DEPARTMENT OF MECHANICAL ENGINEERING
THE UNIVERSITY OF TEXAS AT AUSTIN

Nuclear Engineering Teaching Laboratory • (512) 471-5787 • FAX (512) 471-4589

March 27, 1996

Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

Subject: Docket 5-602
Annual Report 1995

Dear Sir:

A report is enclosed for the R-129 license activities of The University of Texas at Austin. The report covers the activities during the 1995 calendar year.

Sincerely,

Thomas L. Bauer

Thomas L. Bauer
Assistant Director,
Nuclear Engineering Teaching Laboratory

enclosure: 1995 Annual Report

cc:	Region IV	w/enclosure 1 copy
	A. Adams	w/enclosure 1 copy
	B. Wehring	w/enclosure 1 copy
	D. Klein	w/enclosure 1 copy

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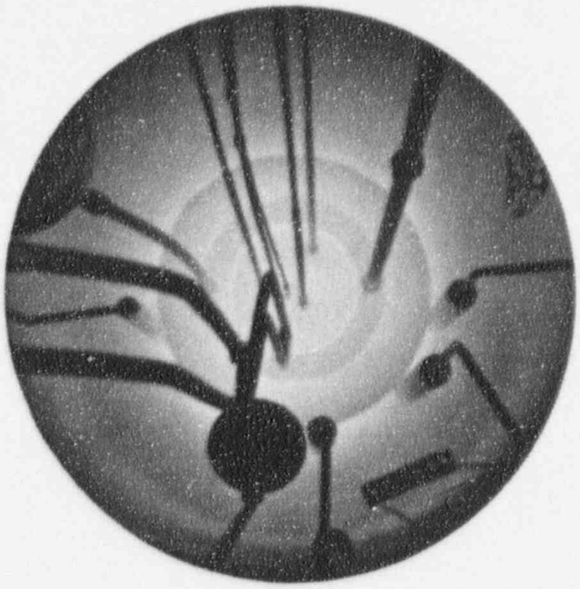
Street Address: 10100 Burnet Road • Austin, Texas 78758 • Mail Address: J.J. Pickle Research Campus • Bldg. 159 • Austin, Texas 78712



NUCLEAR REACTOR LABORATORY

TECHNICAL REPORT

THE UNIVERSITY OF TEXAS
COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

Annual Report

1995

Nuclear Engineering Teaching Laboratory

J.J. Pickle Research Campus

The University of Texas at Austin

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FORWARD

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

1. preserve, disseminate, and create knowledge,
2. help educate those who will serve in the rebirth of nuclear power and in the expanding use of nuclear technology in industry and medicine, and
3. provide specialized nuclear resources for educational, industrial, medical, and government organizations.

The above objectives are 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 UT-TRIGA 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 UT-TRIGA research reactor provides opportunities to do research in nuclear science and engineering. It can also contribute to multidisiplinary studies in medicine, epidemiology, environmental sciences, geology, archeology, paleontology, etc. Research reactors, one megawatt and larger, constitute unique and essential research tools for examining the structure of crystals, magnetic materials, polymers, biological molecules, etc.

The UT-TRIGA research reactor benefits a wide range of on-campus and off-campus clientele, 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.

Bernard W. Wehring

Bernard W. Wehring, Director
Nuclear Engineering Teaching Laboratory

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% $\Delta k/k$.

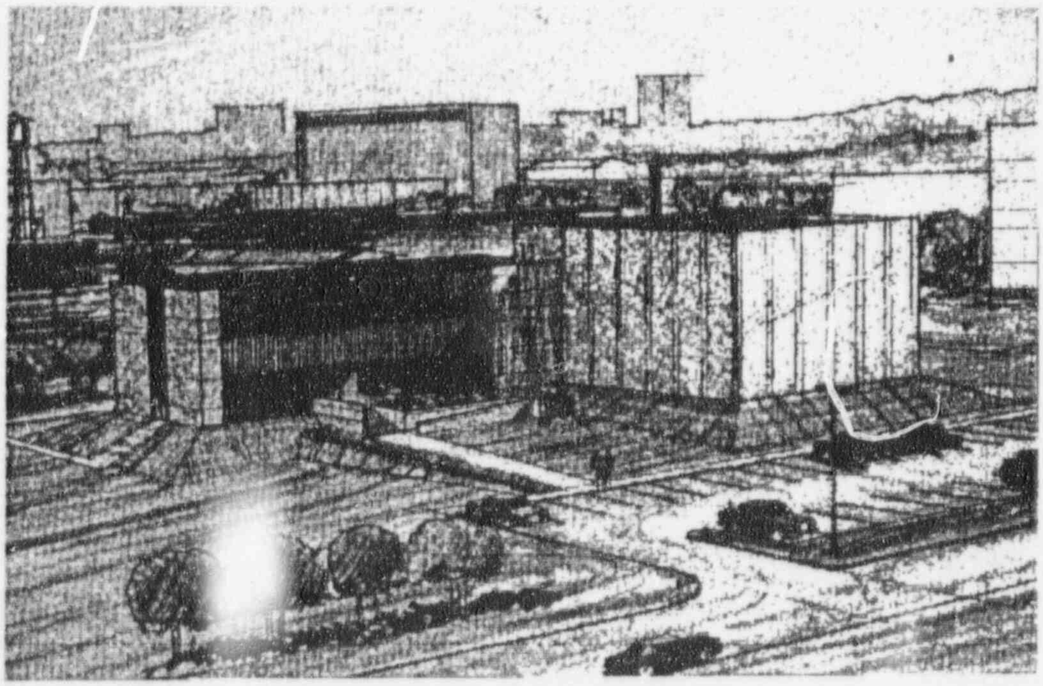

Figure 1-1 NETL - Nuclear Engineering Teaching Laboratory

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], and the licensing agency, the U.S. Nuclear Regulatory Commission (NRC) [docket number 50-602]. This annual report covers the period from January 1, 1995 to December 31, 1995.

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 is 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 R-129, a class 104c research reactor license. Another 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. Dismantlement 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. Ten separate research units and several 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.

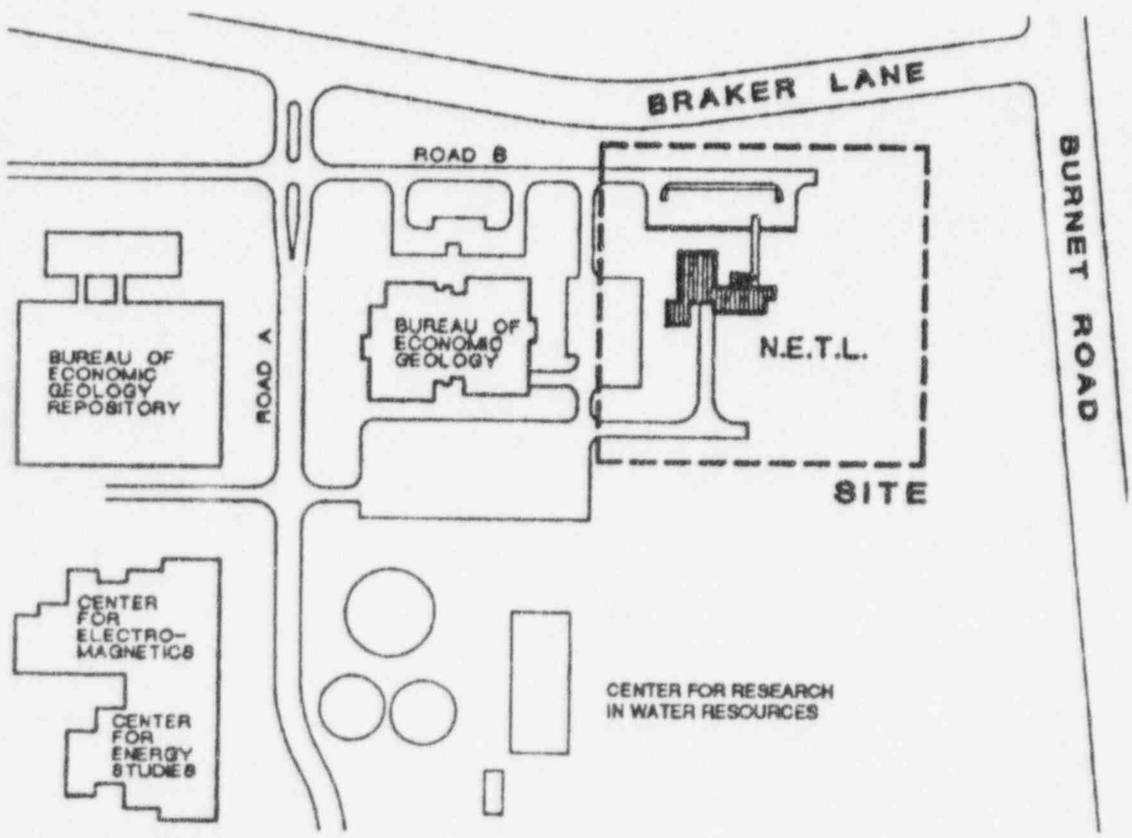

Figure 1-2 NETL Site - J.J. Pickle Research Campus

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. Figure 1-3 and 1-4 show the building and floor layouts for office and laboratory areas.

