available for large experiment equipment or facilities. Table 1-1 lists the workable experiment volumes available in the standard experiment facilities.

Table 1-1
Physical Dimensions of Standard
Experiment Systems

Center Tube		
Length:	15.0 in.	38.1 cm
Tube OD:	1.5 in.	3.81 cm
Tube ID:	1.33 in.	3.38 cm
Rotary Rack		
Length:	10.8 in.	27.4 cm
Diameter:	1.23 in.	3.18 cm
Pneumatic Tube		
Length:	4.5 in.	11.4 cm
Diameter:	0.68 in.	1.7 cm

The reactor is equipped with a central thimble for access to the point of maximum flux in the core. The central thimble consists of an aluminum tube that fits through the center hole of the top and bottom grid plates. Experiments with the central thimble include irradiation of small samples and the exposure of materials to a collimated beam of neutrons or gamma rays.

A rotary multiple-position specimen rack located in a well in the top of the graphite reflector provides for batch production of radioisotopes and for the activation and irradiation of multiple samples. When rotated, all forty positions in the rack are exposed to neutron fluxes of the same intensity. Samples are loaded from the top of the reactor through a tube into the rotary rack using a specimen lifting device. A rack design feature provides pneumatic pressure for insertion and removal of samples from the sample rack positions.

A pneumatic transfer system permits applications with short-lived radioisotopes. The in-core terminus of the system is normally located in the outer ring of fuel element positions, a region of high neutron flux. The sample capsule (rabbit) is conveyed to a sender-receiver station via pressure differences in the tubing system. An optional transfer box permits the sample to be sent and received from one to three different sender-receiver stations.

Beam Port Facilities

Five neutron beam ports penetrate the concrete biological shield and reactor water tank at core level. These beam ports were designed with different characteristics to accommodate a wide variety of experiments. Specimens may be placed inside a beam port or outside the beam port in a neutron beam from the beam port. When a beam port is not in use, special shielding reduces the radiation levels outside the concrete biological shield to safe values. This shielding consists of an inner shield plug, outer shield plug, lead-filled shutter, and circular steel cover plate.

Beam Port (BP) #1 is connected to BP #5, end to end, to form a through beam port. The through beam port penetrates the graphite reflector tangential to the reactor core, as seen in Figure 1-6. This configuration allows introduction of specimens adjacent to the reactor core to gain access to a high neutron flux, allows access from either side of the concrete biological shield, and can provide beams of thermal neutrons with relatively low fast-neutron and gamma-ray contamination.

Beam Port #2 is a tangential beam port, terminating at the outer edge of the reflector. However, a void in the graphite reflector extends the effective source of neutrons into the reflector to provide a thermal neutron beam with minimum fast-neutron and gamma-ray backgrounds.

Beam Port #3 is a radial beam port. The beam port pierces the graphite reflector and terminates at the inner edge of the reflector. This beam port permits access to a position adjacent to the reactor core, and can provide a neutron beam with relatively high fast-neutron and gamma-ray fluxes.

Beam Port #4 is a radial beam port which also terminates at the outer edge of the reflector. A void in the graphite reflector extends the effective source of neutrons to the reactor core. This configuration is useful for neutron-beam experiments which require neutron energies higher than thermal energies.

A neutron beam coming from a beam port may be modified by using collimators, moderators and neutron filters. Collimators are used to limit beam size and beam divergence.

Moderators are used to change the energy of neutron beams (e.g., cold moderator). Filters allow neutrons in selected energy intervals to pass through while attenuating neutrons with other energies.

Table 1-2
Physical Dimensions of Standard Beam Ports

Beam Port	Port Diameter	
BP#1, BP#2, BP#4		
At Core:	6 in.	15.24 cm
At Exit:	8 in.	20.32 cm
BP #3, BP#5		
At Core:	6 in.	15.24 cm
	8 in.	20.32 cm
	10 in.	25.40 cm
At Exit:	16 in.	40.64 cm

1.4 Nuclear Engineering Academic Program

The Nuclear Engineering Program (NE) at The University of Texas at Austin is located within the Mechanical Engineering Department. The Program's undergraduate degree is the Bachelor of Science in Mechanical Engineering, Nuclear Engineering Option. It is best described as a major in Mechanical Engineering with a minor in Nuclear Engineering. As such, all Mechanical Engineering degree requirements must be met.

The Program's graduate degrees are completely autonomous; they are Master of Science in Engineering (Concentration in Nuclear Engineering) and Doctor of Philosophy (Concentration in Nuclear Engineering). Course requirements for these degrees and the qualifying examination for the Ph.D. are separate and distinct from other areas of Mechanical Engineering. A Dissertation Proposal and Defense of Dissertation are also required for the Ph.D. degree and are acted on by a NE dissertation committee.

Of the five undergraduate Nuclear Engineering courses and the dozen graduate Nuclear Engineering courses, five courses make extensive use of the reactor facility. Table 1-3 lists the courses that use the reactor and its experiment facilities.

Table 1-3
Nuclear Engineering Courses

Undergraduate	
ME 361F	Instrumentation and Methods
ME 361G	Reactor Operations and Control
ME 177K	Nuclear and Radiation Engineering Concepts
Graduate	
ME 388R.3	Kinetics and Dynamics of Nuclear Systems
ME 389R.1	Nuclear Engineering Laboratory
ME 389R.2	Nuclear Analytical Measurement Techniques
ME 397M	Radioactive Waste Management
ME 337D	Radiation and Radiation Protection

1.5 **NETL Divisions**

The Nuclear Engineering Teaching Laboratory operates as a unit of the Department of Mechanical Engineering at The University of Texas. Figure 1-8 shows the staff organization of the Nuclear Engineering Teaching Laboratory. The staff includes the Health Physics and the Reactor Operations to support the Experimenter and Users groups and to insure compliance with all licensed activities.

The Operation and Maintenance Division (OMD) is responsible for the safe and effective operations of the TRIGA nuclear reactor. Activities of OMD include neutron and gamma irradiation service, operator/engineering training courses, and teaching reactor short courses.

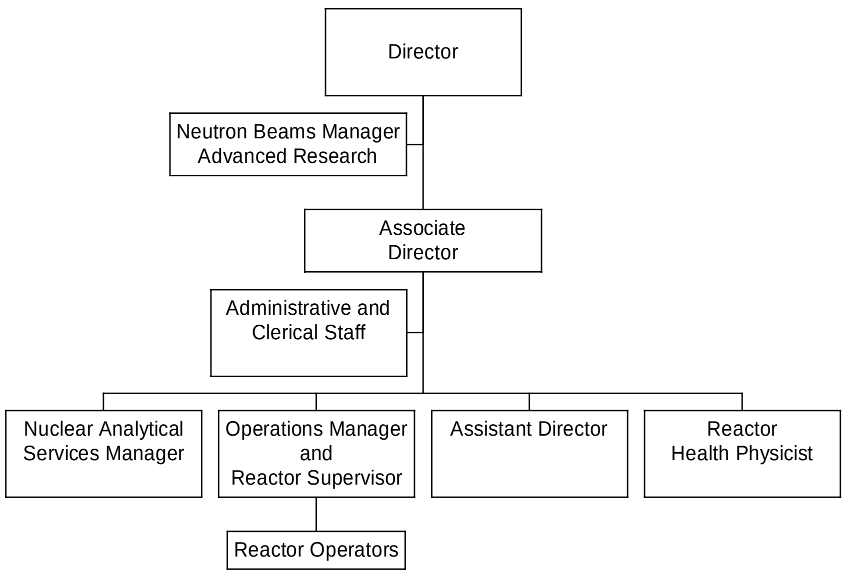


Figure 1-8 NETL Staff Organization

The Nuclear Analytical Services Division (NAS) is responsible for providing analytical services such as Neutron Activation Analysis (NAA), low level radiation counting, and isotope production. Other service activities of NAS include teaching NAA short courses.

The Neutron Beam Projects Division (NBP) is responsible for the development and operation of experimental projects associated with neutron beam tubes. One permanent facility, a cold neutron source/neutron guide tube facility, is a unique facility for experimenting with low energy neutrons.

Operation and Maintenance Division

The primary purpose of the OMD is the routine maintenance and safe operation of the TRIGA Mark II Research Reactor. With the assistance of the NETL licensed operators, this division performs most of the work necessary to meet the Technical Specifications of the reactor license. Division personnel implement modifications to reactor systems and furnish design assistance for new experiment systems. The division operates standard reactor experiment facilities.

Other activities of the division include operation and maintenance of radioisotope irradiators, such as the cobalt-60 irradiator, and radiation producing equipment. Radiation producing equipment consists of a 14-MeV neutron generator.

Services provided to other divisions at the laboratory include assistance in the areas of initial experiment design, fabrication, and setup. Maintenance, repair support, and inventory control of computer, electronic, and mechanical equipment is also provided. Building systems maintenance is also coordinated by the OMD. Other activities include scheduling and coordination of facility tours.

Nuclear Analytical Service Division

The principal objectives of the Nuclear Analytical Services Division (NAS) involve support of the research and educational missions of the university at large. Elemental measurements using instrumental neutron activation analysis provide nuclear analytical support for individual projects ranging from student project support for classes to measurements for faculty research projects. Project support is in the areas of engineering, chemistry, physics, geology, biology, zoology, and other areas. Research project support includes elemental measurements for routine environmental and innovative research projects. In the area of education, the division, with available state-of-the-art equipment, helps stimulate the interest of students to consider studies in the areas of science and engineering. Education in the irradiation and measurement of radioactivity is presented to college, high school and other student groups in class demonstrations or on a one-on-one basis. The neutron activation analysis technique is made available to different state agencies to assist with quality control of sample measurements. Analysis of samples for the presence of various elements and measurements of environmental effects assists detection of toxic elements.

