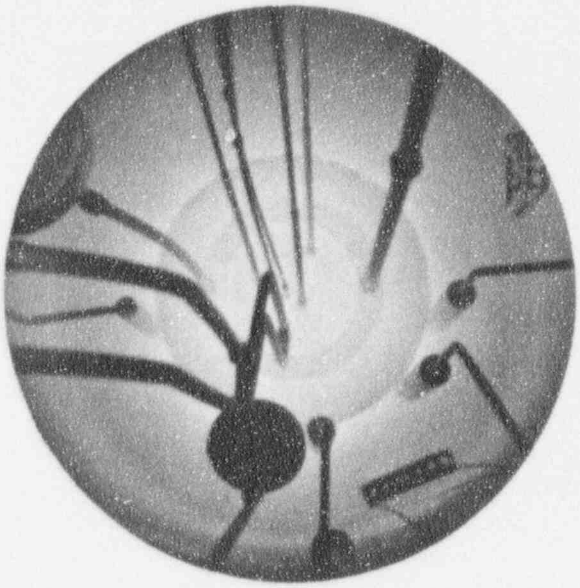

NUCLEAR REACTOR LABORATORY

TECHNICAL REPORT

THE UNIVERSITY OF TEXAS

COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Annual Report

1993

Nuclear Engineering Teaching Laboratory

Balcones Research Center

The University of Texas at Austin

List of Figures

Figure

List of Tables

EXECUTIVE SUMMARY

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

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,
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 18 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.

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 facility. A TRIGA nuclear reactor is the primary piece of equipment at the facility. The reactor operates at power levels up to 1100 kilowatts or with pulse reactivity insertions up to 2.2% $\Delta k/k$.

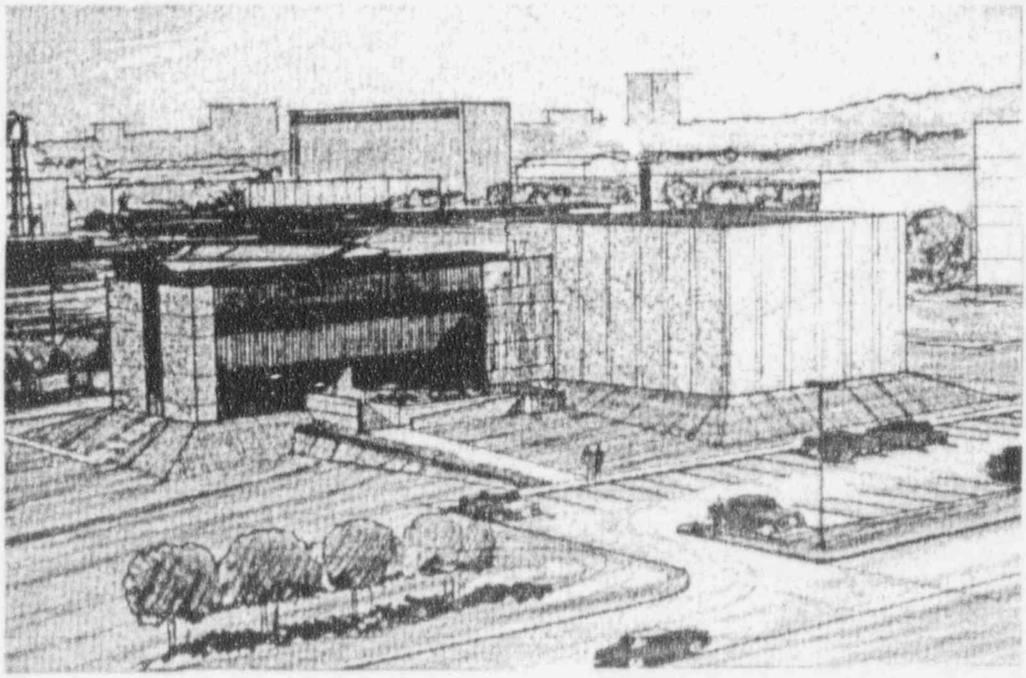

Figure 1-1 NETL - Nuclear Engineering Teaching Laboratory

The report also satisfies 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 report covers the period from January 1, 1993 to December 31, 1993.

Availability of the Facility

The NETL facility serves a multipurpose role beyond the research of facility faculty, staff and students. Use of NETL by faculty, staff and students in the College of Engineering is the facility's primary function. However, a supplemental goal of the facility is the development and application of nuclear methods to assist the research of university, industry, government and other researchers.

NETL provides services to industry, government and other laboratories for the testing and evaluation of materials. Public education through tours and demonstrations are 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 Safety Office.

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. The program installed, operated and dismantled a TRIGA nuclear reactor at a site on the main campus in the engineering building, Taylor Hall. Operating requirements were intermittent from 1963 to 1988, accumulating a total burnup of 26.1 megawatt-days. 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). 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 was completed in December 1992.

Planning for a new facility, which led to the shutdown of the campus facility, began in October 1983, with construction taking from December 1986 to May 1989. The final licensing was issued January 1992 with initial criticality occurring March 1992. The new facility, including support laboratories, administrative offices and the reactor is the central location for all NETL activities. The reactor as the primary piece of equipment operates at power levels up to 1100 kilowatts and pulses to reactivity insertions of 2.2% $\Delta k/k$.

1.2 NETL Building

Balcones Research Center

The Balcones Research Center (BRC) is a multi discipline research center on 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 center. 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 at the center. A Commons Building provides cafeteria service, recreation areas, meeting rooms and conference facilities. Access to the NETL site is shown in Figure 1-2.