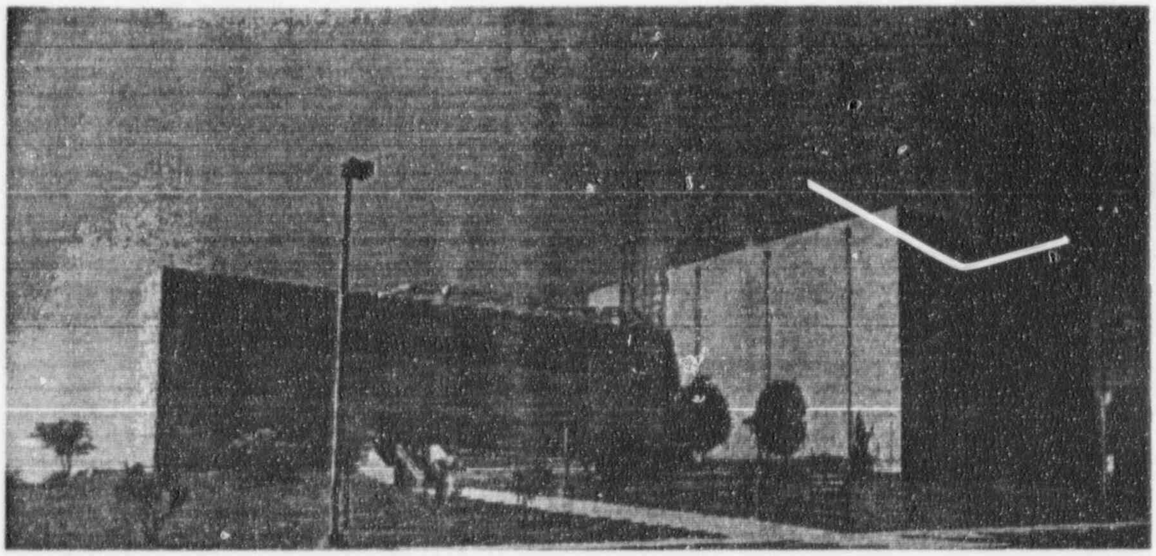

Figure 1-3 NETL Building Profile

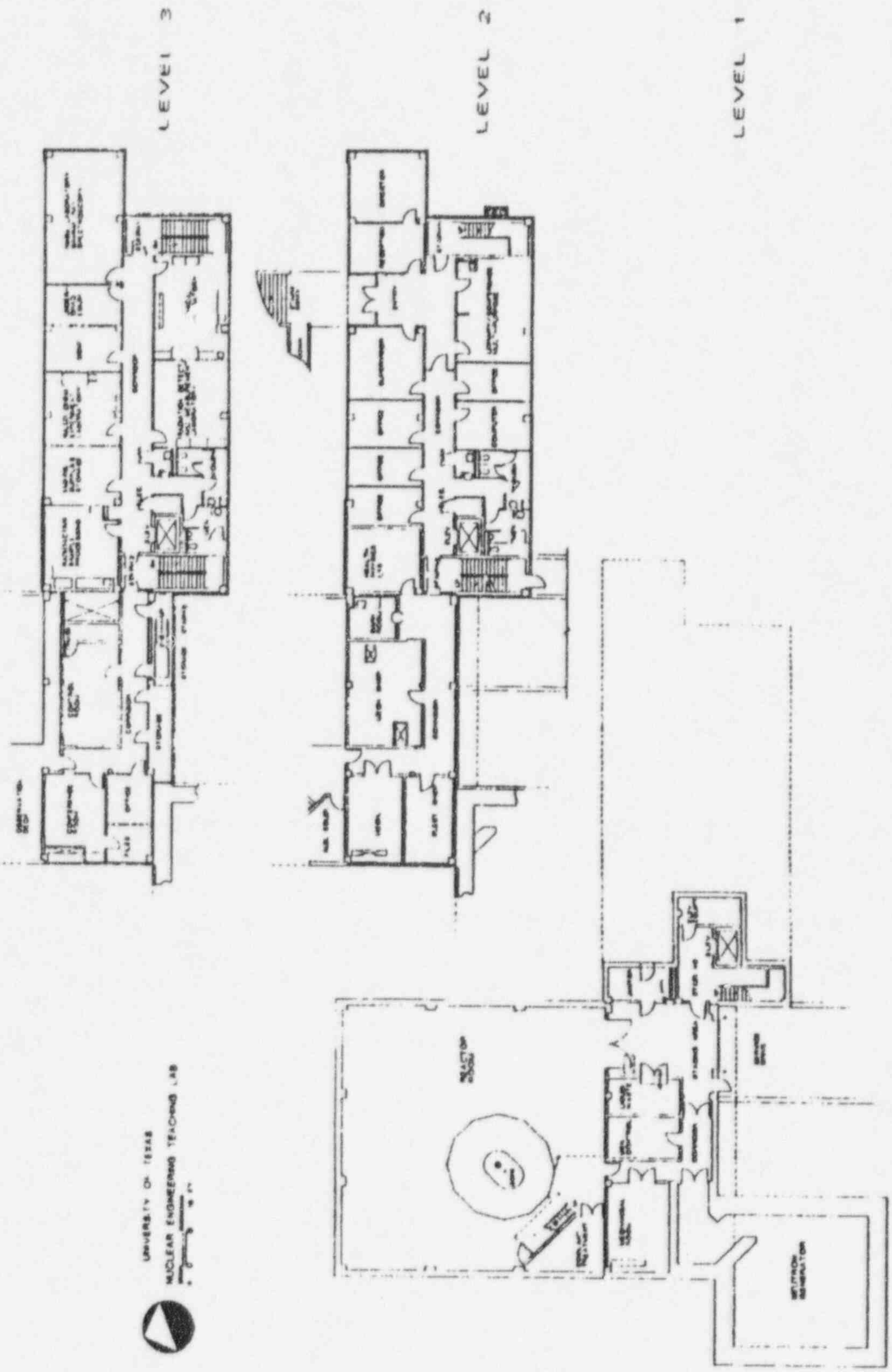

Figure 1-4 NETL Building - Layout

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.

Radiation producing equipment such as x-ray units for radiography and density measurements are available as both fixed and portable equipment. Laboratories provide locations to setup radiation experiments, test instrumentation, prepare materials for irradiation, process radioactive samples and experiment with radiochemical reactions.

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. Figure 1-5 is a picture of the reactor core structure.

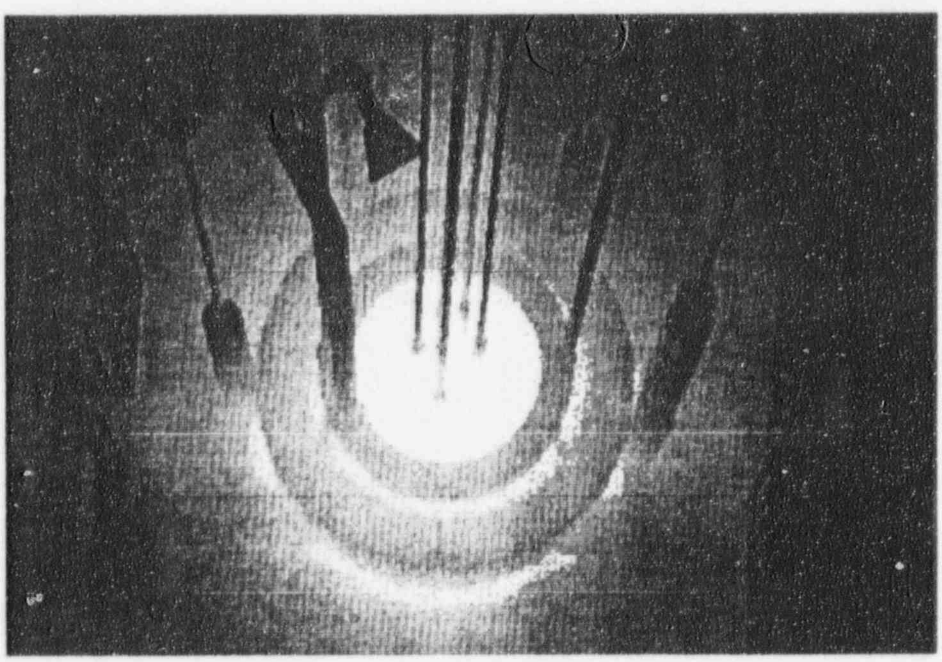

Figure 1-5 TRIGA Reactor Core

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.