Radiation measurement systems available include several high purity germanium detectors with relative efficiencies ranging from 20 to 40%. The detectors are coupled to a Vaxstation 3100 or PC-based systems. Two of the detectors are equipped with an automatic sample changer for full-time (i.e., 24 hrs a day) utilization of the counting equipment. The Vaxstation is connected to a campus wide network. This data acquisition and analysis system can be accessible from any terminal on campus and to any user with proper authorization, a modem and the necessary communication software. Safeguards by special protocols guard against unauthorized data access. One detector operates in a Compton Gamma Ray Suppression System that provides improved low background measurements. APC based acquisition and analysis system supports the analysis of Compton Suppression spectra and short half-life nuclear reaction.

Neutron Beam Projects and Advanced Research Division

The Neutron Beam Projects Division (NBP) manages the use of the five beam ports. Experiments at the beam ports may be permanent systems which function for periods in excess of one or two years or temporary systems. Temporary systems function once or for a few months, and generally require removal and replacement as part of the setup and shutdown process. The reactor bay contains floor space for each of the beam ports. Available beam paths range from 6 meters (20 ft) to 12 meters (40 ft).

The main objective of the Neutron Beam Projects division is to develop and operate experimental research projects associated with neutron beams. The objectives of the research function are to apply nuclear methods at the forefront of modern technology and to investigate fundamental issues related to nuclear physics and condensed matter. Another mission of the division is to obtain new, funded research programs to promote the capabilities of the neutron beam projects division for academic, government and industrial organizations and/or groups.

The Neutron Beam Projects manager is responsible for all phases of a project, beginning with the proposal and design, proceeding to the fabrication and testing, and concluding with the operation, evaluation and dismantlement. Projects available at NETL are the Texas Cold Neutron Source, Neutron Depth Profiling, Neutron Guide and Focusing System, Prompt Gamma Activation Analysis, Gadolinium Neutron Capture Therapy studies and Texas Intense Positron Source.

Health Physics Group

The Health Physics (HP) group is responsible for radiation safety and protection of personnel at the NETL as well as the protection of the general public. The laws mandated by Federal and State government agencies are enforced at the facility through various measures. Health physics procedures have been developed that are facility-specific to ensure that all operations comply with the regulations. Periodic monitoring for radiation and contamination assures that the use of the reactor and radioactive nuclides is conducted safely with no hazard to personnel outside of the facility. Personnel exposures are always maintained ALARA ("as low as is reasonably achievable"). This practice is consistent with the mission of the NETL. Collateral duties of the Health Physics group include the inventory and monitoring of hazardous materials, and environmental health.

The Health Physics group consists of one full time Health Physicist. The Health Physicist is functionally responsible to the Director of the NETL, but maintains a reporting relationship to the University Radiation Safety Office. This arrangement allows the Health Physicist to operate independent of NETL operations constraints to insure that safety is not compromised. A part-time Undergraduate Research Assistant (URA) may assist the Health Physicist. The URA reports to the Health Physicist and assists with technical tasks including periodic surveys, equipment maintenance, equipment calibration, and record keeping.

The equipment currently used by the Health Physics group is presented in Table 1-4. Supplementing the health physics equipment are supplies such as plastic bags, rubber gloves, radiation control signs/ropes for routine and emergency use.

Table 1-4
Health Physics Equipment

Equipment	Radiation	Number
High and low range self-reading pocket dosimeters	gamma	>10
Thin window friskers	alpha/beta/gamma	>8
Scintillation microremmeter	low level gamma	1
High range portable ion chamber	beta/gamma	2
BF3 proportional counter	neutron	2
Hand and Foot monitor	beta/gamma	1
Low level gas-flow proportional counter	alpha/beta/gamma	1
Continuous air particulate monitor	alpha/beta/gamma	2
Gaseous Ar-41 effluent monitor	beta	1
Liquid Scintillation Counter	low energy beta	1
Thin end window G-M meter	beta/gamma	1

The Health Physics Group provides radiation monitoring, personnel exposure monitoring, and educational activities. Personnel for whom permanent dosimeters are required must attend an eight hour course given by the Health Physicist. This course covers basic radiation principles including general safety practices, and facility-specific procedures and rules. Each trainee is given a guided tour of the facility to familiarize him with emergency equipment and to reinforce safety/emergency procedures. The group supports University educational activities through assistance to student experimenters in their projects by demonstration of the proper radiation work techniques and controls. The Health Physics group participates in emergency planning between NETL and the City of Austin to provide basic response requirements and conducts off-site radiation safety training to emergency response personnel such as the Hazardous Materials Division of the Fire Department, and Emergency Medical Services crews.

Chapter 2

2.0 ANNUAL PROGRESS REPORT

2.1 Faculty, Staff, and Students

Organization. The University administrative structure overseeing the NETL program is presented in Figure 2-1. A description follows, including titles and names of personnel, of the administration and committees that set policy important to NETL.

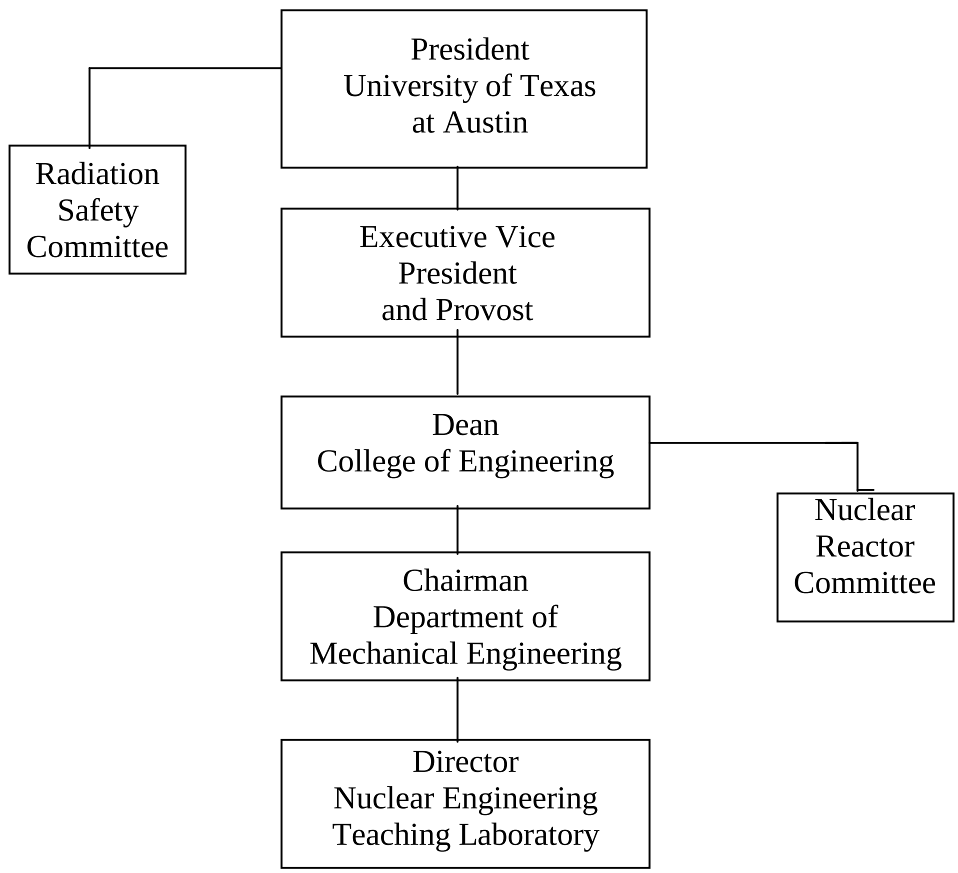


Figure 2-1 - University Administrative Structure over NETL

Administration. The University of Texas at Austin is one campus of 15 campuses of the University of Texas System. As the flagship campus, UT Austin consists of 16 separate colleges and schools. The College of Engineering consists of six engineering departments with separate degree programs. NETL is one of several education and research functions within the college.

Table 2-1 and Table 2-2 list The University of Texas System Board of Regents which is the governing organization and the pertinent administrative officials of The University of Texas at Austin.

Table 2-1
The University of Texas System
Board of Regents

Chairman	D.L. Evans
Vice Chairman	T. Loeffler
Vice Chairman	R.C. Clements
Executive Secretary	F. A. Frederick
Chancellor	William Cunningham

Member to 2003	Member to 2005	Member to 2001
P.C Oxford	W. L. Hunt	R. C. Clements
A.W. Riter	C. Miller	T. Loeffler
A.R. Sanchez	R. R. Romero	D.L. Evans

Table 2-2
The University of Texas at Austin
Administration

President	Larry R. Faulkner
Executive Vice President and Provost ad interim	Sheldon Ekland-Olson
Dean of College of Engineering	Ben Streetman
Chairman of Department of Mechanical Engineering	Parker Lamb

Radiation Safety Committee. The Radiation Safety Committee convenes to review radiological safety practices at the University during each academic term. The committee composition is shown in Table 2-3. Committee general responsibilities are review of activities of University research programs that utilize radiation source materials.