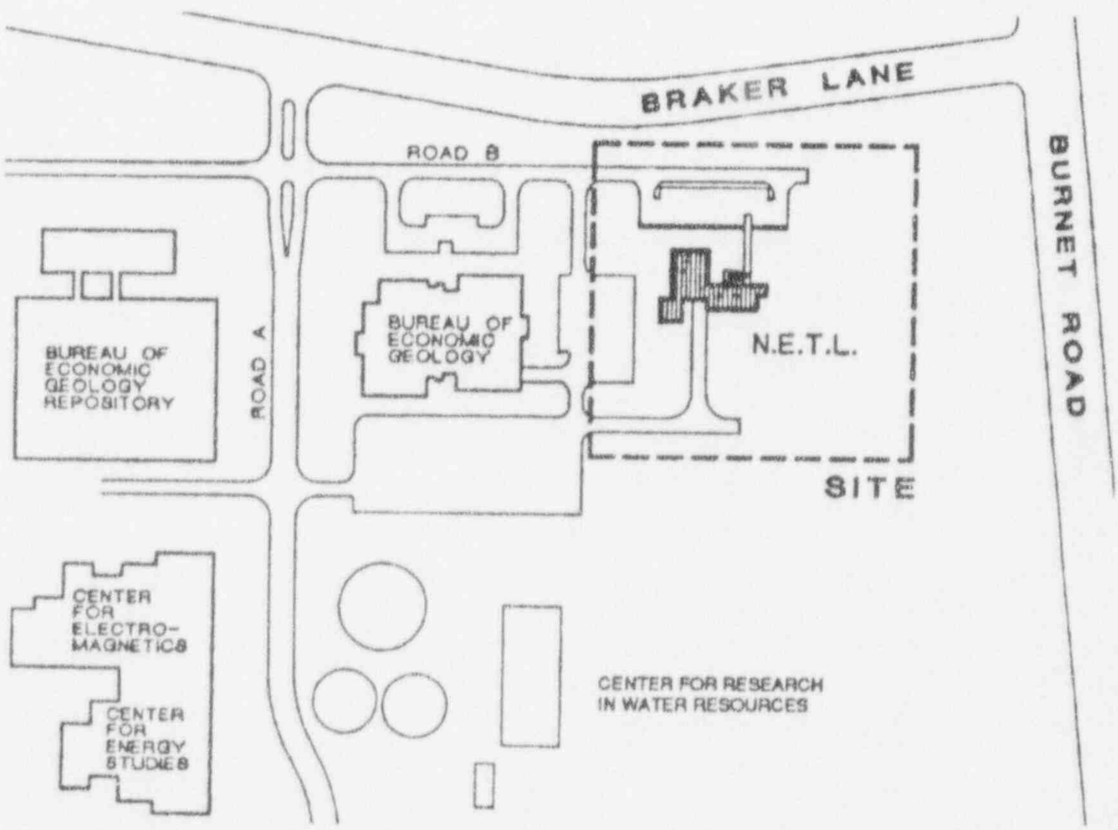

Figure 1-2 NETL Site - Balcones Research Center

NETL Building Description

The NETL building is a 1950 sq. meter (21,000 sq. ft), facility with laboratory and office areas. Building areas consist of two primary laboratories of 330 sq. m (3600 sq. ft) and 80 sq. m (900 sq. ft), 8 support laboratories (217 sq. m, 2340 sq. ft), and 6 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 and shield structure including 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.