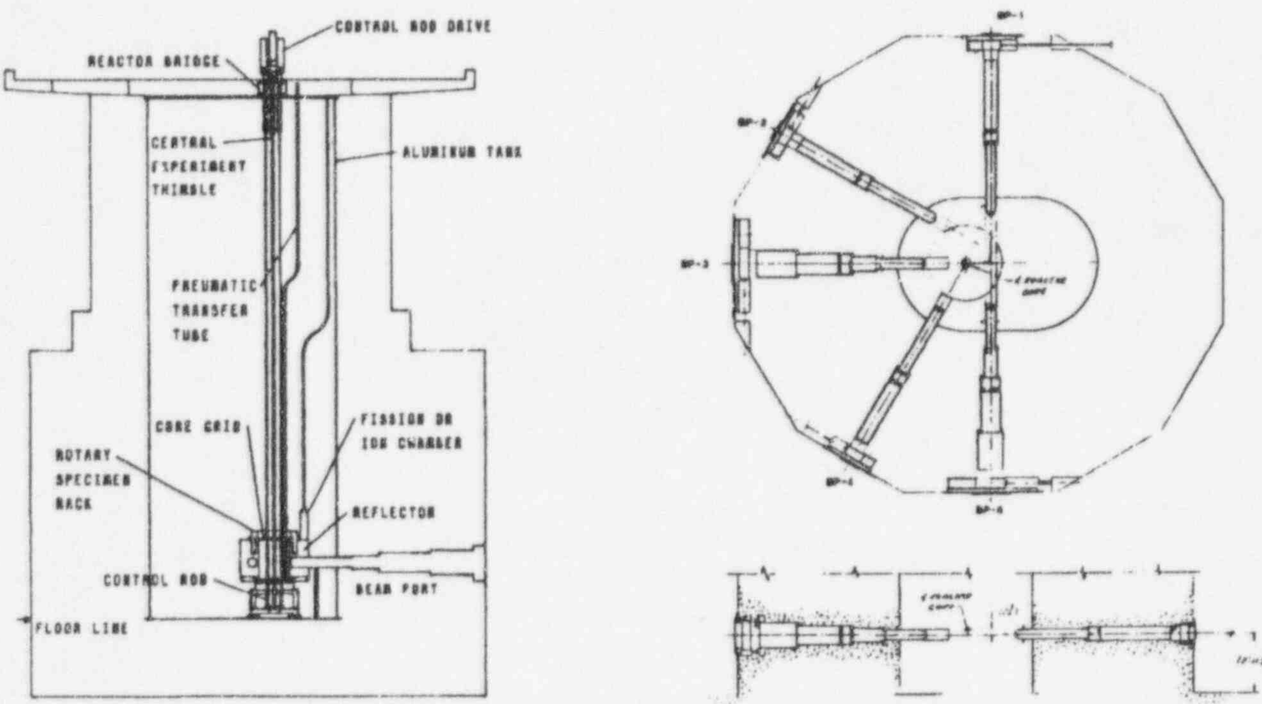

Figure 1-6 Reactor Pool and Beam Ports

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.	3.88 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 a collimator and/or neutron filter. Collimators are used to limit beam size and/or beam divergence. 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
At Exit:	8 in.	20.32 cm
	10 in.	25.40 cm
	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 an NE dissertation committee.

Of the five undergraduate Nuclear Engineering courses and the dozen graduate Nuclear Engineering courses, five 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
Graduate	
ME 388R.3	Kinetics and Dynamics of Nuclear Systems
ME 389R.1	Nuclear Engineering Laboratory
ME 389R.2	Nuclear Analytical measurement Techniques

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. It is based on three divisions, each with a manager and workers. The remaining staff including the Health Physics group is called the administration, and supports the three divisions.

The Operation and Maintenance Division (OMD) is responsible for the safe and effective operations of the TRIGA nuclear reactor. Other duties include maintenance of the 14-MeV neutron facility, the gamma irradiation facility, industrial x-ray units, and the NETL computer system. Activities of OMD include neutron and gamma irradiation service, operator/engineering training courses, and giving reactor short courses.

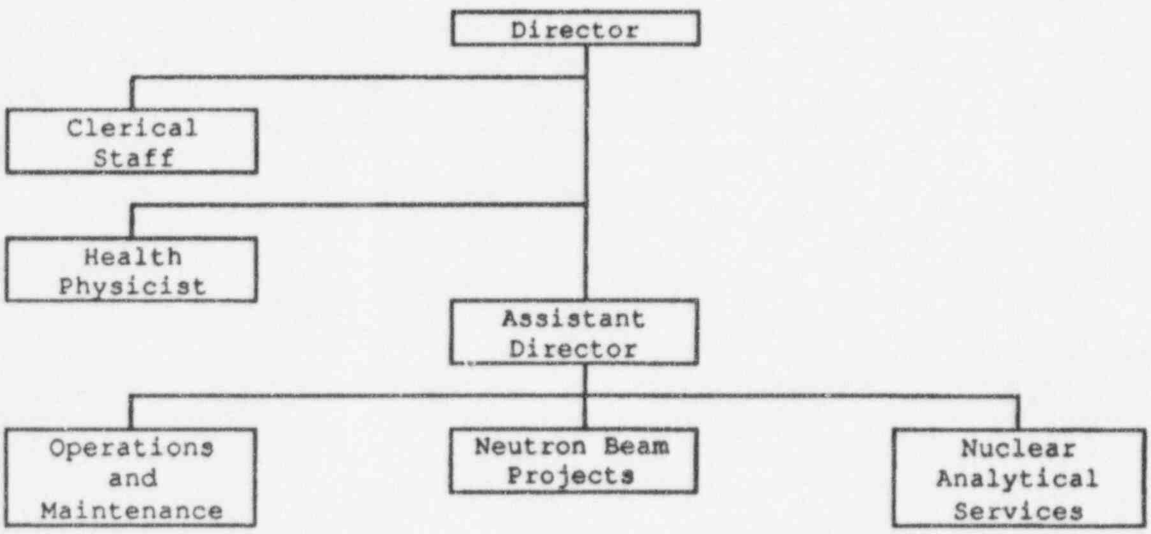

Figure 1-8 NETL Staff Organization

The Nuclear Analytical Services Division (NAS) is responsible for providing, in a safe and effective manner, 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 Operation and Maintenance Division (OMD) is the routine maintenance and safe operation of the TRIGA Mark II Research Reactor. 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, and industrial x-ray machines.

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 Operation and Maintenance Division. 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 tehcnique is made available to different state agencies to assist with quality control of sample measurements and evaluation of the presence of and the environmental effects of certain 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. 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. However, safeguards by special protocols guard against any unauthorized access.

Neutron Beam Projects 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, and Gadolinium Neutron Capture Therapy studies.

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 micro remmeter	low level gamma	1
High range portable ion chamber	beta/gamma	2
BF3 proportional counter	neutron	2
Hand and Foot monitor	beta	1
Low level gas-flow proportional counter	alpha/beta	1
Continuous air particulate monitor	alpha/beta	1
Gaseous Ar-41 effluent monitor	beta	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 paractices, 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.

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.

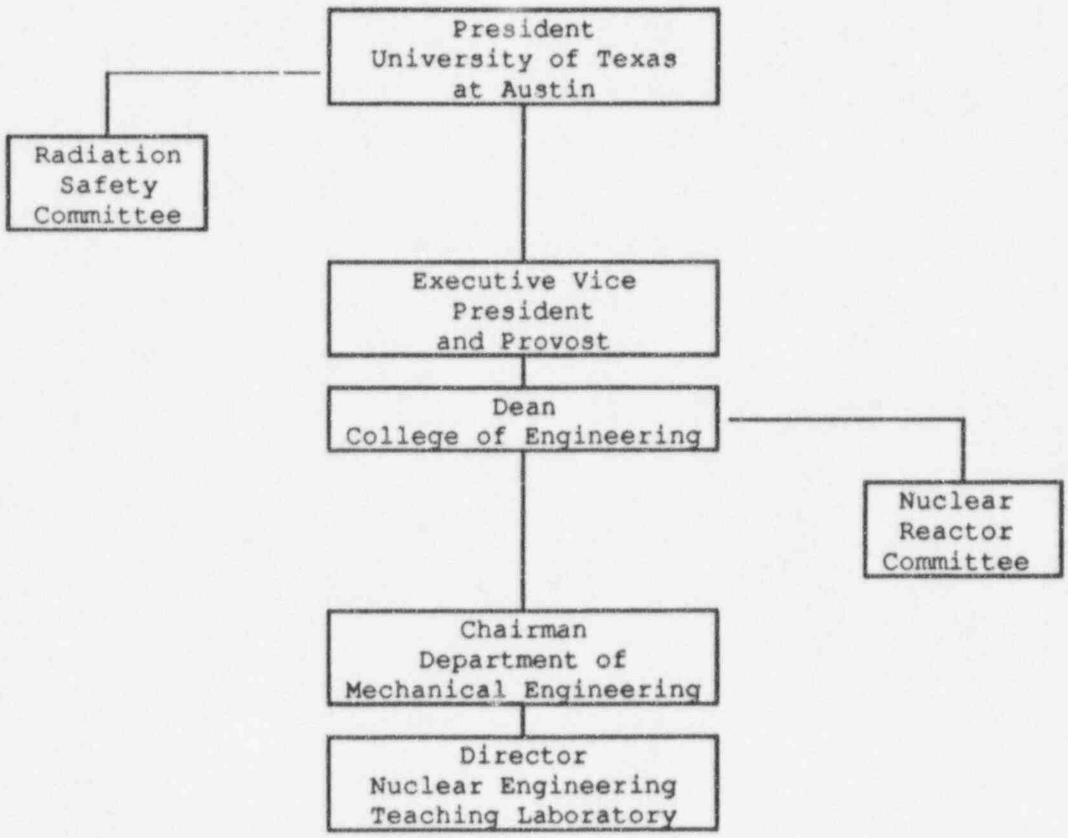

Figure 2-1 - University Administrative Structure over NETL

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	B. Rapaport
Vice Chairman	T.O. Hicks
Vice Chairman	M.E. Smiley
Executive Secretary	A.H. Dilly
Chancellor	William Cunningham