Table 2-3
Radiation Safety Committee

Chairman	D. Klein
Vice-Chair	J.M. Sanchez
Member	G. Hoffmann
Member	S.A. Monti
Member	J. Robertus
Member	B.G. Sanders
Member	B.W. Wehring/Carl Beard
Ex officio member	J.C. White
Ex officio member	E. Janssen

Nuclear Reactor Committee. The Nuclear Reactor Committee convenes to review the activities related to facility operation during each quarter of the calendar year. The committee composition is shown in Table 2-4. Committee general responsibilities are review of reactor operation and associated activities.

Table 2-4
Nuclear Reactor Committee

Chairman	D. Klein
Member	K. Ball
Member	R. Corsi
Member	J. F. Higginbotham
Member	R.T. Johns
Member	H. M. Liljestrand
Student Member	D. Dorsey
Member	B.W. Wehring/C. Beard
Member	J.C. White
Ex officio member	R. J. Charbeneau
Ex officio member	J.P. Lamb
Ex officio member	D. S. O’Kelly
Ex officio member	A.J.Teachout

Table 2-5
NETL Personnel

<u>NETL Facility Staff</u>

Director	B.W. Wehring, retired 8/2000
Associate Director	D. S. O'Kelly
Reactor Supervisor	M.G. Krause
Manager NAS	F.Y. Iskander, resigned 8/2000
Manager NBP	D. J. O'Kelly
Assistant Director	T. L Bauer, left UT 8/2000
Health Physicist	A.J. Teachout
Administrative Associate	J.L. Wiley

<u>Faculty</u>

C. A. Beard	W. Charlton
D.E. Klein	B.W. Wehring
S. Landsberger	

Funding. NETL funding is provided by state appropriations, research grants, and service activities. Research funding supplements the base budget provided by the State and is obtained mostly through the process of competitive project proposals. Funds from service activities supplement the base funds to allow the facility to provide quality data acquisition and analysis capabilities. Both sources of supplemental funds, research projects and service activities, contribute to the education and research environment for students.

NETL Research 2000

Project Title	Project Sponsor
Reactor Based Intense Positron Beam for Materials Characterizations	TATP
Ultra Cold Neutron Research	TARP
Radiation Damage and Microstructural Changes of Stainless Steel Due to Long Term Irradiation by Alpha Particles	ANRCP
University Reactor Sharing Program	DOE
Ultra Cold Neutron Localization and Sub-Barrier Penetration	DOE
Neutron Imaging System for Materials Characterization Research at The University of Texas Reactor	NSF/ NAS
Development and Characterization of Plutonium Storage Containers	ANRCP
Investigation of Lead and Heavy Metals from Contaminated Surface Soils from PANTEX Firing Ranges	ANRCP
Technical Graduate Education for Texas Panhandle Via Distance Learning	ANRCP
Nuclear Fellowship Training for Scientists from Developing Countries	NRC/IAEA
Determination of Heavy Metals in Filters Collected over the Great Lakes	CARE
Determination of Trace Elements in Archaeological Materials	TARL
Determination of Cs-137 in Fort Hood soils	US Corps of Eng.

2.2 Education and Training Activities

Tours and special projects are available to promote public awareness of nuclear energy issues. Tours of the NETL facility are routine activities of NETL staff and students. A typical tour is a general presentation for high school and civic organizations. Other tours given special consideration are demonstrations for interest groups such as physics, chemistry and science groups.

A total of 1545 visitors were given access to the facility during the reporting period. The total includes tour groups, official visitors, and facility maintenance personnel. Tours for 16 groups with an average 20 persons/group were taken through the facility during the reporting period. This is a significant increase in the number of tours for education.

Table 2-7
Public Access

Tour Groups	205
Individuals	855
Workers	485
Total	1545

Presentations by NETL staff, including demonstrations with laboratory equipment, were given to several high school organizations. These presentations were done as part of school wide programs sponsored by the high schools.

2.3 Example Service and Commercial Activities

PROJECT: Determination of Selenium and Other Toxic Elements

SPONSOR: Texas Parks And Wildlife Department

Tissue from muscle and liver of fish samples from several Texas lakes are analyzed for selenium, mercury, arsenic, chromium and zinc. These measurements are part of an on-going environmental project for the State of Texas to examine the conditions of waters subjected to certain types of power plant or industrial effluent releases.

PROJECT: Determination of Toxic and Other Elements in Mexican Coffee

SPONSOR: NETL

The concentration of trace elements was determined in several samples of Mexican coffee. The results were compared to the concentration of these elements from several other sources. The results may be used to evaluate the local soils and the affect on the coffee crop.

2.4 Examples of On-going Research and Development Projects

PROJECT: Neutron Depth Profiling

SPONSOR: NETL

The University of Texas (UT) NDP instrument utilizes thermal neutrons from the tangential beam port (BP#2) of the reactor. The NDP technique is not normally available to the research community due to the limited number of appropriate neutron sources.

Neutron depth profiling is an isotope specific nondestructive technique used to measure the near-surface depth distributions of several technologically important elements in various substrates. NDP is based on neutron induced reactions to determine concentration versus depth profiles. Because of the potential for materials research, particularly for semiconductor research, the UT-NDP facility has been developed and is available for scientific measurements.

The UT-NDP facility consists of a collimated thermal neutron beam, a target chamber, a beam catcher, and necessary data acquisition and process electronics. A collimator system was designed to achieve a high quality thermal neutron beam with good intensity and minimum contamination of neutrons above thermal energies.

A target vacuum chamber for NDP was constructed from 40.6 cm diameter aluminum tubing. The chamber can accommodate several small samples or a single large sample with a diameter up to 30 cm. The other degrees of freedom for an NDP measurement, location of charged particle detector and angle between sample and neutron beam, are set with the top cover of the chamber removed.

Depth profiles of various borophosphosilicate glass from Intel Corporation and Advanced Micro Devices, Inc. have been measured. Measurements were repeated at the National Institute of Standards and Technology (NIST) NDP facility using the same samples. The NETL results showed good agreement with the NIST depth profiles.

Boron-10 implanted silicon wafers from Advanced Micro Devices have been used for NDP measurements for the comparison of reported implant dose and profile. Also several measurements of Helium-3 implanted in stainless steel samples were carried out in order to examine helium behavior on metals and alloys.

Other possible applications of the UT-NDP facility include study of nitrogen in metals as it affects wear resistance, hardness, and corrosion.

PROJECT: Texas Cold Neutron Source

SPONSOR: Advanced Technology Program and the State of Texas

A cold neutron source has been designed, constructed, and tested by NETL personnel. The Texas Cold Neutron Source (TCNS) is located in one of the radial beam ports (BP #3) and consists of a cold source system and a neutron guide system.

The cold source system includes a cooled moderator, a heat pipe, a cryogenic refrigerator, a vacuum jacket, and connecting lines. Eighty milliliters of mesitylene moderator is maintained by the cold source system at ~36 K in a chamber within the reactor graphite reflector. Mesitylene, 1,3,5-trimethylbenzene, was selected for the cold moderator because it has been shown to be an effective and safe cold moderator. The moderator chamber for the mesitylene is a 7.5 cm diameter right-circular cylinder 2.0 cm thick. The neon heat pipe (properly called thermosyphon) is a 3-m long aluminum tube which is used for cooling the moderator chamber. The heat pipe contains neon as the working fluid that evaporates at the moderator chamber and condenses at the cold head.

Cold neutrons coming from the moderator chamber are transported by a 2-m-long neutron guide inside the beam port and a 4-m-long neutron guide (two 2-m sections) outside the beam port. Both the internal neutron guide and the external neutron guide are curved with a radius of curvature equal to 300 m. To block line-of-sight radiation streaming in the guides, the cross-sectional area of the guides is separated into three channels by 1-mm-thick vertical walls. All reflecting surfaces are coated with Ni-58.

The TCNS system provides a low background subthermal neutron beam for neutron reaction and scattering research. Installation and testing of the external curved neutron guides, the shielding structure, neutron focusing and a Prompt Gamma Activation Analysis facility are completed. The only other operating reactor cold neutron sources in the United States are at Brookhaven National Laboratory, the National Institute of Standards and Technology, and Cornell University. At least four major centers for cold neutron research exist in Europe, with another two in Japan.

PROJECT: Prompt Gamma Activation Analysis

SPONSOR: DOE and the State of Texas

A Prompt Gamma Activation Analysis (PGAA) facility has been designed, constructed, and tested. The UT-PGAA facility utilizes the focused cold-neutron beam from the Texas Cold Neutron Source. The PGAA sample is located at the focal point of the converging guide focusing system. The use of a guided focused cold-neutron beam provides a higher capture reaction rate and a lower background at the sample-detector area as compared to other facilities using filtered thermal neutron beams.

The UT-PGAA facility has been designed taking into account the advantage of the low background. The following criteria have been used during the design: a) The structure and shielding materials for the UT-PGAA facility were chosen to minimize the background contribution for elements to be detected in the samples to be studied. b) The sample handling system was designed to be versatile to permit the study of a wide range of samples with quick and reproducible sample positioning with a minimum of material close to the samples.

A 25% efficient gamma-ray detector in a configuration with an offset-port dewar was purchased to be used at the UT-PGAA facility. The detector was selected in order to incorporate a Compton suppression system at a later date. A gamma-spectrum analysis system with 16,000 channels is used for data acquisition and processing.

The applications of the UT-PGAA will include: i) determination of B and Gd concentration in biological samples which are used for Neutron Capture Therapy studies,
ii) determination of H and B impurity levels in metals, alloys, and semiconductor, iii) multielemental analysis of geological, archeological, and environmental samples for determination of major components such as Al, S, K, Ca, Ti, and Fe, and minor or trace elements such as H, B, V, Mn, Co, Cd, Nd, Sm, and Gd, and iv) multielemental analysis of biological samples for the major and minor elements H, C, N, Na, P, S, Cl, and K, and trace elements like B and Cd.