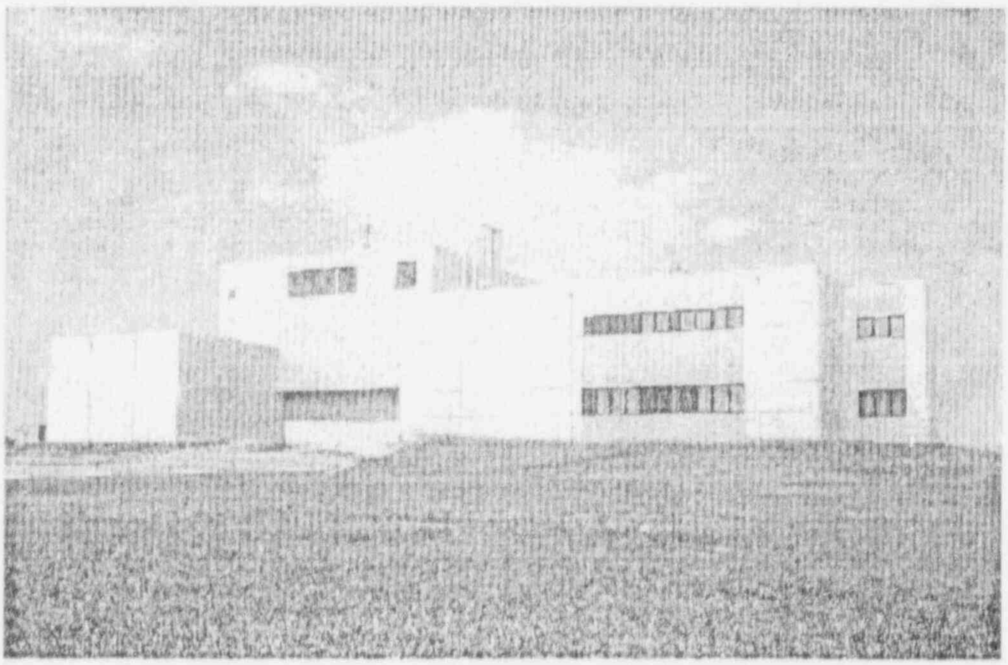

Figure 1-3 NETL Building Profile

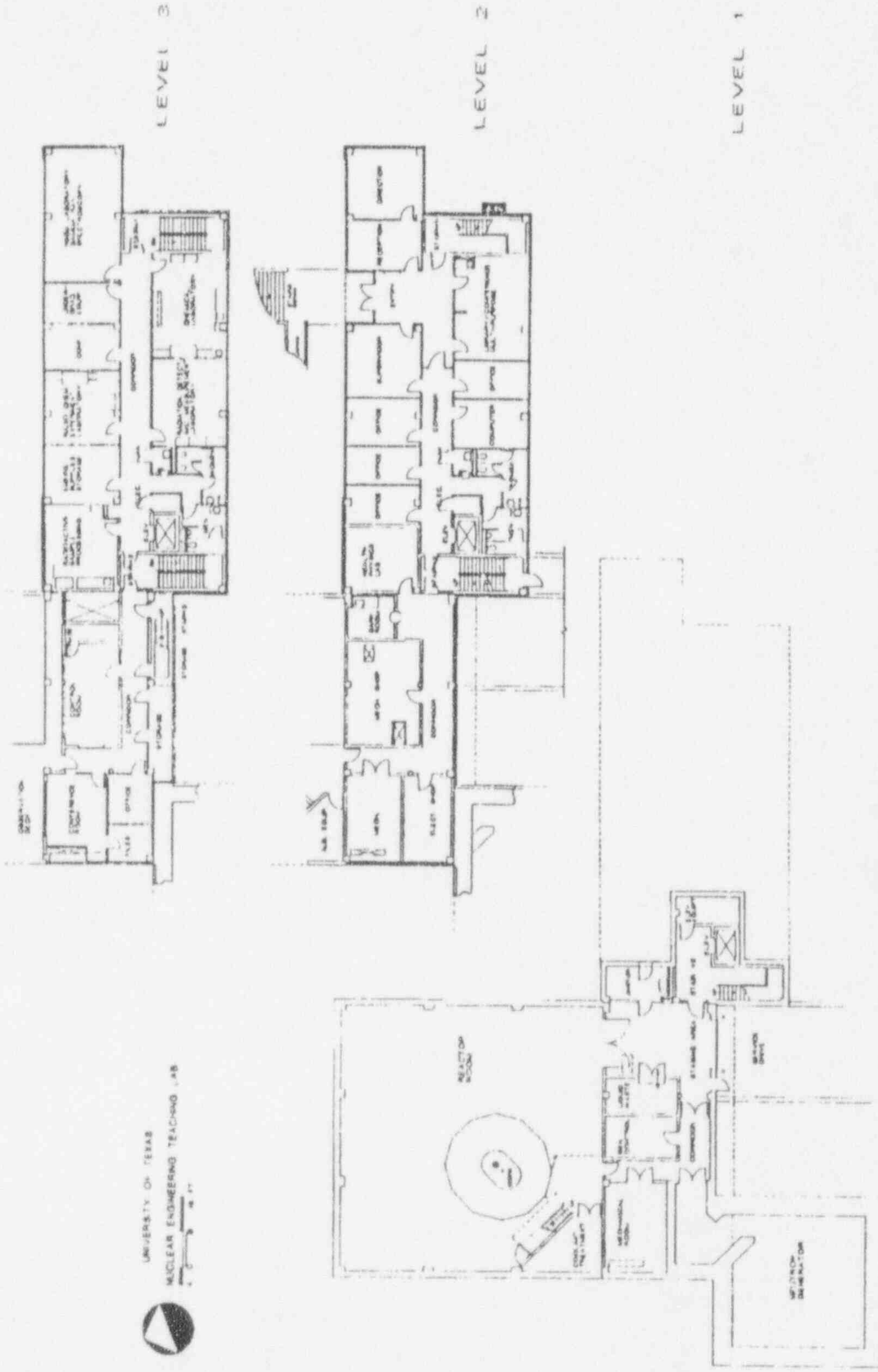

Figure 1-4 NETL Building - Layout

Laboratories, Equipment

The NETL facility makes available several types of radiation facilities and an array of radiation detection equipment. Besides the reactor, facilities include a subcritical assembly, a gamma irradiator, miscellaneous radioisotope sources and one or more radiation producing machines.

The gamma irradiator is a multi curie 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 experiment 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 a 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 requirements for 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, and General Atomics. Figure 1-5 is a picture of the reactor core structure.

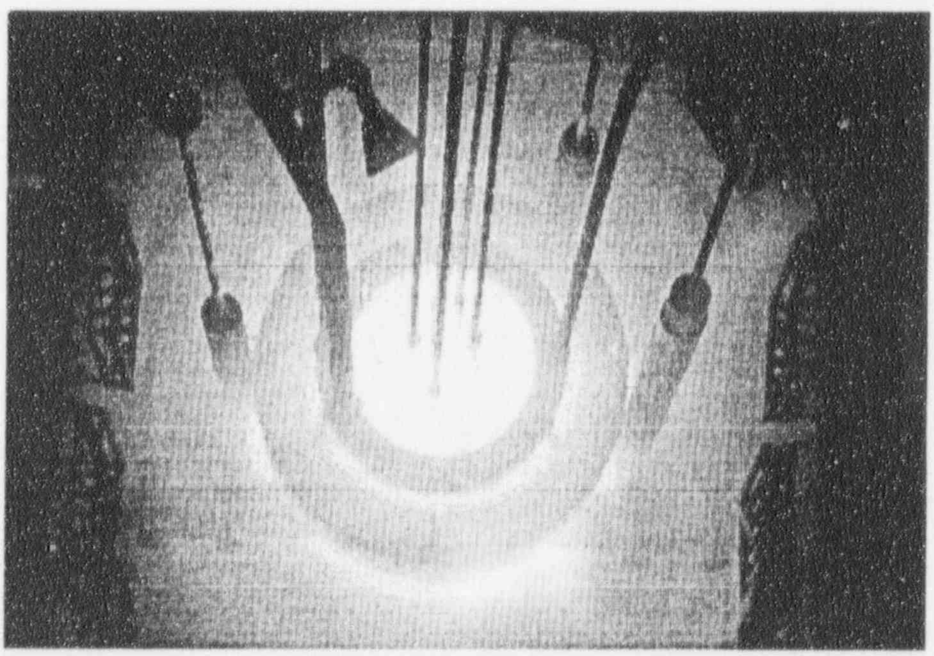

Figure 1-5 TRIGA Reactor Core

Reactor Description

Reactor Operation. The UT-TRIGA research reactor can operate continuously at nominal powers of up to 1 MW or in the pulsing mode where typical peak powers of 1500 MW can be achieved for short times of about 10 msec. The UT-TRIGA with its new digital control system provides a unique facility for performing reactor physics experiments and 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 can 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 rises 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 continual 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 (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.