Member 1997	Member 1999	Member 2001
Z.W. Holmes, Jr.	T.O. Hicks	L.F. Deily
B. Rapaport	L.H. Lebermann	T. Loeffler
E.C. Temple	M.E. Smiley	D.L. Evans

Table 2-2
The University of Texas at Austin
Administration

President	Robert Berdahl
Executive Vice President and Provost	Mark Yudof
Dean of College of Engineering	Herbert Woodson
Chairman of Department of Mechanical Engineering	Kenneth Diller

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	E.L. Sutton
Member	M.A. Fox (94-95)
Member	G. Hoffmann
Member	D.E. Klein
Member	S.A. Monti
Member	J. Robertus
Member	J. Sanchez (95-96)
Member	B.W. Wehring
Ex officio member	G. Monroe
Ex officio member	J.C. White

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	R. Charbeneau
Member	D. Blackstock
Student Member	R. Canaan
Member	E. Peters (1995-96)
Member	D.E. Klein
Member	S. Morriss (1994-95)
Member	B.W. Wehring
Ex officio member	T.L. Bauer
Ex officio member	J. White
Ex officio member	K. Diller

Personnel. NETL state funding supports full-time positions for a Reactor Supervisor/Assistant Director, three managers, a Health Physicist, and a Senior Administrative Associate. External funding by research grants and service activities support student assistantships. The personnel involved in the NETL program during the year are summarized in Table 2-5.

Table 2-5
NETL Personnel

NETL Facility Staff	
Director	B.W. Wehring
Reactor Supervisor/Assist. Dir.	T.L. Bauer
Manager NAS (Research Scientist)	F.Y. Iskander
Manager NBP (Research Scientist)	K. Unlu
Manager O&M (Research Associate)	M.G. Krause
Health Physicist (Research Associate)	A.J. Teachout
Sr. Administrative Associate	J.G. Rawlings
Faculty	
N. Abdurrahman	B.V. Koen
D.E. Klein	B.W. Wehring
Student Assistants	
Graduate Level:	
Hector Vega	Mohamed Elsawi
Carlos Rios-Martinez	Gursoy Akguc
Harry Felsher	Syed Zain Mujtaba
Young Jo	Georgeta Radulescu
Mark Kelly	Horia Raul Radulescu
Brahim Boumakh	Mehmet Saglam
Bill Spiesman	Sinan Goktepeli
Ed Reott	
Undergraduate Level:	
Ingmar Sterzing	
William Gerber	David Haist

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. Table 2-6 lists the current supplemental funds.

Table 2-6
Supplemental Funds

Project Title	Funding Period	Funding Source	Amount
Instrumentation for the University of Texas Reactor	9/30/92-9/29/96	DOE	26,506
Study of Neutron Focusing at the Texas Cold Neutron Source	4/15/92-4/14/95	DOE	98,179
An Expert System to Enhance Software Reliability	9/30/91-6/31/95	NRC	99,998
Analysis for Selenium	9/01/94-8/31/95	TPW	10,983
Readiation Damage and Microstructural Changes of Stainless Steel Due to Long-term Irradiation by Alpha Particles Emitted from Plutonium	6/1/95-5/31/96	ANRCP	100,000
Water-Reactor Options for Disposition of Weapons Plutonium	6/1/95-5/31/96	ANCRP	90,158
Development of Non Destructive Assay Methods for Weapons Plutonium and MOX Fuel Safeguards	6/1/95-5/31/96	ANCRP	155,324
Neutron Imaging System for Materials Characterization Research at The University of Texas Reactor	9/15/95-8/31/96	NSF	75,000
ALCOA gift	3/22/95-		10,490
		Total	666,638

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 1041 visitors were given access to the facility during the reporting period. The total includes tour groups, official visitors, and facility maintenance personnel. Tours for 11 groups with an average 27 persons/group were taken through the facility during the reporting period.

Table 2-7
Public Access

Tour Groups	300
Individuals	375
Workers	366
Total	1041

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 *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 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 Cigarettes

SPONSOR: NETL

The concentration of 27 elements was determined in wrapping paper and cigarette tobacco in several Mexican cigarette brands. The results were compared to the concentration of these elements in the American and other national cigarette brands. In a closed environment, the accumulation of cigarette ash may represent a source of potentially toxic elements in particular to children. Therefore, the concentration of the same elements were also measured in the cigarette ash.

PROJECT: Multielement determination in plants used in Mexican folklore medicine

SPONSOR NETL

The study focused on the concentration of various elements in 31 plants used in Mexican folklore medicine. This study has two goals. The first goal is to estimate the intake of toxic or potentially toxic elements during the course of treatment. The second goal is to establish whether or not a specific element is found in higher concentration in one group of plants used for the treatment of specific diseases.

PROJECT: Multielement Determination in Airborne Particulate

SPONSOR NETL

Airborne particulates from 30 locations in Zacatecas, Mexico were collected. All samples were analyzed to determine the concentration of toxic and other elements around the city. The results will help in mapping the concentration of each element. Concentration distributions may provide data to identify the source of pollution.

PROJECT: Measurement of toxic and other elements in food

SPONSOR: Welstart International, Washington, D.C.

This study is being conducted by Welstart International of Washington, D.C., a non-profit organization with the goal of providing scientific basis for the relationship between the contamination level in food nutrition. The existence of some of the elements is anticipated, but their level is not.

The study is being conduct in two phases: Phase I; focused on selected chlorinated contaminants such as dioxins and furans, PCBs and chlorinated pesticides. Phase II; focuses on heavy metals such as lead, cadmium and arsenic. INAA was selected as the technique of choice. The concentration of nine elements in 161 samples was investigated.

PROJECT: Determination of several elements in Cu process effluent

SPONSOR: Professor E. F. Gloyna, Center of Energy Study. The University of Texas at Austin

The concentration of Ce, Co, Cs, La, Sr, U and Zn in process effluent was measured by instrumental neutron activation analysis. The goal of the study is to understand the fate of heavy elements in copper simulated effluent and magnetite

simulated effluent after supercritical treatment. Measurements provided data to calculate the mass balance.

PROJECT: Measurements of ultra-trace concentration of several elements in silicon wafer
SPONSOR: Dr. Tim Hossian, Advanced Micro Devices.

The concentration of Na, K, Cr and Cu was measured in silicon wafer samples. INAA was the technique of choice due to its high sensitivity and minimum handling of the very high purity material (silicon wafer) thus minimize the possibility of sample contamination.

2.4 *Research and Development Projects*

PROJECT: Neutron Depth Profiling

SPONSOR: NETL

A neutron depth profiling (NDP) instrument has been designed, constructed, and tested. 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 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.

(NIST) NDP facility using the same samples. The NETL results showed good agreement with the NIST depth profiles.

Other possible applications of the UT-NDP facility include the study of implanted boron in semiconductor material as a function of wafer treatment; study of nitrogen in metals as it affects wear resistance, hardness, and corrosion; and study of helium behavior in metals, and metallic, and amorphous alloys.

PROJECT: Gadolinium Neutron Capture Therapy Dosimetry Measurements

SPONSOR: NETL and The University of Texas MD Anderson Cancer Center

Neutron capture therapy (NCT) is a technique which employs neutrons in conjunction with neutron-absorbing drugs to create localized radiation damage. It shows promise in the treatment of some malignant tumors of the human central nervous system. Boron-10 is the material most often suggested for use as an NCT agent due to its large thermal neutron absorption cross section for the (n, alpha) reaction.

Another material, gadolinium, has been considered as an NCT agent. In comparison to boron, most of the energy from neutron capture in gadolinium is nonlocalized gamma radiation. Thus, gadolinium does not need to be located in or on tumor cells, but only in the tumor to deliver a radiation dose to the cancerous cells. A possible negative result of using gadolinium is that healthy cells may also be damaged. Thus, a knowledge of the dose distribution near the tumor is very important. Several calculations have predicted this spatial variation, but it has not been measured for Gadolinium Neutron Capture Therapy. A research program was initiated at the NETL to measure the low-LET dose distribution in a head phantom with and without a Gd loaded tumor region.

Epithermal neutrons give better results than thermal neutrons for the treatment of deep seated tumors. In order to provide epithermal neutrons BP #4 is used for the NETL study. The problem with using this type of beam port is that high background of core gamma rays make it difficult to measure the

exist for the corresponding Boron Neutron Capture Therapy (BNCT) experiment.