PROJECT: Alpha Radiation Damage in Plutonium Encapsulating Materials

SPONSOR: Amarillo National Resource Center for Plutonium (ANRCP)

This ANRCP sponsored project is a study to determine radiation damage and microstructural changes in stainless steel and beryllium samples by helium (alpha particle) irradiation using a near surface nuclear technique called Neutron Depth Profiling, along with Transmission Electron Microscopy measurements, and Rutherford Backscattering and Channeling Analysis. The long term effects of high dose alpha particle irradiation to the stainless steel and beryllium cover which surrounds the weapons grade Pu will be investigated. Alpha particles with an energy spectrum up to 5 MeV will be implanted into the stainless steel and beryllium samples up to a depth of about 9 mm. The implanted dose rate is expected to be greater than 10^{15} alphas/cm^2-year which corresponds to a dose of greater than 10^{17} alpha/cm^2 in 100 years. Such a high dose may cause degradation of mechanical strength in the surface layer of these materials, but more importantly, if the He diffuses to defects and forms localized bubbles of He gas, the internal pressure may cause exfoliation and/or could lead to the formation of cracks in the stainless steel or beryllium. These cracks could propagate and lead to failure of the encapsulating materials.

PROJECT: Collimator Design for Neutron Radiography

SPONSOR: Department of Mechanical Engineering

A collimator design is being developed for beam port #5 of the TRIGA reactor. The collimator will provide neutrons for imaging various objects for analysis by neutron radiography. An image intensifier, display and acquisition system and analysis software are being acquired. The system will provide standard neutron radiography and provide for research into neutron tomography.

PROJECT: Texas Intense Positron Source

SPONSOR: Advanced Technology Program and the State of Texas

A reactor-based slow positron beam facility is being fabricated at theNuclear Engineering Teaching Laboratory (NETL). This is a joint effort between UT-Austin and UT-Arlington researchers. The facility (Texas Intense Positron Source) will be one of a few reactor-based slow positron beams in the world when completed. The Texas Intense Positron Source consists of a copper source, a source transport system, a combined positron moderator/remoderator assembly, a positron beam line and a sample chamber. High energy positrons from the source will be slowed down to a few eV by a solid Kr moderator that also acts as a remoderator to reduce the beam size to enable beam transport to a target for experimentation. The beam will be electrostatically guided and will deliver about 10^8 positrons/sec in the energy range of 0 - 50 keV.

Reactor-based positron beams utilizing a copper source have been implemented at Brookhaven National Laboratory (BNL) and at Delft University of Technology, The Netherlands. There are several differences between TIPS and these reactor based positron beams. The source/moderator array of the Delft positron beam is located inside one of the neutron beam ports of their reactor and the positron beam is transported out of the reactor and then remoderated before it enters into an experimental chamber. For the BNL positron beam, a 200 mg copper pellet is irradiated in the High Flux Beam Reactor ($8.3x10^{14}$ n/cm^{2}sec) and then transported to their positron beam facility at a different location where the copper is evaporated onto a source holder. The BNL positron beam uses solid Kr to moderate the fast positrons while at Delft a tungsten moderator is applied. The TIPS will have a joint moderator/remoderator stage using solid Kr, an approach that is similar in concept to that suggested for a magnetically guided positron beam. A major advantage is that our moderator/remoderator stage is operated in a magnetic field free environment such that electric fields can be established to increase its overall efficiency.

Based on general experience on reactor based positron sources, we have decided that the moderator/remoderator assembly and the positron beam optics should be entirely outside the reactor biological shield. A source transport system will be placed in a 4 meter long vacuum jacket that will be inserted into one of the neutron beam ports of the NETL 1-MW TRIGA Mark II research reactor. The vacuum jacket will be evacuated to high vacuum and will have a rectangular section to allow for some shielding materials inside the beam port. The transport system will be used to move the source to the irradiation location and out of the biological shield. The source will be moved away from the neutron beam line to an ultra high vacuum (at around 10^{-10} torr) chamber, where the moderator/remoderator assembly is located. The high vacuum and ultra high vacuum systems will be separated by a gate valve.

The copper source of TIPS will be irradiated across from the core in the graphite reflector, in the middle section of the through port. The isotope ^{64}Cu formed by neutron capture in ^{63}Cu (69 % in natural copper) has a half life of 12.7 hours, and the branching ratio for b $^+$ emission is 19 %. Our current source design consists of 400 copper cylinders with 1 cm height and 0.5 cm diameter mounted on a 10x10 cm^2 copper plate forming a square lattice. The source activity will be around 100 Ci of which 14 Ci or more is available for positron beam production. The combined efficiency of the moderator/remoderator assembly is approximately 10^{-3} and, therefore, TIPS should deliver about 10^8 positrons/sec at the sample chamber.

Preliminary designs and construction of the source transport system and the vacuum jacket are completed. The designs and construction of the copper source, moderator/remoderator assembly, and the positron beam optics are completed and testing of these components are currently in progress. The high-intensity low-energy positron beam of TIPS will be applied to defect characterization of metals, semiconductors, and polymers.

PROJECT: Gallium Interactions with Zircalloy Cladding

SPONSOR: DOE and Amarillo National Resource Center for Plutonium

This ANRCP sponsored project is a join effort between The University of Texas at Austin and Texas A&M University researchers. The effort is aimed toward determining a bound on Ga concentration in MOX pellets such that the Ga does not produce unacceptable damage to the cladding

Although the real test will be the fuel qualification work, we should be able to experimentally simulate and examine some aspects of the Ga-cladding interaction. The Ga that is released from the pellet will be incident on the cladding while the cladding is also being irradiated with fission fragments, neutrons, betas, and gammas. Clearly, the Ga interaction will not be under thermal equilibrium conditions. The irradiation of the cladding, especially by the fission fragments, will probably lead to enhanced diffusion and possibly to enhanced chemical reactions. We do not know the Ga release rate from the pellet nor whether the Ga will be monatomic or in chemical form, i.e., possibly in an oxide of Ga. In the molecular case the irradiation conditions will probably lead to breakup of the molecule so that in both cases the Ga will probably diffuse into the cladding.

Each ppm of Ga in the fuel corresponds to about 5E16 Ga atoms/cm^3. Since a pellet is about 1 cm^3 surrounded by about 3 cm^2 of cladding, if all the Ga were released from the fuel, the cladding would be impacted by roughly 1E16 Ga atoms/cm^3. For example, 100 ppm would give roughly 1E18 Ga atoms/cm^2.

To approximate the situation, we are implanting Ga ions into Zircaloy to a shallow depth of about 400 A (100 keV ions). Fluences are in the 1E17 to 1E18 range while maintaining the target at typical cladding temperatures. If there were no diffusion nor sputtering, a 1E17 fluence would give a peak concentration of 40% in Zr (corresponding to a standard deviation in projected range of 229 A). The Ga depth profile can then be measured approximately using Rutherford backscattering (RBS) of energetic He ions. Unfortunately, since the mass of Ga is less than that of Zr, the sensitivity will only be in the percent range. Even so, major effects may be observable. Perhaps, the Ga totally indiffuses or totally outdiffuses or forms a well-defined compound layer.

The depth profile measurements will be supplemented with scanning electron microscopy for morphology, transmission electron microscopy for structure measurements, and electron microprobe measurements of especially the lateral distribution of Ga as well as the identification of possible compounds. Laterally, it may be possible to determine whether Ga diffuses to grain boundaries.

PROJECT: Development of Non Destructive Assay Methods for Weapons Plutonium and MOX Fuel Safeguards

SPONSOR: DOE and Amarillo National Resource Center for Plutonium

The focus of this project is to develop and eventually aid in the implementation of practical nondestructive fissile assay techniques to promote the nonproliferation of nuclear weapons. Our activities during this year covered both computational and experimental related work. We continued our computational effort focusing on the neutronics of a new nondestructive assay concept that uses graphite slowing down time spectrometry. We have developed a computational model of a cylindrical graphite slowing down time spectrometer, and performed a number of assay simulations using a detailed BWR fuel assembly model. In addition, we investigated the isotopic resolving power and self shielding effect in the fuel assembly for the graphite spectrometer.

On the experimentally related part, the pulsed neutron generator, transferred from The University of Michigan, has been set up at the Nuclear Engineering Teaching Laboratory and is operated routinely. Measurements using a 101 X 105 X 122 cm rectangular parallelepiped graphite pile have been initiated.

2.5 Significant Modifications

No significant modifications have been made to the NETL building, TRIGA reactor or experiment facilities this reporting period. A summary of the types of modifications that did occur during the year follows.

Reactor. No changes were made to the reactor core or basic instrumentation systems during the year.

Experiment Facilities. Standard experiment facilities for the reactor are the center tube, pneumatic tube, rotary specimen rack and beam ports. No significant modifications were made to the original installation for any of the standard experiment facilities.

Testing of components of the neutron cold source has been in progress at various reactor power levels up to full power. The cold neutron source system insertion into the beam port #3, takes advantage of the reflector penetrating port and 16 inch (40.6 cm) diameter access at the reactor shield exit. Operating tests of the cold source at 250 kw, 500 kw, and 950 kw were completed in 1994. No unusual operating conditions that relate to safety of the experiment system have been found. A review of pressure and temperature data from the TCNS is still in progress, however, to improve the understanding of the power performance. A series of tests in 1995 demonstrated the advantage of an improvement in refrigeration capacity. A moderate gain in refrigeration capacity was sufficient to extend indefinitely the stable operating time for the cold neutron source. An upgrade of the refrigerator was made in 1997.