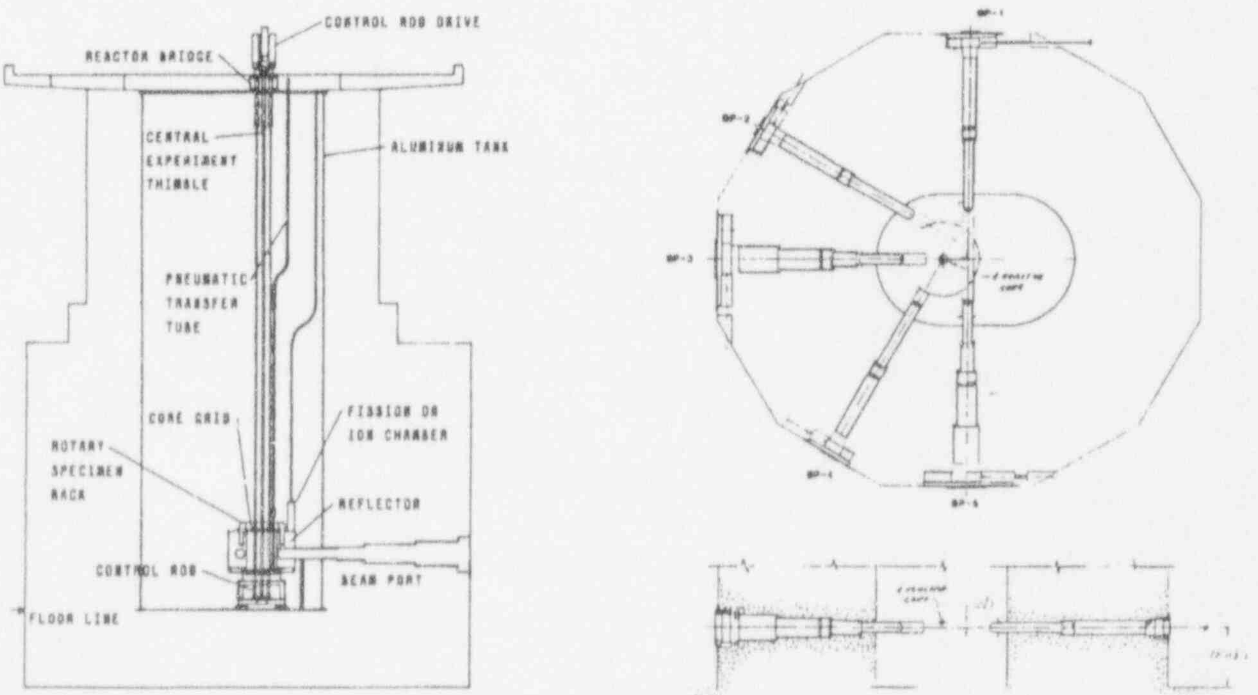

Figure 1-6 Reactor Pool and Beam Ports

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 the batch production of radioisotopes and for the activation and irradiation of multiple samples. All forty positions in the rack are exposed to neutron fluxes of comparable 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

The beam ports penetrate through the concrete shield and the reactor tank water, making beams of neutrons available for a variety of experiments. Five tubular beam ports provide access to the reactor core neutrons. Two beam port categories are defined by the reactor reflector interface.

Penetrating beam ports are the thru port beam ports #1 and #5 and the radial beam port #3. Thru beam ports, beam port BP#1 and BP#5, are connected together to result in one thru tube beam port. These tubes penetrate the concrete shield and are each coupled to opposite ends of a tube extending from the reflector with a flexible bellows. Penetrating Beam Port, BP#3 pierces the graphite reflector and terminates at the inner edge of the reflector. This beam port permits access to a position adjacent to the core.

Two beam ports, non penetrating beam ports #2 and #4, do not provide physical access beyond the reactor reflector interface. BP#2 is oriented tangentially to the outer edge of the core terminating at the outer edge of the reflector. A hole is drilled in the graphite tangential to the outer edge of the core. BP#4 is a radial beam port that terminates at the outer edge of the reflector. A hole is drilled in the graphite radially to the outer edge of the core. Both BP#2 and BP#4 penetrate the concrete shield structure and the reactor water.

The inner section of each beam tube is an aluminum pipe that penetrates the pool wall to the reactor reflector. The outer sections of beam ports BP#1, BP#2 and BP#4 are formed of a stainless steel pipe. Outer sections of the beam ports BP#3 and BP#5 are composed of three sections joined to form a diverging cavity. Neutrons passing through the beam tubes can be defined by using filters, collimators and moderators. Table 1-2 lists the size of each beam port access to the reactor.

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 is under the Department of Mechanical Engineering at The University of Texas. The attached figure 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, called the administration, supports the three divisions. Health physics is a support group for all 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.

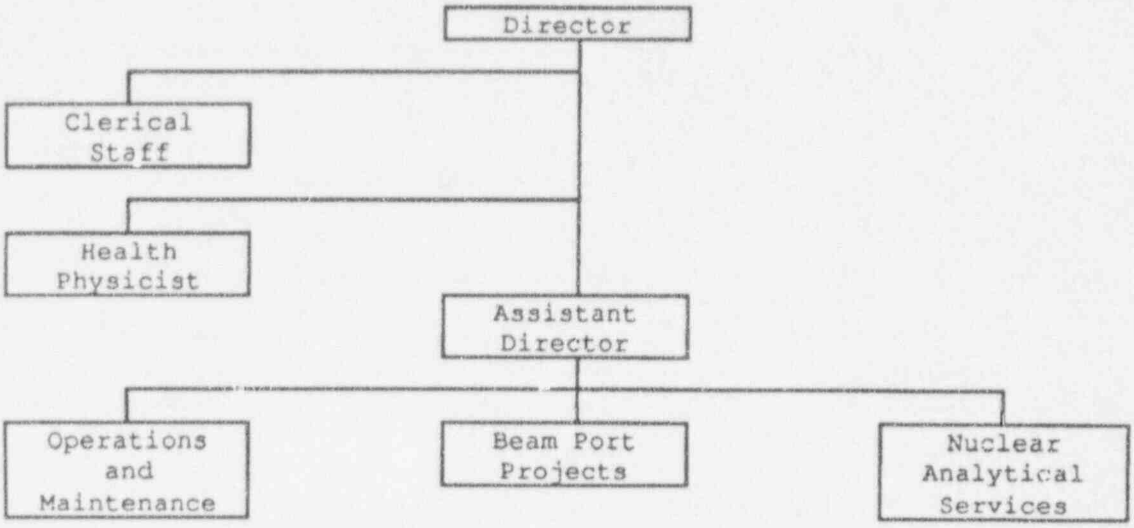

Figure 1-8 NETL Staff Organization

The Nuclear Analytical Services Division (NAS) is responsible for providing, in a safe and effective manner, analytical services such as Neutron Activation Analysis, 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 is the routine maintenance and safe operation of the TRIGA Mark II Research Reactor. This division performs most of the work necessary to meet Technical Specifications of the reactor license. Work by the division implements modifications to reactor systems and furnishes 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 and repair support for computer, electronic, and mechanical equipment is provided. Coordination of building systems maintenance is also coordinated by the Operation and Maintenance Division.

Nuclear Analytical Service Division

The main objectives of the nuclear analytical services division include services and education. In the area of services, the division serves the university at large. Elemental measurements using instrumental neutron activation analysis to provide nuclear analytical support for individual projects range 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. Similar services have been made available to different state agencies in order to assist with quality control of sample measurements and evaluation of environmental effects of some toxic elements. In the area of education, the division, with available state-of-the-art equipment, helps stimulate the interest of students about 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.

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.