Neutron filters were designed to improve the quality of the neutron beam, i.e., to decrease the dose rate of core gamma rays, to facilitate Gadolinium Neutron Capture Therapy (GdNCT) dose measurements, and to decrease the flux of MeV neutrons to better simulate proposed clinical neutron beams. Several neutron filters, to be placed midway in the beam port, were constructed which contained lead to attenuate core gamma rays, cadmium to attenuate thermal neutrons, aluminum to attenuate neutrons with energies above 30 keV, and titanium to attenuate neutrons which leak through the aluminum with energies between 10 and 30 keV.

A cylindrical head phantom made of brain tissue equivalent plastic was constructed by The University of Texas, M.D. Anderson Cancer Center researchers. The phantom, a 16-cm diameter 16 cm long cylinder, consists of 11 disks. Gold foils and thermoluminescent dosimeter (type TLD-600 and TLD-700) were placed in depressions on the surfaces of some of the disks.

The initial efforts at measuring gadolinium dose rates were not successful because the background gamma dose rate was too high. Measurements and calculations indicate that the lead used to attenuate the core gamma dose also attenuates the keV neutrons. Thus, the signal to noise was not significantly improved. Extensive design calculations and measurements have been done during the past year for a new geometry for these measurements.

The current work involves scattering the neutron beam to create the dose on the head phantom. The geometry involves a D_2O sphere place at the exit of the beam port, and the head phantom placed near the D_2O sphere perpendicular to the exiting neutron beam. The phantom was placed outside the beam port exit, 300 cm away from the core.

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. After installation of the external curved neutron guides and completion of the shielding structure, neutron focusing and a Prompt Gamma Activation Analysis facility will be installed at the TCNS. The only other operating reactor cold neutron sources in the United States are at Brookhaven National Laboratory and

the National Institute of Standards and Technology. At least four major centers for cold neutron research exist in Europe, with another two in Japan.

PROJECT: Study of Neutron Focusing at the Texas Cold Neutron Source

SPONSOR: DOE

The design and construction of a neutron focusing system for use with the Texas Cold Neutron Source (TCNS) were thoroughly investigated. The focusing system will be located at the end of the TCNS curved neutron guide to increase the neutron flux for neutron capture experiments which benefit from the low background expected at the end of the curved guide. One example of such an experiment is Prompt Gamma Activation Analysis, a nondestructive nuclear analytical technique based on spectroscopy of neutron capture gamma rays.

After examining several methods for neutron focusing, a converging neutron guide was chosen for use as a focusing system. Different multielement converging guides were designed and analyzed. Each consisted of a number of truncated rectangular conical sections coated with Ni-C/Ti supermirrors. A four-element 80-cm-long converging guide was selected for use with the TCNS. Ovonic Synthetic Materials of Michigan, a small company which is the only company in the US capable of doing Ni-C/Ti coating for supermirrors, built the converging neutron guide focusing system to our specifications.

The focused cold neutron beam will be used for neutron capture experiments, e.g., Prompt Gamma Activation Analysis and Neutron Depth Profiling. Because of the increased intensity of the neutron beam due to neutron focusing, we will be able to analyze small samples with high sensitivity. The technique will provide a unique capability to address a wide variety of analytical problems of importance in science and technology.

PROJECT: Prompt Gamma Activation Analysis

SPONSOR: DOE and the State of Texas

A Prompt Gamma Activation Analysis (PGAA) facility has been designed. The UT-PGAA facility will utilize the focused cold-neutron beam from the Texas Cold Neutron Source. The PGAA sample will be located at the focal point of the converging guide focusing system. The use of a guided focused cold-neutron beam will provide 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 other components of the UT-PGAA system are under development.

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: Radiation Damage And Microstructural Changes Of Stainless Steel Due To Long-Term Irradiation By Alpha Particles Emitted From Plutonium

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 samples by helium (alpha particle) irradiation using a near surface nuclear technique called Neutron Depth Profiling, Transmission Electron Microscopy, and Rutherford Backscattering and Channeling Analysis. The long term effects of high dose alpha particle irradiation to the stainless steel 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 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 the stainless steel, 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. These cracks could propagate and lead to failure of the stainless steel cover.

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: Cyclic Activation for Detection of Aluminum and Sodium.

SPONSOR: Aluminum Company of America (ALCOA)

A gift of funds from ALCOA is being used to study the application of neutron isotopic sources for the measurement of industrial process solutions. Neutron activation analysis detects and measures the concentrations of short-lived radionuclides. The work examines the measurement requirements, irradiation cell design, and effects of neutron source including use of fast or thermal neutrons. Analysis methods including simple activation and cyclic activation are being applied. Models of the irradiation and measurement process and the facility design have been developed for general application.

2.5 *Significant Modifications*

No significant modifications have been made to the NETL building, TRIGA reactor or experiment facilities. A summary of the types of modifications that did occur during the year follows. A significant effort from the previous year continues in progress during this year to test a cold neutron source for the reactor.

Building. Routine repair and maintenance of building equipment were the only activities. No changes to the building systems effect the safety of operation of the reactor.

Reactor. No changes were made to the reactor core or basic instrumentation systems during the year. Funds have been obtained to upgrade two control rod drives taken from the Taylor Hall facility. The two drives will be replaced with stepper motor drives. An amendment to the Technical Specifications will be necessary to correct language regarding simultaneous motion of two or more control rods during automatic operation. This work remains in progress from the previous 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.

The pneumatic tube (PNT), including support equipment is not currently part of the installation. Installation of the pneumatic system was a low priority during this year, although planning and installation was in progress. The installation is 85% complete. An experiment authorization for the PNT was completed. Final installation and test of the irradiation terminal should occur during 1996.

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. The moderate gain in refrigeration capacity was sufficient to extend indefinitely the stable operating time for the cold neutron source.

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.

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.

Ph.D.Dissertations/M.S. Thesis

1. Carlos Rios-Martinez, "Prompt Gamma Activation Analysis using the Texas Cold Neutron Source," Ph.D. dissertation, The University of Texas at Austin, May 1995.

2. Hector R. Vega-Carrillo, "Neutron Field Characterization in the Vicinity of a PET Cyclotron," Ph.D. dissertation, The University of Texas at Austin, May, 1995.

Publications

Summaries:

1. B.W. Wehring, C. Rios-Martinez, and K. Ünlü, "Cold-Neutron Prompt Gamma Activation Analysis Facility at The University of Texas at Austin," Trans. Am. Nucl. Soc. 72, 112 (1995).

2. H.R. Vega-Carrillo, N.E. Hertel, A.J. Teachout, and B.W. Wehring, "Paired Thermoluminescent Dosimeter Technique in Bonner Sphere Spectometry," Trans. Am, Nucl. Soc. 73, 359 (1995).

3. N.M. Abdurrahman and B.W. Wehring, "Neutron Imaging System for Neutron Tomography, Radiography, and Beam Diagnostics," Trans. Am, Nucl. Soc. 73, 154 (1995).

4. K.-P. Cheng, K. Ünlü, A.J. Teachout, N.M. Abdurrahman, and B.W. Wehring, "Gadolinium Neutron Capture Therapy Dosimetry Measurements," Trans. Am, Nucl. Soc. 73, 30 (1995).

5. B.W. Wehring and Y.N. Pokotilovski, "Storage of Ultra Cold neutrons and a TRIGA Pulse, A marriage Made in Heaven," Trans. Am, Nucl. Soc. 73, 153 (1995).

Papers:

1. B.W. Wehring and K. Ünlü, "The University of Texas Cold Neutron Source,"International Seminar on Advanced Pulsed Neutron Sources: Physics of/at Advanced Pulsed Neutron

Sources, PANS II, Dubna, Russia, June 14-16, 1994, 285 (1995).

2. K. Ünlü, C. Rios-Martinez, and B.W. Wehring, "Prompt Gamma Activation Analysis with the Texas Cold Neutron Source," J. Radioanal. Chem. 193, 145 (1995).

3. F. Y. Iskander, "Multielement determination in honey." J. Radioanal. Nucl. Chem. Letters 201:401 (1995).

4. F. Y. Iskander, Elemental content in baseflow water samples as indicator for surface contamination with toxic and other elements. J. Sci Total Environ 172:127 (1995).

5. H. R. Vega-Carrillo, F. Y. Iskander, "Trace and minor elements in Mexican cigarette tobacco." J. Radioanal. Nucl. Chem. Letters 200:137 (1995).

6. K. Ünlü, "Turks take steps to revive their Nuclear Programme," Nuclear Engineering International, 40, No: 486, 16, January (1995)

7. C. Rios-Martinez, K. Ünlü, T L. Bauer, and B. W. Wehring, " Operational Features of the Cold-Neutron Prompt Gamma Activation Analysis Facility at The University of Texas at Austin," Sociedad Nuclear Mexicana, VI. Congreso Anual Memorias, Vol I, 333 (1995)

8. H.R. Vega-Carrillo, A.J. Teachout, and T.L. Bauer, "Water-extended Polyester Based Neutron Shielding Calculation," Sociedad Nuclear Mexicana, VI Congreso Internacional Anual, September 17-20, 1995.

9. H.R. Vega-Carrillo, B.W. Wehring, and A.J. Teachout, "New Neutron Sources for Calibration Purposes," Sociedad Nuclear Mexicana, VI Congreso Internacional Anual, September 17-20, 1995.