Other changes to the Texas Cold Neutron Source were the installation of a focusing element in the facility beam line. A number of experiments are still in progress to determine the alignment and focusing properties of the new element. A prompt gamma analysis system was installed on the TCNS beam line. Initial use of the prompt gamma analysis system has been with the cold neutrons from the wave guide but without the additional cooling or presence of the mesitylene moderator.

2.6 Publications, Reports, and Papers

Reports, publications, and presentations on research done at NETL are produced each year by NETL personnel. The following list documents research done by NETL faculty, staff, and students during the reporting period.

1. S. EATON, K. RAMSEY, J. BUKSA, K. CHIDESTER, and C. BEARD, "Development of Non-Fertile and Evolutionary Mixed-Oxide Nuclear Fuels for Use in Existing Water Reactors," accepted for publication in *Nuclear Science and Engineering.*

2. S. L. EATON, C. A. BEARD, L. L. DAEMEN, W. B. WILSON, and M. L. ADAMS, "Calculational Analysis of Structural Activation Induced by 20-100 MeV Proton Beam Loss in High-Power Linear Accelerators," *Nuclear Instruments and Methods in Physics Research B, 168,* 88-91 (2000).

3. KENNETH L. SCHWARTZ and CARL A. BEARD, "Process Modeling of Plutonium Conversion and MOX Fabrication for Plutonium Disposition," *Nuclear Technology, Vol. 129,* 152-174 (2000).

4. W. S. Charlton and W. D. Stanbro, “Monitors for the Prediction of Alternate Nuclear Material Concentrations for PWR Spent Fuel,” accepted for publication in Nuclear Technology (2000).

   W. S. Charlton, W. D. Stanbro, and R. T. Perry, “Comparisons of HELIOS, ORIGEN2, and Monteburns Calculated 241Am and 243Am Concentrations to Measured Values for PWR, BWR, and VVER Spent Fuel,” J. Nucl. Sci. Technol., 37(7), p. 615 (2000).

   W. S. Charlton, R. T. Perry, and T. A. Parish, “Calculated Actinide and Fission Product Concentration Ratios for Gaseous Effluent Monitoring Using Monteburns 3.01,” Nucl. Tech., 131, p. 1 (2000).

   W. D. Stanbro, W. S. Charlton, P. H. Hemberger, J. Poths, T. L. Burr, and B. L. Fearey, “The Use of Stable Xenon Isotope Monitoring in Strengthened Safeguards at Large Reprocessing Plants,” JNMM, 28(2), p. 22 (2000).

   W. S. Charlton, B. L. Fearey, C. W. Nahkleh, T. A. Parish, R. T. Perry, J. Poths, J. R. Quagliano, W. D. Stanbro, and W. B. Wilson, “Operator Declaration Verification Technique for Spent Fuel at Reprocessing Facilities,” Nucl. Inst. and Meth./B, 168, p. 98 (2000).

5. Kaminski, M. D. and S. Landsberger, " Heavy Metals in Urban Soils of East St. Louis, Illinois, Part I: Total Concentration of Heavy Metals in Soils", J. Air and Waste Management Association, 60, 1667-1679 (2000).

6. Kaminski, M. D. and S. Landsberger, "Heavy Metals in Urban Soils of East St. Louis, Illinois, Part II: Leaching Characteristics and Modeling", J. Air and Waste Management Association, 60, 1680-1687 (2000).

7. F. Iskander, S. Landsberger and S. D. Warren "Compton Suppression Low Level Counting of 137Cs in Environmental Soil Samples" J. Radioanal. Nuc. Chem., 244, 159-163 (2000)

8. Landsberger, S., M. Kaminski, M. Basunia and F. Iskander "Multielemental Analysis of Solid Wastes and Leachates" J. Radioanal. Nuc. Chem., 244, 35-40 (2000)

9. Dodoo-Amoo, D. and S. Landsberger, "Gamma-Ray Self-Attenuation Calculations in Neutron Activation Analysis", J. Radioanal. Nuc. Chem., (in press)

10. Iskander, F., M. Basunia and S. Landsberger, " Halogen Determination in Arctic Aerosols by Neutron Activation Analysis with Compton Suppression Methods" J. Radioanal. Nuc. Chem., (in press).

11. Defee, T., F. Iskander and S. Landsberger " Leaching of Chlorine from Celotex Packaging in Stainless Steel Containers Storing Plutonium Pits", J. Radioanal. Nuc. Chem., (in press).

Chapter 3

3.0 FACILITY OPERATING SUMMARIES

3.1 Operating Experience

The UT-TRIGA reactor operated for 128 days in 2000. The reactor produced a total energy output of 224.248 MW-hrs during this period. The burnup per quarter is shown in Figure 3-1. The reactor did not operate in the first quarter of 2000 due to problems with the Reflector. The reactor was primarily used for reactor pulsing and cold source operations in the third quarter of the year.

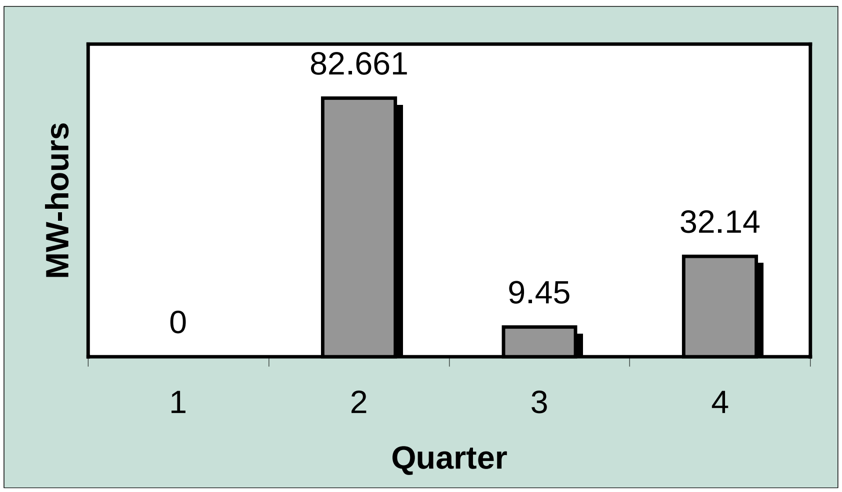


Figure 3-1 Quarterly Operating History for 1999

3.2 Reactor Shutdowns

The reactor safety system classifies protective action trips as one of three types, a limiting safety system (LSSS) trip, a limiting condition for operation (LCO) trip or a trip of the SCRAM manual switch. In the event the switch is used for a normal reactor shutdown, the operation is not considered a protective action shutdown. The following definitions in Table 3-1 classify the types of protective actions recorded.

Table 3-1
Protective Action Definitions

Protective Action	Description
Safety System Setting LSSS	Setpoint corresponds to detection of limiting safety system setting. Examples: fuel temperature percent power
Condition for Operation LCO - (analog detection)	Hardware action detects inoperable conditions within a safety channel or the instrument control and safety system. Examples: pool water level detector high voltage external circuit trips
Condition for Operation LCO - (digital detection)	Software action detects inoperable conditions within a program function of the instrument control and safety system. Examples: watchdog timers program database errors
Manual Switch (protective action)	Operator emergency shutdown
Manual Switch (intentional operation)	Operator routine shutdown

Scrams are further categorized according to the technical specification requirement given in Table 3-2. External scrams that provide protection for experiment systems are system operable conditions.

There were seventeen safety system protective unscheduled shutdowns in 2000. Eight of these were considered watchdog scrams when one of the computer systems locked up. Two scrams were caused by a failing fuel temperature conditioning module. Five scrams were caused by operator error while operating too close to a high power scram trip setpoint. Two remaining scrams were caused by a DAC power supply intermittent failure.

Table 3-2
Instrumentation, Control and Safety System
Protective Action Events (1)

Technical Specification Requirement	Yes	No
SCRAM Type		
Safety System Setpoint (LSSS)	5	0
System Operable Condition (LCO)		
Analog detection (hardware)	4	0
Digital detection (software)	8	0
Manual Switch		
Protective action	0	0
Intentional operation (2)	-	-
Total Safety System Events	13	0

(1) Tests of the SCRAM circuits are not recorded
(2) Intentional SCRAMS (non-protective action) are not recorded

A review is always done to determine if routine corrective actions are sufficient to prevent the recurrence of a particular reactor safety system shutdown.

Table 3-3
Summary of Safety System
Protective Actions

Trip Action	Number of Occurrences
Operator Error	5
System Operable Condition	12
Total	17

3.3 **Utilization**

There was a significant increase in the number of external users during the reporting period compared to previous years of NETL operations. The facility was shutdown for all of the first quarter in the year, but the number of total samples were near 1999 levels. The NETL staff continues to perform activation and analysis services as a public service and in support of the overall UT mission. Neutron activation analysis accounted for much of the reactor utilization time with teaching labs and beam port research projects making up the remainder. Several neutron beam projects were in various stages of development and construction during the year and did not contribute to the facility reactor hours.