Beam Port Division

The Beam Port Division manages the use of the five beam ports. Experiments at the beam ports may be permanent systems that will function for periods in excess of 1 or 2 years or temporary systems. Temporary systems function once or for a few months, generally requiring removal and replacement as part of the setup and shutdown process. The reactor bay contains floor space for each of the beam ports with available beam paths ranging 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 the neutron beam tubes. 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 create new funded research programs promoting the capabilities of the neutron beam projects division to academic, government and industrial organizations and/or groups.

Beam port management assists with all phases of a projects, beginning with the proposal, design, proceeding to the fabrication, test, and concluding with the operation, evaluation and dismantlement. Projects to be available at NETL are both traditional, such as neutron radiography, and unique, as is the cold neutron source facility. Two nuclear diagnostic techniques, neutron depth profiling (NDP) and prompt gamma activation analysis (PGAA) are examples of neutron beam port experiment facilities.

Health Physics Group

The Health Physics group is responsible for radiation safety and protection of personnel at the NETL as well as protecting the general public. The laws set down by Federal and State government are maintained and enforced at the facility by various means. Health Physics procedures have been developed that are facility specific to ensure that operation complies with all facets of the regulations. Periodic monitoring for radiation and contamination ensures that the use of the reactor and radioactive nuclides is conducted safely with no hazard to personnel outside of the facility. Personnel exposures are at all times maintained ALARA ("as low as is reasonably achievable") consistent with the mission of the NETL. Collateral duties of the Health Physics group include 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 ensure 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 in use by the Health Physics group is presented in Table 1-4. Other health physics equipment and supplies such as plastic bags, rubber gloves, radiation control signs/ropes are kept available for immediate use.

Table 1-4
Health Physics Survey Equipment

Equipment	Radiation	##
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	1
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 exposures, and educational activities. Personnel who are issued permanent dosimeters are required to attend an eight hour course given by the Health Physicist. This course covers basic radiation principles and facility specific procedures and rules. Each trainee is given a guided tour of the facility to familiarize him with emergency equipment and procedures. The group supports University educational activities by assisting with student experiments and projects by demonstrating proper radiation work techniques and controls to the students. The Health Physics group participates in emergency planning between NETL and the City of Austin to provide basic response requirements and radiation training to emergency personnel such as Fire and EMS crews.

2.0 ANNUAL PROGRESS REPORT

2.1 Faculty, Staff and Students

Organization. The administrative structure of 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.

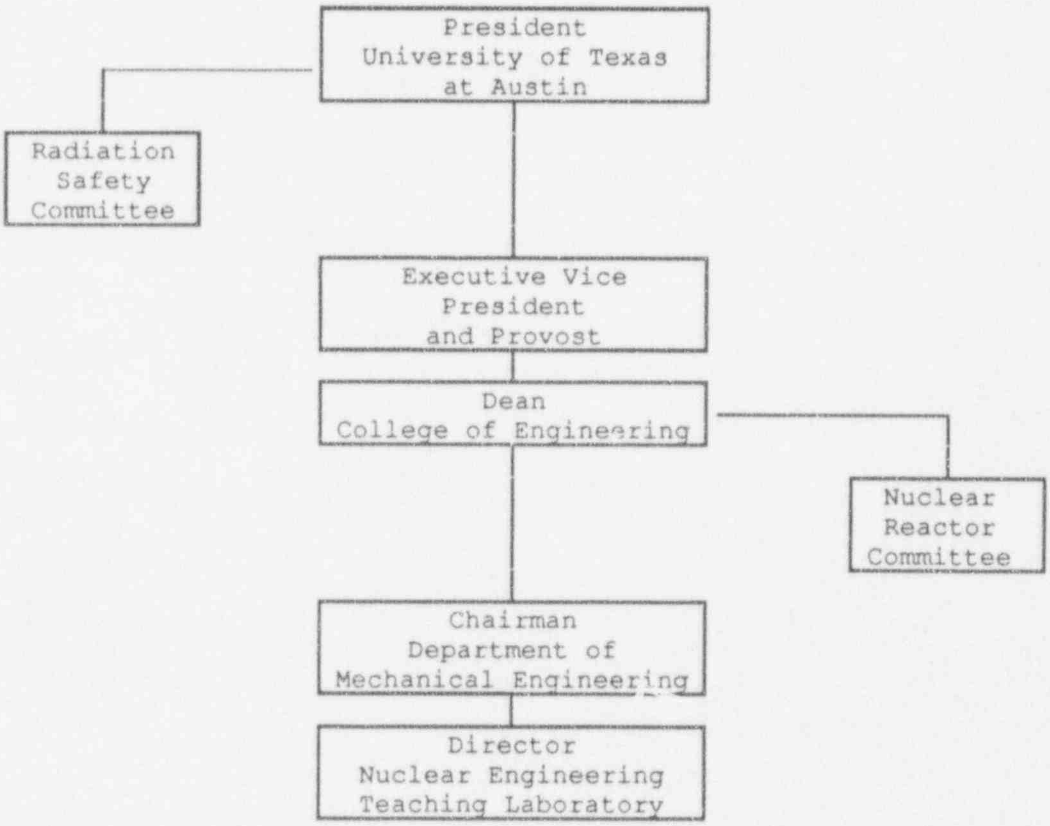

Figure 2-1 - NETL Administrative Structure

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 or 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	E.C. Temple
Vice Chairman	L.H. Lebermann, Jr.
Executive Secretary	A.H. Dilly
Chancellor	William Cunningham

Member 1993	Member 1995	Member 1997
S. Barshop	R.J. Cruikshank	Z.W. Homes, Jr.
L.A. Beecherl	T. Loeffler	B. Rapaport
W.A. Moncrief	M.E. Ramirez	E.C. Temple

Table 2-2
The University of Texas at Austin
Administration

President	Robert Berdahl
Executive Vice President and Provost	Gerhard Fonken
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	B.W. Wehring
Member	D.E. Klein
Member	B.G. Cook
Member	G. Hoffmann
Member	S.A. Monti
Member	L.O. Morgan
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	B.W. Wehring
Member	D.E. Klein
Member	J. Reis
Member	D. Blackstock
Student Member	R. Canaan
Ex officio member	T.L. Bauer
Ex officio member	J. White
Ex officio member	K. Diller

Personnel. Budgeting of NETL funding of the primary staff supports full time positions for a Supervisor/Assistant Director, health physicist, reactor operator and secretary. Other budget support includes funding for two research associates and a part time research assistant or office assistant. Positions for persons in this budget are Managers for the three divisions, Operation and Maintenance, Nuclear Analytical Services, Beam Port Projects and a Senior Administrative Associate.