Presentations (speaker underlined)

1. B.W. Wehring, "Cold Neutron and Ultra Cold Neutron Facilities at the University of Texas." 1995 meeting og the National Organization of Test, Research and Training Reactors (TRTR), with NRC Non-power Reactor Seminar, Albuquerque, NM, November 6-9, 1995.

2. B.W. Wehring, "A Plan for Federal Funding of Nuclear Reactor Operations," 1995 meeting og the National Organization of Test, Research and Training Reactors (TRTR), with NRC Non-power Reactor Seminar, Albuquerque, NM, November 6-9, 1995.

3. K. Ünlü, B. W. Wehring, "Neutron Depth Profiling Applications at The University of Texas Research Reactor," presented at the 9th Int. Conf. Modern Trends in Activation Analysis, Seoul, Korea, 24-30 September 1995 and to be published in the J. of Radioanal. Nucl. Chem.

4. K. Ünlü, "Neutron Depth Profiling Applications at The University of Texas Research Reactor," Department of Mechanical Engineering, Nuclear Engineering Seminar, April 27, 1995 Austin, Texas.

5. K. Ünlü, "Neutron Beam Research," Istanbul Technical University, Nuclear Energy Institute, (invted talk), July 5, 1995, Istanbul, Turkey. (Sponsored by United Nations International Short-Term Advisory Resources (UNISTAR), Transfer of Knowledge Through Expatriate Nationals (TOKTEN), and The Scientific And Resear.ch Council Of Turkey (TUBITAK), Project (TUR/99/007/A/01/99).

6. K. Ünlü, "Neutron Capture Therapy," Istanbul Technical University, Nuclear Energy Institute, (invited talk), July 7, 1995, Istanbul, Turkey. (Sponsored by United Nations International Short-Term Advisory Resources (UNISTAR), Transfer of Knowledge Through Expatriate Nationals (TOKTEN), and The Scientific And Research Council Of Turkey (TUBITAK), Project (TUR/99/007/A/01/99).

7. K. Ünlü, "Recent Developments and the Future of Boron/Gadolinium Neutron Capture Therapy," Hacettepe University, Institute of Oncology, (invited talk), July 20, 1995, Ankara, Turkey. (Sponsored by United Nations International Short-Term Advisory Resources (UNISTAR), Transfer of Knowledge Through Expatriate Nationals (TOKTEN), and The Scientific And Research Council Of Turkey (TUBITAK), Project (TUR/99/007/A/01/99).

8. K. Ünlü, "Materials Research Using Neutron Beams," Bilkent University, Department of Physics, (invited talk), July 26, 1995, Ankara, Turkey. (Sponsored by United Nations International Short-Term Advisory Resources (UNISTAR), Transfer of Knowledge Through Expatriate Nationals (TOKTEN), and The Scientific And Research Council Of Turkey (TUBITAK), Project (TUR/99/007/A/01/99).

9. K. Ünlü, "Neutron Beam Research at the University of Texas Reactor," University of Illinois, Department of Nuclear Engineering, Seminar, November 14, 1995, Urbana-Champaign, IL.

3.0 FACILITY OPERATING SUMMARIES

3.1 **Operating Experience**

The UT-TRIGA reactor at the J.J. Pickle Research Campus became operational during 1992. Operating times remain about the same for each of the first four years of operation. Total energy production continues to increase by approximatley the same amount each year. The total burnup after four years of operation is 9.2 MW-days. A total of 51.9 MW-hours were generated in the fourth year of operation. The reactor was critical for approximately 126 hours. A summary of the burnup history is shown in Figure 3-1.

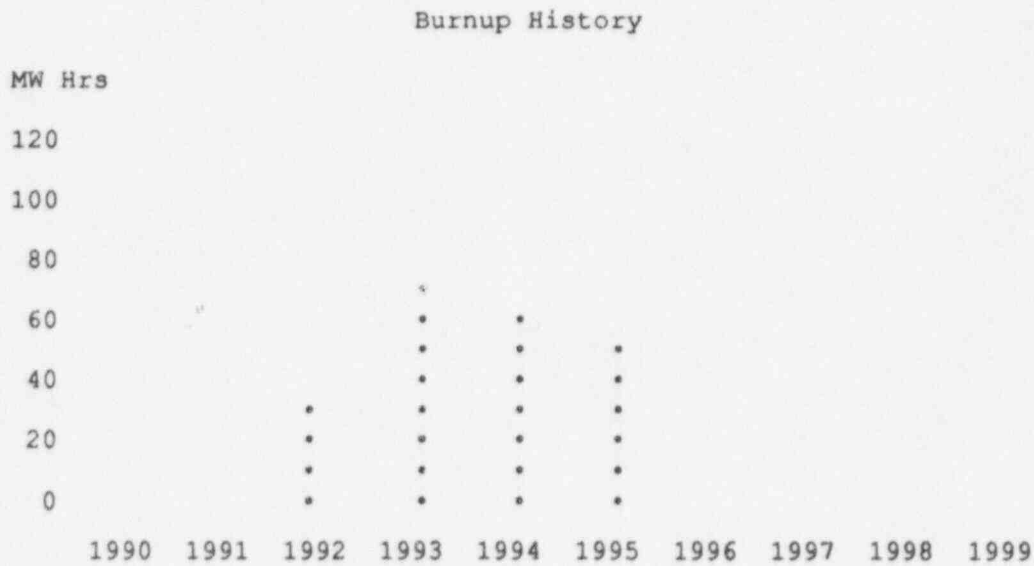

Figure 3-1 Operating History

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 which provide protection for experiment systems are system operable conditions.

The total number of safety system protective actions during 1995 was three. Of the three total protective action shutdowns two were actions of a safety system setting, and one was action of a system operable condition (see Table 3-3).

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

Technical Specification Requirement	Yes	No
SCRAM Type		
Safety System Setpoint (LSSS)	2	0
System Operable Condition (LCO)		
Analog detection (hardware)	1	0
Digital detection (software)	0	0
Manual Switch		
Protective action	0	0
Intentional operation (2)	-	-
Total Safety System Events	3	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
Safety System Setpoint	2
System Operable Condition	1
Total	3

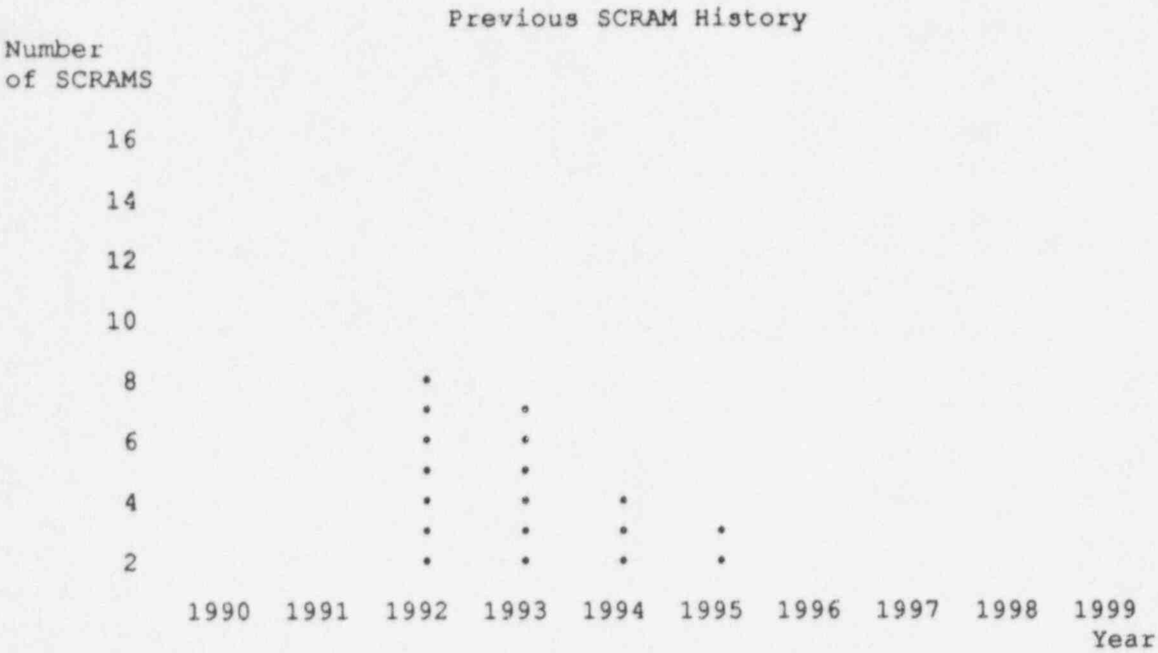

Figure 3-2 Summary of All SCRAM Events

3.3 **Utilization**

Primary utilization of the reactor during the year was by NETL staff. Neutron activation analysis represents roughly half the utilization of reactor time and MW-hours with beam port projects representing the other half of reactor use. Development testing of the Texas Cold Neutron Source (TCNS) continued throughout the year. The basic testing phase of the TCNS was complete in 1994. Work continued in 1995 to improve full power performance, analyze system performance and develop the beam guides.