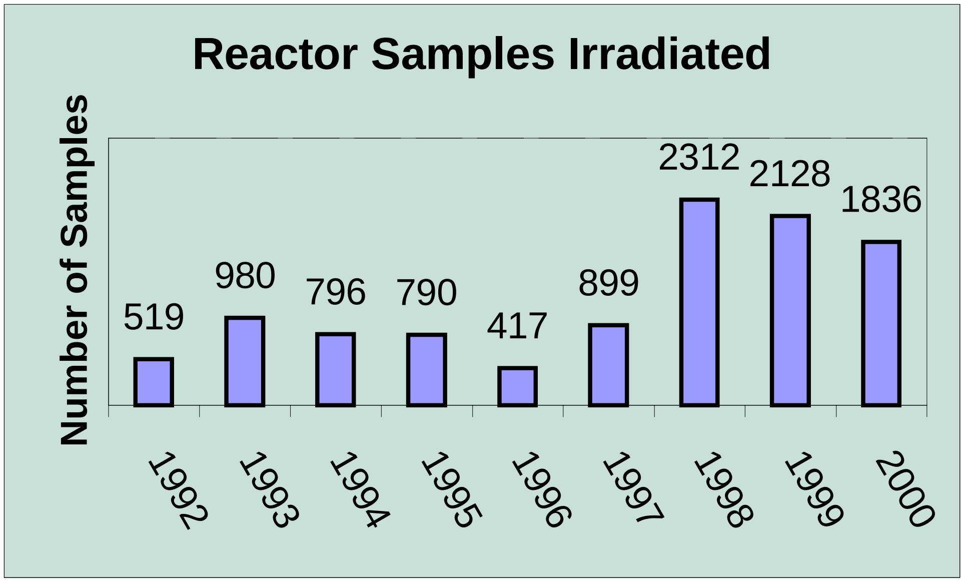


Figure 3-2 Experimental Use of Facility

3.4 Maintenance

All surveillances and scheduled maintenance were completed during the reporting year. All results met or exceeded the limits of the Technical Specifications. No reactor safety equipment upgrades were performed during the reporting period. The Digital Console system was evaluated for Year 2000 safety risk and was found to be satisfactory. The Digital Console clock had to be set to 1972 for calendar daily dates but this was seen as a minor inconvience.

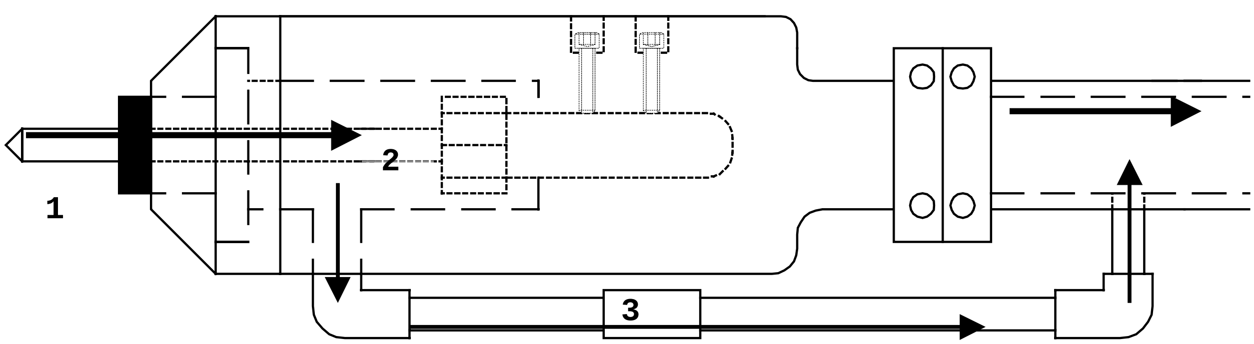
3.5 Facility Changes

The year commenced with the majority of the TRIGA fuel removed from the reactor core and stored in the floor fuel pits in the reactor bay. The remaining fuel elements and the cobalt irradiator were removed to storage in early January. The fuel had been removed to storage for safety purposes because of the 2:1 Hydrogen to Oxygen mixture within the Reflector can. The

Reflector was discovered in November 1999 to have bulged to the point that several graphite elements were difficult to remove from the outer G-ring of the grid. Multiple safety evaluations were performed to determine the detonation risk caused by handling the reflector gas mixture. On January 20, the Reactor Committee approved a final safety review and corrective actions for the Reflector-Pool condition. The University had determined the gases within the Reflector should be vented as soon as practical and the Reflector be allowed to flood. The NETL and the Reactor Committee concluded the risk to the general public was extremely small because of the low levels of radioactive material remaining in the pool and there was a low probability of gas ignition.

Drill Tool Design and Approval to Vent

The NETL staff desired to vent the Reflector by drilling a small hole into the upper surface of the assembly from the pool surface. It would be necessary to prevent rapid depressurization by controlling the venting path. Several designs were evaluated with the assistance of engineers from NIST and the UT Applied Research Lab. The final design allowed controlled venting and measurement of internal Reflector pressure.



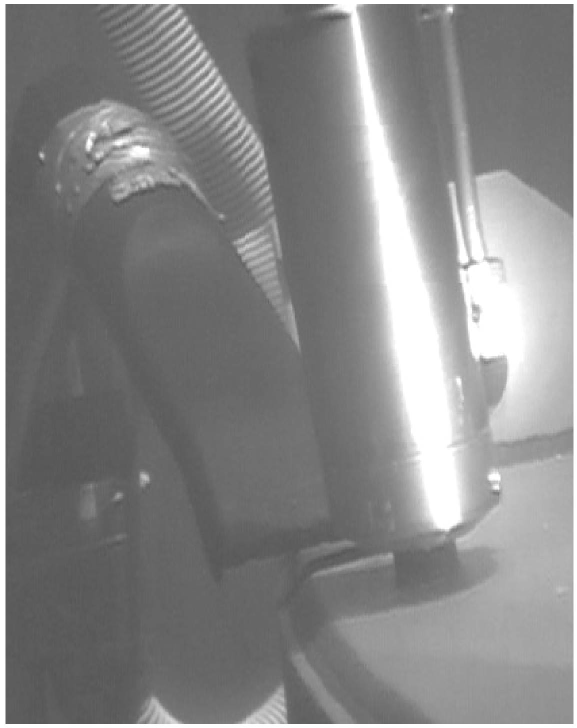
The drill bit (1) passes through a machined rubber stopper cut to seal directly to the upper Reflector surface at the point of drill breakthrough (~0.4 inches). The gases would pass through the center of the stopper past the bit into a small chamber (2). The small chamber is pressurized and the pressure is transferred through a small copper tube and check valve (3) into the center of the drill shaft. The drill shaft is a hollow, flooded 26 foot chamber with two pressure gauges at the pool surface. Pressurization of the drill rig and shaft will cause a reading on the gauges as a measurement of the internal Reflector pressure.

The drill design was reviewed by the Reactor Committee on February 9, 2000 with NRC representatives (Adams, Mendonca) and reviewers from TRTR (Weiss, Brand) present. The safety aspects of drilling the Reflector were discussed and the public opinion in the event there were an ignition during drilling. It was concluded there were no unreviewed safety questions and the public health would not be compromised during the drilling of the Reflector. Authorization to vent the Reflector was given pending successful drill rig tests.

A mockup of the Reflector was built using 0.5 inch machined aluminum plate on the end of a pressurized (approximately 150 psig) six inch pipe. The mockup was placed on the bottom of the reactor pool in a location representing the location and angle of the Reflector surface. The initial design test failed because the internal pressure of the drill rig forced the rubber stopper out. A redesign of the drill rig involved a machined lip and cementing the stopper in place. Further tests were successful but the gauge pressure generally read 30 to 60 psi lower than mockup pressure. This was determined to be an acceptable loss as pressure indications were secondary to safe venting. A Reactor Subcommittee approved drilling and venting the Reflector on February 25.

On February 25, the NETL staff began drilling the top plate of the Reflector. Drawings from General Atomic indicated the top plate was 0.5 inch thick. The drill length was set such that the rubber stopper would seat on the Reflector at the point of drill breakthrough. Drilling was halted when bubbles were seen as the stopper made contact with the Reflector surface. These bubbles are believed to have been forced out of the stopper/drill bit gap during compression. The drill did not breakthrough at the 0.5 inch point. The NETL staff evaluted the conditions and reset the drill for a total depth of 5/8 inch.

Shortly after starting to drill the Reflector, the drill broke through and the gas began to vent. The drill rig successfully maintained the vent rate to a controlled level. Venting of the Reflector took approximately 6 hours. The drill rig in place is shown in the following photograph taken with a video camera.



Drill Head on Reflector

An additional six vent holes were drilled into the reflector following the depressurization by moving the drill rig and milling machine around the pool area for access. These holes were necessary to ensure no large volumes of gas mixture remained in the Reflector.

Committee Authorization to Operate with Reflector Flooded

On March 9, the full Reactor Committee met to review the Reflector drilling and evaluate the safety of reactor operation with the Reflector flooded. MCNP calculations indicated there would be a marginal affect on the reactor characteristics as indicated by very small changes in K_{eff} and expected critical rod heights. However, there would be reduced neutron flux in most experiment locations as indicated in the following table.

Experiment Location	Percent Change in Flux
Rotary Specimen Rack	-40%
Beam Port 1	-33%
Beam Port 2	-95%
Beam Port 3	-17%
Beam Port 4	-94%
Beam Port 5	-27%
Average of 3 detectors	-63%

Neutron Flux Reduction in Experiment Areas

The Reflector aluminum plate did not return to the normal dimension and was permanently deformed. The bulges on the inner shroud blocked several grid plate holes in the outer G-ring and fuel or graphite would not be allowed in those holes. This is expected to become a problem over core life because it will preclude adding replacement fuel. The Reactor Committee approved reactor startup for annual maintenance and operations.