Personnel associated with the laboratory consist of NETL staff, faculty, students, and certain other university personnel. 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
Assistant Director/Supervisor	T.L. Bauer
Research Scientist/NAA	F.Y. Iskander
Research Scientist/NBP	K. Unlu
Manager of Reactor Operations	M.G. Krause
Health Physicist	J.C. White
	A.J. Teachout
Sr. Administrative Associate	J.G. Rawlings
Sr. Office Assistant	M. McGee
Faculty	
N. Abdurrahman	B.V. Koen
D.E. Klein	B.W. Wehring
Student Assistants	
Graduate Level:	
Jong-Youl Kim	Desh Anand
Carlos Rios-Martinez	
Undergraduate Level:	
Ralph Graham	Michael Scott
Edmund Shum	Ingmar Sterzing

Funding. NETL funding is provided by state funds, research contracts and miscellaneous service work. A base budget for the staff, maintenance and operation, and teaching is provided by the state allocations. Research funding supplements the base funds and are provided 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
Reactor Sharing	9/30/92-9/29/94	DOE	$ 5,000
Instrumentation for the University of Texas Reactor	9/30/92-9/29/94	DOE	26,506
Study of Neutron Focusing at the Texas Cold Neutron Source	4/15/92-4/14/94	DOE	98,179
An Expert System to Enhance Software Reliability	9/30/91-12/30/94	NRC	99,998
Analysis for Selenium	3/6/92-8/31/93	TPW	10,143
		Total	235,826

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 a routine activity of NETL staff and students. A typical tour is general presentations 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 1238 visitors were given access to the facility during the reporting period. The total includes tour groups, official visitors, and facility maintenance personnel. Tours for 18 groups with an average 24 persons/group were taken through the facility during the reporting period.

Table 2-7
Public Access

Tour Groups	461
Individuals	300
Workers	477
Total	1238

Two special group projects by area students were done by arrangement with NETL staff. Another two persons conducted individual projects with NETL staff. 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 Uranium and Thorium in Water Residue

SPONSOR: Radian Corporation, Austin, Texas

The advantages of low detection limit and no sample processing were the important factor in selecting the concentration of uranium and thorium in over 80 samples.

PROJECT: The Effect of Copper Absorption on Metal Content in the Leaves of a Specific Plant Species (French Beans)

SPONSOR: LBJ Science Academy and NETL

The effect of copper uptake on the concentration of various elements in French Beans plant was carried out by allowing the plant to grow in controlled environment that contain varied concentration of copper. The plants then harvested and the concentration of copper and other nutrition and toxic elements were measured using instrumental neutron activation analysis.

PROJECT: Determination of Na in Biological Materials Using Instrumental Neutron Activation Analysis -

SPONSOR: Food and Drug Administration, DHHS

An interlaboratory study for the determination of sodium in foods and related materials by instrumental neutron activation analysis. Experience gained from the study is to be used to improve the method and to be submitted for endorsement to the ASTM Task Group E10.05.12, Task Group on Nuclear Methods of Chemical Analysis.

PROJECT: Using NAA to Measure Gold in Ore Samples
SPONSOR: Southwest Research Institute, San Antonio, Texas

The concentration of gold in ore samples and processed samples was measured by INNA to evaluation different procedure and calculate the percentage of gold extracted from the ore.

PROJECT: Determination of Selenium in Soil, Fish and Vegetation Samples Around a Coal-Fired Power plant.
SPONSOR: McNeil High School, Austin, Texas

Fish tissues (liver and muscle), soil, plants, coal and coal fly ash were collected from and around a coal-fire power plant as part of a science fair project. The concentration of selenium was determined using neutron activation analysis. The student won the "Best of the Fair" for the Austin Area high school science project, and was invited to participate in the International Science Fair held in Mississippi.

2.4 *Research and Development Projects*

PROJECT: Determination of 21 elements in meibomain gland secretions.

SPONSOR: Southwestern Medical Center at Dallas, University of Texas

NAA was performed on measure 21 elements in samples of meibomain gland secretion. The method was also applied to measure the same elements in tear samples .

PROJECT: Neutron Depth Profiling

SPONSOR: NETL

A neutron depth profiling (NDP) instrument has been designed, constructed and tested. The UT-NDP instrument utilizes thermal neutrons from the tangential beam port (BP#2) of the reactor. The NDP technique is not commonly 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 will be made 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 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 30.5 cm. A rotating fixture with up and down motion may be controlled from outside the chamber by using a mechanical feed through. 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.

The thermal neutron flux at the aperture of the beam port was measured to be 1.5×10^8 n/cm^2-sec. Depth profiles of various borophosphosilicate glass (BPSG) from Intel Corporation have been measured. Measurements were repeated at National Institute of Standards and Technology (NIST) NDP facility using the same samples. The results showed similar depth profiles for the samples.

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: Neutron Beam Filters for Gadolinium Capture Therapy Dosimetry Measurements

SPONSOR: NETL

A research program was initiated at the Nuclear Engineering Teaching Laboratory, The University of Texas at Austin, to measure the low-LET dose distribution in a head phantom with and without a Gd loaded tumor region. In order to enhance the epithermal flux, neutrons are provided for the study by a beam port which points directly at the reactor core of the 1-MW TRIGA research reactor. One problem of this type of beam port is a high background of core gamma rays which make it difficult to distinguish the dose delivered by the Gd gamma rays and electrons. This problem does not exist for the corresponding Boron Neutron Capture Therapy (BNCT) measurement.

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, 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.

Bonner sphere spectrometry measurements were made to determine the performance of the various neutron filters. Because the beam port has an exit diameter of 20 cm., the smaller of the polyethylene spheres were used, 5.0, 7.6, and 12.7 cm. diameter, along with the bare detector. The Bonner sphere spectrometer was located just outside of the neutron beam port, and the counting rates were unfolded with the BUNKI-UT code, a local PC version of the Naval Research Laboratory BUNKI code.

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) are placed in depressions on the surfaces of some of the disks. The phantom is placed inside the beam port exit, 250 cm away from the core.

The initial effort at measuring gadolinium dose rates was not successful because the background gamma dose rate was too high. Measurements and design calculations indicate that the lead used to attenuate the gamma dose also attenuates the keV neutrons with respect to MeV neutrons. The attenuation is an undesirable effect. An alternative plan is to not require the neutron beam to simulate a clinical beam. Accordingly, the head phantom measurements will be repeated using a neutron filter consisting of only lead, 20 cm. thick.