A summary of the reactor utilization for 1995 is presented in Table 3-4 with the monthly distribution shown in Figure 3-3. Table 3-5 summarizes the sample irradiations and experiments. Figure 3-4 records the historical trend of sample irradiations.

Table 3-4
Summary of 1995
UT-TRIGA Operation

	Q1	Q2	Q3	Q4	Total
# of "Key On" Hours					
Operator #1	8.6	1.2	3.4	0.0	13.2
Operator #2	33.0	24.7	21.4	6.0	85.1
testing/maintenance	4.0	20.8	2.6	5.0	32.4
Total hours	45.6	46.7	27.5	11.0	130.7
MW-Hours Energy					
Operator #1	6.3	0.5	2.7	0.0	9.5
Operator #2	13.3	7.8	15.7	4.2	41.0
testing/maintenance	<0.1	<0.1	0.6	0.8	1.4
Total	19.6	8.3	19.0	5.0	51.9

Figure 3-3 Operating Data 1994

Table 3-5
Summary of Utilization 1995
UT-TRIGA Experiments

	Q1	Q2	Q3	Q4	Total
<u>No. of Samples</u>					
In-core	166	231	342	0	739
Ex-core	3	5	18	25	51
<u>No. of Experiments</u>					
Type A	9	11	5	3	28
Type B	3	4	4	0	11
Other	0	1	2	1	4
Total	12	16	11	4	43

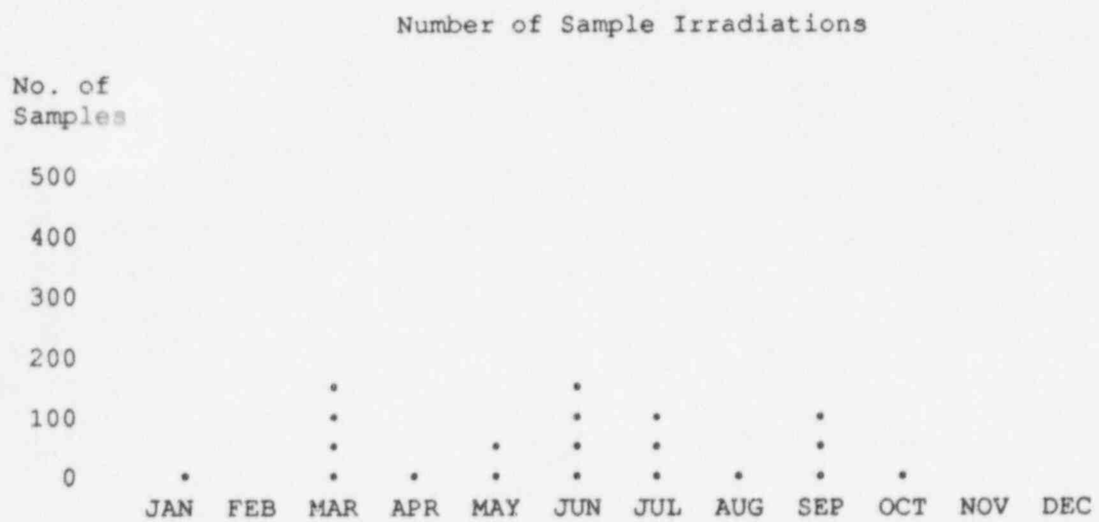

Figure 3-4 Operating Data 1995

3.4 Maintenance

Maintenance in 1995 was routine. Replacements were made to several digital components of the reactor control system. All changes were made to meet or exceed original manufacturer's specifications. No significant safety considerations were detected during the maintenance activities.

A design flaw in the argon-41 monitoring system was found in 1994. The manufacturer of the argon counting system provided a replacement circuit. A test of the replacement circuit was unsuccessful and the circuit was rejected. Final resolution is awaiting response of the manufacturer. An interim replacement counting system continues to provide argon-41 count data until a permanent design for the defect part is available.

One instrument element failed during the year. Replacement of the fuel element was necessary since the failure was the third of three thermocouple sensors, two of which had already failed. A spare instrument element was available to replace the failed element. One of three thermocouples in the replacement element was also found as bad. Serial numbers of the failed element and replacement element differ by one. A request has been made to obtain two new instrument elements.

3.5 Facility Changes

One significant experiment authorization begun during 1993 is continuing in the test phase. The experiment authorization was for the installation, test and operation of the Texas Cold Neutron Source (TCNS). No unreviewed safety question was found during review of the Safety Analysis Report for the Texas Cold Neutron Source. Several tests of the system were done during 1994 to determine heat removal capabilities of the system.

Tests during 1994 and 1995 determined the effect of nuclear heating on the TCNS heat removal capability. Changes have been made to improve the system. Work, including installation and tests, on the neutron-wave guide system have been in progress throughout 1994 and 1995. Completion of the test program should occur in 1996.

The main components of the TCNS are a cold source cryostat system and a neutron guide tube system. Components of the cold source cryostat system are a vacuum system, neon gas handling system, and mesitylene moderator. The TCNS was designed to shift the energy of thermal neutrons available at the reactor to subthermal neutrons at an experiment. The process is done by moderating the neutrons at low temperature and transporting the cold neutrons to the experiment. Mesitylene, a room temperature liquid, is frozen to solid form in a chamber to act as the cooling moderator. A neon liquid-gas heat pipe provides cooling of the mesitylene moderator. Both moderator chamber and neon heat pipe are contained in a vacuum system with insulation from thermal heat sources.

The safety problems associated with commonly used moderators such as hydrogen, deuterium or methane are eliminated by using mesitylene, 1,3,5-trimethylbenzene, as a moderator. The H2, D2, and methane are gaseous at room temperature, and possible sudden temperature changes may lead to a dangerous pressure buildup in the moderator chamber. Mesitylene is a liquid at room temperature, and is not explosive. It is a hydrogenous material and its nuclear properties are comparable with hydrogen. The radiolysis of mesitylene and stored energy in the moderator chamber and mesitylene have been evaluated. Possible ozone generation in vacuum chamber, radioactivity of components, and consequences of various system failures have been examined in detail. Also, the operation and the TCNS system's response to safety problems have been considered. Examples of operating failures are mesitylene transfer system failure, neon handling system failure, loss of refrigeration and loss of vacuum. It was concluded that even with worst-case scenarios, failures will not create a safety issue related to damage to the reactor components or reactor core. Analysis demonstrated no credible accident involving the Texas Cold Neutron Source could cause damage to the reactor beam tube or to the reactor core or cause releases of radioactivity in excess of the limits in 10 CFR 20.

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

Radiation Safety Committee	
Spring Term	April 19, 1995
Fall Term	November 16, 1995
Nuclear Reactor Committee	
First Quarter	January 1, 1995
Second Quarter	April 6, 1995
Third Quarter	July 21, 1995
Fourth Quarter	October 12, 1995

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	March 28-31, 1995 December 4-5, 1995(1)
SNM-180	None
L00485(48)	None

(1) Site visit by the Office for Evaluation and Analysis of Performance Data.

NRC made two visits to the facility during the year. The latter visit was not a site inspection. The former visit was a routine inspection with a notice of violation.

A visit was made by the USNRC Office of Evaluation and Analysis of Performance Data. This site visit was for the purpose of supplementing the findings made at other sites regarding the general state of operation of research reactors. Results from these visits are expected to be published as a report in 1996.

One violation for non compliance with license audit requirements was found. A failure to provide proper records for three audit functions was noted.

One case was a failure to perform annual audits of actions to correct reactor facility deficiencies. Facility deficiencies are reported to the reactor committee as part of the routine items of business at each committee meeting. Actions taken and followup, if any, are recorded as part of reactor committee minutes. An explicit audit of the committee minutes or other records that might indicate deficiencies was not being done since it was felt that the minutes were a record of the actions on deficiencies.

A review of the reactor committee minutes by the facility director was done for the period of 1/92 to 4/95. A list of deficiencies was made for the period of 1/92 to 4/95. The list was presented for discussion at the next reactor committee meeting. Nine items were noted as deficiencies. Four items occurring in 1992-93 included timely resolution. Of the five remaining items in 1994-95 only two are outstanding. Actions on both these deficiencies were in progress.

A second case was failure to perform biennial audits of the retraining and requalification program for reactor operators. Information regarding elements of the program such as exams, operating hours, and training status are routine business items of the reactor committee meetings. An explicit audit of the complete written records by the committee was not done, to

review other details of the requalification records regarding reactor operator training.

The training records have been reviewed by the facility director and were found to be in order. A report of the review was made at the next reactor committee meeting.

A third case was failure to provide a report of a completed audit to the Director and Nuclear Reactor Committee within 3 months of the completion of the audit. An audit program including schedule was developed during 1993. Implementation of this schedule began in 1994. Experience with the audit process and persons performing the audit did not meet the original schedule. Although portions of the audit were done within the time frame, the complete audit, including report was not done.

The audit item was complete at the time of the inspection, and the report was being prepared. The report was made to the reactor committee. The period of time to initiate, complete and report this particular audit activity exceeded the license requirements.