Reactor Characteristics with a Flooded Reflector

A return to reactor operation required completion of all postponed reactor maintenance. The Rotary Specimen Rack hold-down brackets needed shimming using 3/8 inch aluminum to compensate for the Reflector deformation. Several Power Calibrations were required due to the reduced flux at the Nuclear Instrumentation detectors.

The NETL reactor was fairly decoupled from the Reflector prior to flooding. This is because the outer ring (G-ring) of the core grid plate rarely had fuel elements in the ring. Most of the G-ring contained graphite dummy elements or were empty (water holes). Hence, the Reflector flooding did not have a significant affect on the reactor characteristics. This is clearly demonstrated by a comparison of control worths before and after the Reflector flooding.

Worth in Cents	Transient	Shim Safety 1	Shim Safety 2	Regulating
July 99	323.4	301.2	321.7	405.4
May 00	321.5	299.0	321.9	397.2

Control Rod Worths Before and After Flooding

Reactor Operations with Flooded Reflector

The most noticeable direct affect of the water-flooded Reflector is the periodic venting of gases from one or two of the drilled vent holes. These gases were analyzed and found to be composed of 2:1 hydrogen and oxygen. This indicates the gas production is continuing and caused by reactor operations. Galvanic corrosion of the aluminum would produce a higher percentage of hydrogen gas, therefore it is concluded this corrosion is not occurring excessively. The current theory is the gas production is caused by radiolysis of the water in proximity to the high surface area of the graphite. Reactor radiation and heat is believed to cause the decomposition of hydrogen peroxide and ions formed from secondary radiolytic reactions. The oxygen and hydrogen gas thus formed would be expected to be at near stochiometric ratios.

3.6 **Laboratory Inspections**

Inspections of laboratory operations are conducted by university and licensing agency personnel. Two committees, a Radiation Safety Committee and a Nuclear Reactor Committee, review operations of the NETL facility. These committees convened at the times listed in Table 3-6.

Table 3-6
Committee Meetings

Nuclear Reactor Committee	
First Quarter	March 9,1999
Second Quarter	No meeting
Third Quarter	August 10, 2000
Fourth Quarter	November 11, 2000

Inspections by licensing agencies include federal license activities by the U. S. Nuclear Regulatory Commission (NRC), Nuclear Reactor Regulation Branch (NRR), and state license activities by the Texas Department of Health (TDH) Bureau of Radiation Control (BRC). NRC and TDH inspections were held at the times presented in Table 3-7.

Table 3-7
Dates of License Inspections

License	Dates
R-129	February 9, 16 and 25
SNM-180	None
L00485(48)	None

Several unscheduled inspections occurred in 2000 as a result of the Reflector Problems. The inspectors attended the Reactor Sub-Committee Meeting on Feburary 9 to observe the approval to drill the Reflector A formal report on all inspections was prepared following the resolution of the Reflector conditions.

Routine inspections by the Office of Environmental Health and Safety (OEHS) for compliance with university safety rules and procedures are conducted at varying intervals throughout the year. In response to safety concerns at other sites on the main campus, several additional OEHS inspections have been made. Inspections cover fire, chemical, and radiological hazards. No significant safety problems were found at NETL, which reflects favorably on the positive safety culture for all hazard classes at the NETL. Safety concerns included such items as storage of combustibles, compressed gases, and fire extinguisher access.

3.7 **Radiation Exposures**

A radiation protection program for the NETL facility provides monitoring for personnel radiation exposure, surveys of radiation areas and contamination areas, and measurements of radioactive effluents. Radiation exposures for personnel, building work areas and areas of the NETL site are shown in the following tables. Site area measurements include exterior points adjacent to the building and exterior points away from the building.

Table 3-8 summarizes NETL personnel dose exposure data for the calendar year. Figure 3-3 locates the building internal and external dosimetry sites. Dots locate fixed monitoring points within the building. Numbers identify the immediate site area radiation measurement points exterior to the building. These measurements do not indicate any measurable dose from work within the NETL building. Table 3-9 and Table 3-10 summarize doses recorded in facility work areas and the site areas. Table 3-11 contains a list of the basic requirements and frequencies of measurements.

Additional measurement data is available from the State of Texas Department of Health. The state agency records environmental radiological exposures at five sites in the vicinity of the research reactor site. Samples are also taken for analysis of soil, vegetation, and sanitary waste effluents.

Table 3-8

Annual Summary of Personnel Radiation Doses Received Within the NETL Reactor Facility (2000)

Personnel Group	Average Annual Dose (1) (mrem)			Greatest Individual Dose (1) (mrem)			Total Person-mrem for the Group (1)		
	Whole Body DDE (2)	Lens of Eye LDE (3)	Extremities SDE (4)	Whole Body DDE (2)	Lens of Eye LDE (3)	Extremities SDE (4)	Whole Body DDE (2)	Lens of Eye LDE (3)	Extremities SDE (4)
Facility Operating and Research Personnel	8.6	8.6	58.6	20	20	170	60	60	370
Students (6)	M	M	6	M	M	71	M	M	73
Visitors Film Badges/TLD PICs (5)	M 0	M N/A	M N/A	M 0	M N/A	M N/A	M 0	M N/A	M N/A

(1) "M" indicates that each of the beta-gamma or neutron dosimeters during the reporting period was less than the vendor's minimum measurable quantity of 10 mrem for x- and gamma rays and thermal neutrons, 40 mrem for energetic betas, and 20 mrem for fast neutrons. "N/A" indicates that there was no extremity monitoring conducted or required for the group.

(2),(3),(4) Deep, Eye and Shallow Dose Equivalents (DDE, LDE, and SDE respectively). DDE applies to external whole-body exposure and is the dose equivalent at a tissue depth of 1 cm (1000 mg/sq cm). LDE applies to the external exposure of the eye lens and is taken as the dose equivalent at a tissue depth of 0.3 cm (300 mg/sq cm). SDE applies to skin or extremity external exposure, and is the dose equivalent at a tissue depth of 0.007 cm (7 mg/sq cm) averaged over an area of 1 square cm.

(5) PICs are pocket ionization chambers issued to persons who enter radioactive materials/restricted areas for periods of short duration, i.e., a few hours or days.

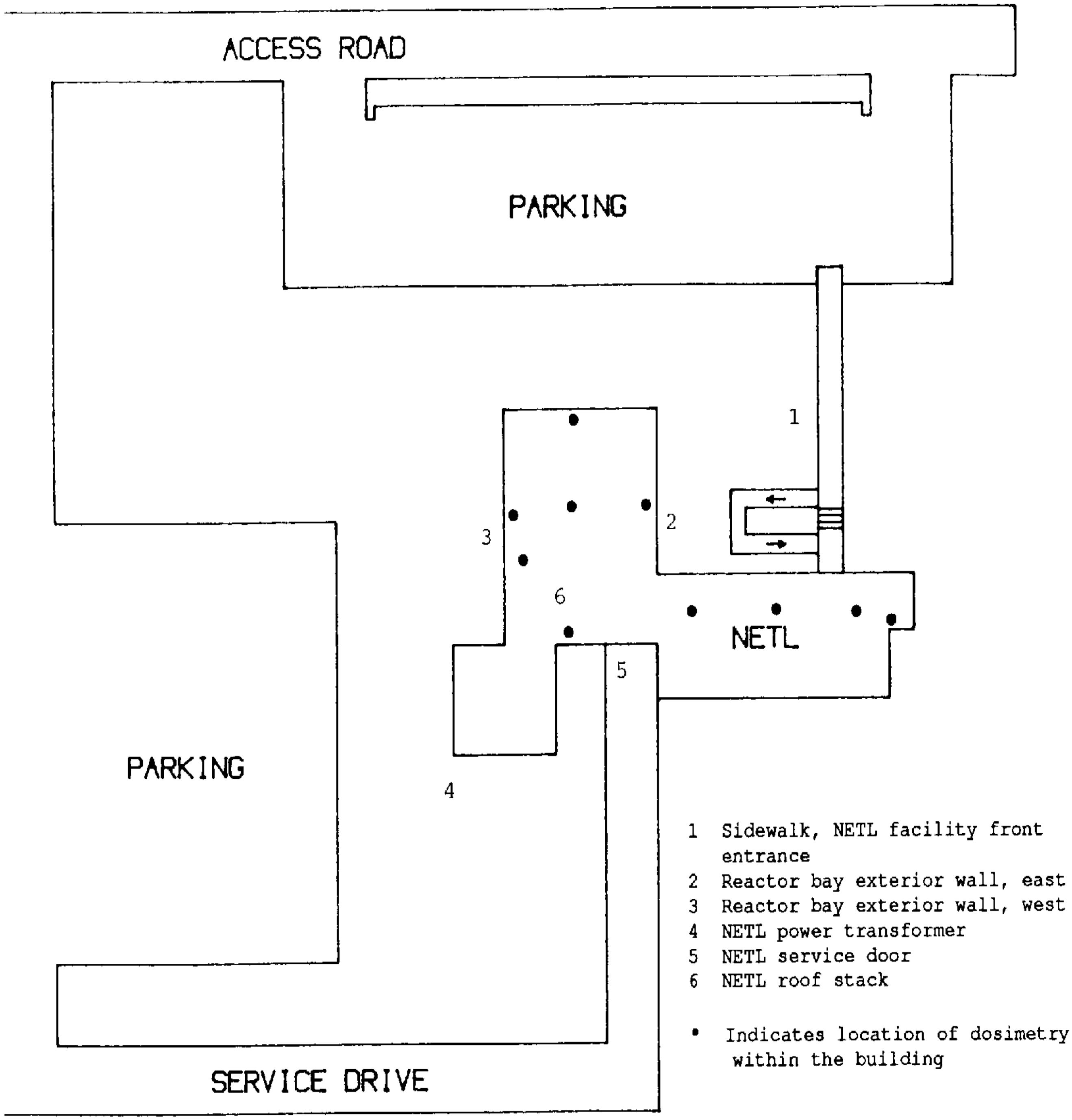


Figure 3-3 Environmental TLD Locations

Table 3-9

Total Dose Equivalent Recorded on Area Dosimeters Located Within the y ETL Reactor y acility

[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(1) The total recorded dose equivalent values reported in mrem do not include natural background contribution and reflect the summation of the results of 12 monthly beta,x- and gamma ray or neutron dosimeters for each location. A total dose equivalent of "M" indicates that each of the dosimeters during the period was below the vendor's minimum measureable quantity of 10 mrem for x and gamma rays, 40 mrem for energetic betas, 20 mrem for fast neutrons, and 10 mrem for thermal neutrons. "N/A" indicates that there was no neutron Monitor at that location.