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 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 by neutron capture gamma rays.

Several methods for neutron focusing were examined to design a converging neutron guide 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. Since the construction cost is quite high, the choice of design may be based on a cost benefit argument.

A total of eight different converging guide systems were designed and analyzed using a 3-D Monte Carlo code. Four different geometries were considered. Two different neutron sources were used. A generic source was taken to be a uniform isotropic source of 4 Å neutrons located at the entrance of the curved guide. A specific source, "the TCNS source", was generated having the energy dependence calculated for neutrons leaving the moderator chamber in the general direction of the guide and biased by the angular and spatial distributions calculated for those neutrons. From the calculational results, a design will be selected to construct for use with the Texas Cold Neutron Source.

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 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: Texas Cold Neutron Source

SPONSOR: Advanced Technology Program, State of Texas

A cold neutron source has been designed, constructed, and tested by the Nuclear Engineering Teaching Laboratory (NETL). The Texas Cold Neutron Source (TCNS) is located in one of the radial beam ports of the NETL. This beam port pierces the graphite reflector forming a diverging cavity with a 6" diameter at the reflector and a 16" diameter at the outside of the biological shield.

The TCNS consists of a cold source system and a neutron guide system. The TCNS cold source system includes a cooled moderator, a heat pipe, a cryogenic refrigerator, a vacuum jacket, and connecting lines. The cold source system was designed to maintain 80 mL of mesitylene moderator at about 30 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 the cooling down of the moderator chamber. The heat pipe is filled with neon gas and is connected to a 6 liter reservoir. One end of the heat pipe is attached to the cold head of a cryorefrigerator and the other end is connected to the moderator chamber. The cold head end of the heat pipe acts as a neon condenser. The measured stable temperatures for the moderator chamber and the cold head without heating are 29 K and 26 K, respectively.

The thermal performance of the TCNS was measured by applying various heat loads to an electrical heater attached to the moderator chamber. Also, the nuclear heating in the TCNS system was measured under various reactor powers after the TCNS had been cooled down. It has been observed that 4 watts of nuclear heating can be tolerated during TCNS operation. We calculated and observed a value of ~2 watts of nuclear heating for the TCNS at full reactor power, prior to heating of the gamma ray shielding.

The cold neutrons obtained from the TCNS will be transported by a curved neutron guide. This 300 m. radius guide is 6 m. long with a 50 x 15 mm cross-section, Ni58 coated, and separated into 3 channels by two vertical mirrors of 1 mm. thickness. The TCNS system will provide a low background subthermal neutron beam for neutron reaction and scattering research. After the installation of the external curved neutron guide and completion of the shielding structure, neutron focusing and a Prompt Gamma Activation Analysis facility will be installed at the TCNS.

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 was in progress during the year to install and 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. One corrective action upgrading the control system software was made, however, to prevent an interlock violation of the reactor control system. An event at another facility with a similar control system found an unusual but possible condition in which one of the interlocks of the control system did not function correctly. The interlock, a function of the program software, was corrected.

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, including support equipment is not currently part of the installation. Installation of the pneumatic system was a low priority during this year, although planning for the installation was in progress.

Installation and testing of components of the neutron cold source was in progress including installation as a unit into the beam port. 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. An operating test of the cold source prior to installation into the beam port and test experiments done at 250

Kw and 500 Kw are complete. A review of the data is in progress. No unusual operating conditions that relate to safety of the experiment system were found.

2.6 *Publications, Reports and Papers*

Various publications, reports, papers and presentations are written or given each year by NETL personnel. The following list documents work efforts by faculty staff and students.

Publications:

Dissertations:

1. B.K. Nabelssi, "Calculations of Dose Equivalent Quantities for High-Energy Neutrons Using Homogeneous and Heterogeneous Phantoms", Dissertation, Univ. of Texas, May 1993.

2. J.Y. Kim, "Neutron Focusing System for Texas Cold Neutron Source", Dissertation Univ. of Texas August 1993.

Theses:

1. A.B. Preece, "Use of the GENII Computer Code in as Low Level Radioactive Waste Disposal Facility Performance Assessment Methodology", Thesis, Univ. of Texas, May 1993.

2. S.J. Manson, "A Homogeneous Equilibrium Model for Two-Phase Thermal Hydraulic Analysis of Spent Nuclear Fuel Shipping Containers", Thesis, Univ. of Texas, Dec 1993.

Periodicals:

1. Iskander, F. Y., Determination of Seventeen Elements in Edible Oils and Margarine", J. American Oil Chemist's Society. 70(8): 703.

2. G.A. Miller, N.E. Hertel, B.W. Wehring, and J.L. Horton, "Gadolinium Neutron Capture Therapy," Nucl. Technology 103, 320 (1993).

Reports:

1. K. Ünlü, B. Wehring, T. Bauer, Safety Analysis Report on Texas Cold Neutron Source, January 1993.

Papers and Presentations:

Abstracts:

1. K. Ünlü and B. W. Wehring, "Neutron Depth Profiling at The University of Texas Research Reactor," Trans. Am. Nucl. Soc., 68, 163 (1993)

2. B. W. Wehring, K. Ünlü, J. Y. Kim, and C. Rios-Martinez, "Applications for the Texas Cold Neutron Source," Trans. Am. Nucl. Soc., 68, 161 (1993)

3. J. Y. Kim, B. W. Wehring and K. Ünlü, "Neutron Guide Performance from 2-D and 3-D calculations," Trans. Am. Nucl. Soc., 68, 162 (1993)

4. K. Ünlü, C. Rios-Martinez, T. L. Bauer, and B. W. Wehring, "Performance of Texas Cold Neutron Source at Reactor Power," Trans. Am. Nucl. Soc., 69, 164 (1993)

5. B. W. Wehring, K. Ünlü, K. P. Cheng, H. Vega-Carrillo, J. Izewska, and J. Horton, "Neutron Beam Filters for Gadolinium Capture Therapy Dosimetry Measurements at a TRIGA Reactor," Trans. Am. Nucl. Soc., 69, 163 (1993)

6. J. Y. Kim, B. W. Wehring, and K. Ünlü, "Converging Neutron Guide for Neutron Focusing at the Texas Cold Neutron Source," Trans. Am. Nucl. Soc., 69, 166 (1993)

7. Carrillo, H. R., Manzanares, A. and Iskander, F. Y.. "Elemental Composition of Dam Sediments". APS/AAPT Spring Meeting, Washington D.C. April 1993, Announcer 23:2.