Other corrective steps were taken as follows. Reactor committee meeting agenda was arranged to explicitly address one or more audit areas at each meeting. The original audit schedule was revised to reflect the lessons learned from previous audit cycles most of which were being done for the first time. Audit instructions (drafts) have been written as guidance for the two audit areas, equipment deficiencies and reactor operator requalification. A written report will be made at each reactor committee meeting, instead of annotations in the committee minutes.

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 3-5 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

	Personnel	Students	Visitors(5)
Average Annual Dose(1)			
Whole Body, DDE(2)	M	2	<1
Extremities, SDE(3)	63	2	N/A
Lens of eye, LDE(4)	M	2	N/A
Greatest Individual Dose			
Whole Body, DDE	M	10	4
Extremities, SDE	90	10	N/A
Lens of eye, LDE	M	10	N/A
Total Person-mrem for Group			
Whole Body, DDE	M	10	4
Extremities, SDE	190	10	N/A
Lens of eye, LDE	M	10	N/A

Notes to Table 3-9

(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, 20 mrem for fast neutrons. "N/A" indicates that there was no extremity monitoring conducted or required for the group.

(2) DDE applies to external whole-body exposure and is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2).

(3) SDE applies to skin or extremity external exposure, and is the dose equivalent at a tissue depth of 0.007 cm (7 mg/cm^2) averaged over an area of 1 cm^2.

(4) 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/cm^2).

(5) Pocket ionization chambers (PICs) are issued to persons who enter radioactive materials/restricted areas for periods of short duration, i.e., a few hours or days annually. One card listed a dose received (4 millirem), out of a total of 159 cards.

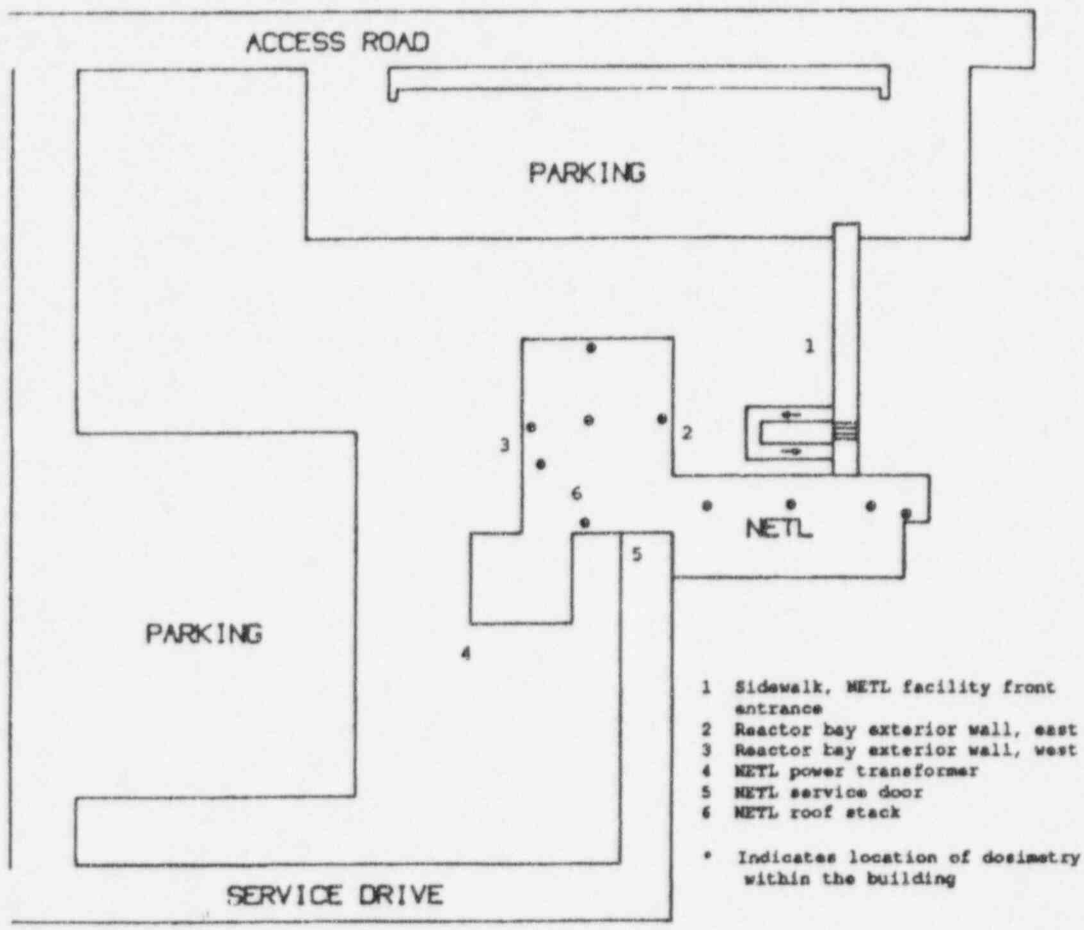

Figure 3-5 Environmental TLD Locations

Table 3-9
Total Dose Equivalent Recorded on
Area Dosimeters Located Within the
NETL Reactor Facility

Location in Reactor Facility	Monitor ID	Total Dose[1] β,γ,X	n
Reactor Bay, North Wall	00167	M	M
Reactor Bay, East Wall	00168	M	M
Reactor Bay, West Wall	00169	590	M
Water Treatment Room	00170	1170	M
Reactor Pool Area, Roof	00171	M	M
Shield Area, Room 1.102	00172	20	160
Sample Processing, Room 3.102	00173	M	N/A
Gamma Spectroscopy Lab, 3.112	00174	M	N/A
Radiation Experiment Lab, 3.106	00175	M	N/A
Reception Area, 2.102	00176	M	N/A

(1) The total recorded dose equivalent values reported in mrem do no 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 measurable 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.

Table 3-10
Total Dose Equivalent Recorded on
TLD Environmental Monitors
Around the NETL Reactor Facility

Location in Reactor Facility	Monitor ID	Total Dose(1)
Sidewalk, NETL front entrance	00156	M
NETL power transformer	00157	M
NETL Roof stack	00158	M
Reactor bay exterior wall, east	00159	M
Reactor bay exterior wall, west	00160	M
NETL service door	00161	M

(1) The total recorded dose equivalent values do not include natural background contribution and reflect the summation of the results of four quarterly TLD dosimeters for each locations. A total dose equivalent of "M" indicates that each of the dosimeters during the period was below the vendor's minimum measurable quantity of 10 mrem for x- and gamma rays, 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 survey of exterior walls and roof. Neutron survey of exterior walls and roof. Swipe survey of 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 survey of all non restricted areas. Swipe survey of all non restricted areas. Swipe survey of building exterior areas. Calibrate personnel pocket dosimeters. 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. 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 Levels and Contamination Levels Within the Reactor Area and NETL Facility

Accessible Location	Whole Body Radiation Levels (mrem/hr)(1)		Contamination Levels (dpm/100cm^2)	
	Average	Maximum	Average	Maximum
TRIGA Reactor Facility				
Reactor Bay North	0.49	10	52.8	1605(3)
Reactor Bay South	0.012	15	MDA(2)	MDA(2)
Reactor Bay East	0.015	0.05	MDA(2)	MDA(2)
Reactor Bay West	0.03	4	MDA(2)	MDA(2)
Reactor Pool Deck (third floor)	0.012	1.5	8.4	261.9(3)
NETL Facility				
NAA Sample Processing (Rm 3.102	0.025	0.5	3.7	42.7
NAA Sample Counting (Rm 3.112)	0.025	0.95	2.6	3.4
Health Physics Laboratory	0.01	0.022	MDA(2)	MDA(2)
Neutron Generator (Rm 1.102)	0.13	6	4.3	21.9
Waste Storage (Rm 1.108)				

(1) Measurements made with a Bicron Microrem portable survey meter in areas readily accessible to personnel.

(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 result, the average contamination level at this location during the reporting period was, for all practical purposes, <500 dpm per 100 cm^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.

Table 3-13
Monthly Summary of Argon-41 Effluent Releases(1)

Date of Discharge (Month, 1994)	Total Quantity of Argon-41 Release (microCuries)	Average Concentration at Point of Release (microCurie/cm^3)	Fraction of Technical Specifications(2) (%)
January	61300	6.09E-09	0.30
February	187	1.86E-11	0.001
March	322000	3.19E-08	1.59
April	10600	1.06E-09	0.053
May	49600	4.92E-09	0.25
June	54800	5.44E-09	0.27
July	104000	1.03E-08	0.52
August	102000	1.02E-08	0.51
September	83200	8.25E-09	0.41
October	54300	5.39E-09	0.27
November	0	0	0.00
December	0	0	0.00
ANNUAL VALUE	842000	6.84E-09	0.34

(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 microCurie/cm^3.

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

Date of Discharge (Month, 1995)	Release Volume (m^3)	Total Quantity of Radioactivity (Curies)
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 from previous experiment programs. The total activity sent to disposal was 3.531 millicuries. Radioactive materials were Pb-210 and Co-60 in liquid form. Most of this radioactive material was ordered some years ago (>10) by a researcher, and was never utilized after receipt. 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

Date of Discharge (Month, 1995)	Release Volume (m^3)	Total Quantity of Radioactivity (Curies)
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	1.50E-04	3.531E-03
December		No Releases