(2) These dose equivalent values do not represent radiation exposure through an exterior wall directly into an unrestricted area.

(3) Deep Indicates deep dose equivalent, which applies to external whole-body exposure and ia the dose equivalent at a tissue depth of 1cm

(4) Shallow indicates shallow dose equivalent, and applies to the external exposure of the skin or an extremity, and is taken as the dose equivalent at a tissue depth of 0.007cm averaged over an area of one square centimeter.

Table 3-10

Total Dose Equivalent Recorded on TLD Environmental Monitors Around the NETL Reactor Facility (2000)

Monitor I.D.	NETL Reactor Facility Location	Total Recorded Dose Equivalent (1) (mrem)
00156	Sidewalk, NETL facility front entrance	M
00157	NETL power transformer	M
00158	NETL roof stack	M
00159	Reactor bay exterior wall, east	M
00160	Reactor bay exterior wall, west	M
00161	NETL service door	M

(1) The total recorded dose equivalent values do not include natural background contribution and reflects the summation of the results of four quarterly TLD dosimeters for each location. A total dose equivalent of "M"indicates that each of the dosimeters during the period was below the vendor's minimum reportable quantity of 10 mrem for x- and gamma rays, and 40 mrem for energetic beta particles.

Table 3-11
Radiation Protection Program
Requirements and Frequencies

Frequency	Radiation Protection Requirement
Weekly	Gamma survey of all Restricted Areas. Swipe survey of all Restricted Areas. Swipe survey of Radioactive Materials Areas. Response check of the continuous air monitor. Response checks of the area radiation monitors. Neutron survey of the reactor bay (during reactor operation).
Monthly	Gamma, neutron and swipe surveys of exterior walls and roof. Exchange personnel dosimeters and interior area monitoring dosimeters. Review dosimetry reports. Response check emergency locker portable radiation measuring equipment. Review Radiation Work Permits. Response check of the argon monitor. Response check hand and foot monitor. Conduct background checks of low background alpha/beta counting system. Collect and analyze TRIGA primary water.
As Required	Process and record solid wastes and liquid effluent discharges. Prepare and record radioactive material shipments. Survey and record incoming radioactive materials. Perform and record special radiation surveys. Issue radiation work permits and provide health physics coverage for maintenance operations. Conduct orientations and training.
Quarterly	Exchange TLD environmental monitors. Gamma and swipe surveys of all non restricted areas. Swipe survey of building exterior areas. Calibrate area monitors in neutron generator room. Perform Chi-square test, and determine HV plateaus and detection efficiencies on the low background alpha/beta counting system.
Semi-Annual	Inventory emergency locker. Calibrate portable radiation monitoring instruments. Calibrate continuous air monitor, argon monitor, and area radiation monitors. Calibrate personnel pocket dosimeters. Leak test and inventory sealed sources.
Annual	Conduct ALARA Committee meeting. Conduct personnel refresher training. Calibrate emergency locker portable radiation detection equipment

3.8 **Radiation Surveys**

Radiation surveys of NETL work areas are shown in Table 3-12. Surveys with portable instruments and measurements of radioactive contamination are routine. Supplemental measurements are also made any time unusual conditions occur. Values in the table represent the result of routine measurements. Environmental monitoring at sample sites exterior to the building are generally done at random times or as a case by case evaluation.

Table 3-12

Annual Summary of Radiation and Contamination Levels Within the NETL Reactor Facility (2000)

Accessible Location	Area Radiation Levels (mrem/hr)		Contamination Levels (dpm/100 sq cm)	
	Average (1)	Maximum (1)	Average	Maximum
TRIGA Reactor Bay:				
Reactor Bay North	15.7	200	MDA (2)	22.4
Reactor Bay South	0.02	0.03	MDA (2)	13.1
Reactor Bay East	0.01	0.5	MDA (2)	18.8
Reactor Bay West	11.2	50	MDA (2)	12.5
Reactor Pool Deck (Third Floor)	3.6	25	14.8	1836.0
NETL Facility:				
NAA Sample Processing (Rm 3.102)	0.11	0.3	MDA (2)	11.3
NAA Sample Counting (Rm 3.112)	0.05	0.3	MDA (2)	15.8
Health Physics Laboratory	1.15	2	MDA (2)	19.6
NAA Laboratory (Rm 3.106)	0.01	0.01	MDA (2)	15.6

(1) Measurements made with Victoreen 450 and/or Bicron Microrem portable survey meters in areas.
(2) MDA for the G-5000 low level alpha-beta radiation counting system is 2.49 dpm/100 cm^2 beta, and 0.58 dpm/100 cm^2 alpha. Calculation of MDA based on NCRP Report No. 58.
(3) The contamination shown for this location assumes 100% smearing efficiency, and was immediately removed. As a result, the average contamination level at this location during the reporting period was, for all practical purposes, < 500 dpm per 100cm^2.

3.9 **Radioactive Effluents, Radioactive Waste**

Radioactive effluents are releases to the air and to the sanitary sewer system. The most significant effluent is an airborne radionuclide, argon-41. Two other airborne radionuclides, nitrogen-16 and oxygen-19, decay rapidly and do not contribute to effluent releases. Argon-41, with a half-life of 109 minutes is the only airborne radionuclide emitted by the facility. A summary of the argon-41 releases are shown in Table 3-13. Total quantity of Ar-41 released in 1999 was 18.5% of the T.S. allowance.

Table 3-13

Monthly Summary of Argon-41
Effluent Releases (1)

Date of Discharge (Month, 2000)	Total Quantity of Argon-41 Released (microcuries)	Average Concentration of Argon-41 at Point of Release (microcuries/cubic cm)	Tech Spec. Percentage of Argon-41 Released
[3]			
January			0.00
February			0.00
March			0.00
April	2.64E+05	1.58E-07	7.90
May	2.19E+06	1.31E-06	65.65
June	1.23E+06	7.36E-07	36.80
July	1.46E+05	8.75E-07	43.73
August	1.27E+04	7.59E-09	0.38
September	2.80E+05	1.68E-07	8.39
October	4.26E+05	2.55E-07	12.75
November	5.56E+05	3.33E-07	16.65
December	5.90E+05	3.53E-07	17.67
ANNUAL VALUE	5.70E+06	3.50E-07	17.49

(1) Point of release is the roof exhaust stack. Concentration includes dilution factor of 0.2 for mixing with main exhaust.

(2) Technical Specification limit for continuous release is 2.00E-6 microcuries/cubic cm.

(3) There were no releases prior to 4/13/00 due to reactor shut down.

Releases to the sanitary sewer are done from waste hold up tanks at irregular intervals. To date, no releases have been made. The liquid radioactive waste tanks allow for segregation of liquids for decay of the activity. Liquids may also be processed on-site to concentrate the radionuclides into other forms prior to disposal. Liquid disposals are infrequent.

Table 3-14

Monthly Summary of Liquid Effluent Releases to the Sanitary Sewer from the NETL Reactor Facility (2000)

Date of Discharge (Month, 2000)	Total Quantity of Radioactivity Released (millicuries)
January	NO RELEASES
February	NO RELEASES
March	NO RELEASES
April	NO RELEASES
May	NO RELEASES
June	NO RELEASES
July	NO RELEASES
August	NO RELEASES
September	NO RELEASES
October	NO RELEASES
November	NO RELEASES
December	NO RELEASES

Radioactive waste disposal of solids are shown in Table 3-15. The inventory of material in Table 3-15 represents the disposal of radioactive material as follows: January and February, legacy glovebox contaminated with transuranics (believed to be Pu-foils from 20+ years ago); May, rotary-type forevacuum pump and miscellaneous dry active waste (DAW) from decommissioning an old neutron generator (tritium); July, mixed activation products (DAW) from sample processing activities. Total activity sent to disposal was on the order of 0.05 mCi. All transfers of material were made to the University Office of Environmental Health and Safety for disposal.

Table 3-15

Monthly Summary of Solid Waste Transfers for Disposal From the NETL Reactor Facility (2000)

Date of Disposal (Month, 2000)	Release Volume (cubic meters)	Total Quantity of Radioactivity (millicuries)
January	0	NONE
February	0	NONE
March	0	NONE
April	0	NONE
May	0.2	NONE
June	0.21	0.09
July	0.21	1.7
August	0	NONE
September	0	NONE
October	0	NONE
November	O	NONE
December	<1.0	0.1