8. Carrillo, H. R., Quirino, L.L. and Iskander, F. Y.. "Instrumental Neutron Activation Analysis of a Powder Baby Milk Formula". APS/AAPT Spring Meeting, Washington D.C. April 1993, Announcer 23:2.

9. C. Rios-Martinez, K. Ünlü, and B. W. Wehring, "Thermohydraulic and Neutronic Performance of the Texas Cold Neutron Source," Sociedad Nuclear Mexicana, IV. Congreso Anual Memorias, Vol 1, 148 (1993).

Presentations:

1. K. Ünlü, and B. W. Wehring, "Development of a Near Surface Analysis Facility at the University of Texas Research Reactor". The Joint Meeting of the Texas Section of the American Physical Society, Texas Section of the American Association of Physics Teachers and Society of Physics Students, Texas A&M University, College Station, Texas, 22-23 Oct. 1993. (Bull. Am. Phys. Soc., 1993)

2. B.W. Wehring, and K. Ünlü, "What Can Be Done with Cold Neutrons." The Joint Meeting of the Texas Section of the American Physical Society, Texas Section of the American Association of Physics Teachers and Society of Physics Students, Texas A&M University, College Station, Texas, 22-23 Oct. 1993. (Bull. Am. Phys. Soc., 1993)

3.0 FACILITY OPERATING SUMMARIES

3.1 **Operating Experience**

The UT-TRIGA reactor at the Balcones Research Center became operational during 1992. Total operating times did not change much from the first to second year of operation although the energy production increased almost a factor of two. The total burnup after two years of operation is 4.3 MW-days. A total of 68.6 MW-hours were generated in the second year of operation. The reactor was critical for approximately 157 hours. A summary of the burnup history is shown in Figure 3-1.

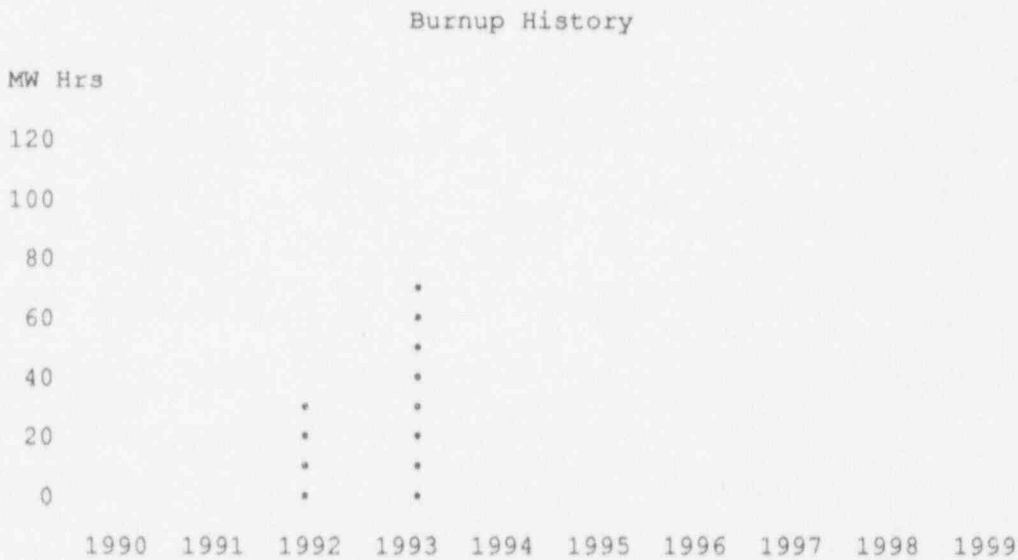

Figure 3-1 Operating History

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 1992 was seven. Of the seven total protective action shutdowns two were actions of a safety system setting, and five were actions 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)	0	0
Digital detection (software)	2	3
Manual Switch		
Protective action	0	0
Intentional operation [2]	-	-
Total Safety System Events	4	3

(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	5
Total	7

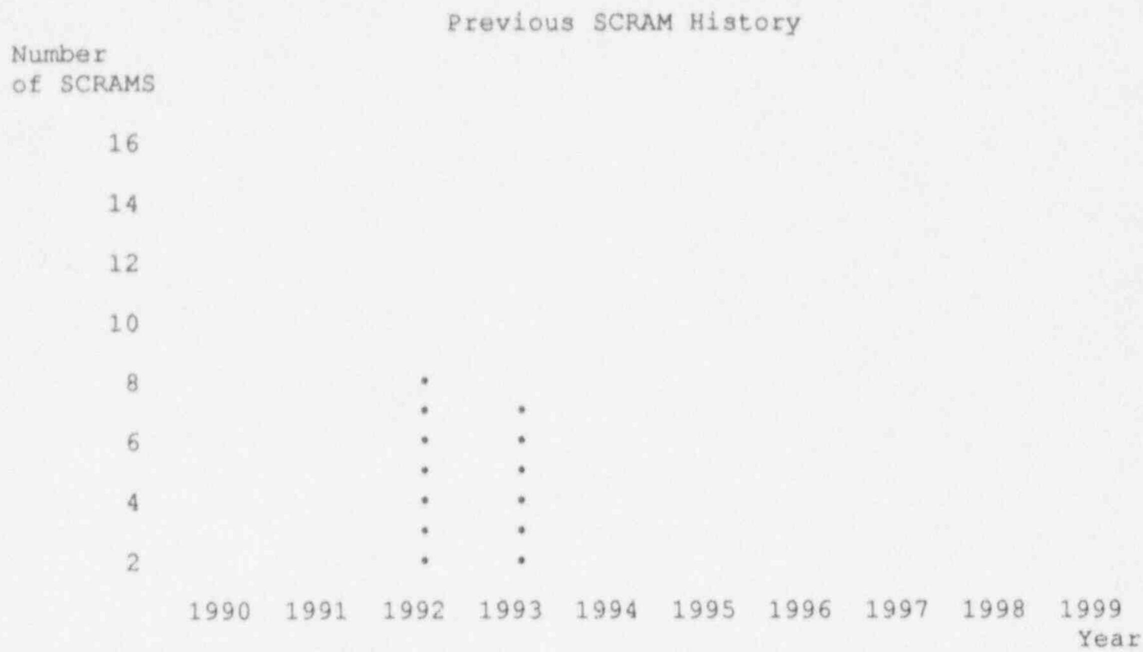

Figure 3-2 Summary of All SCRAM Events

3.3 Utilization

Primary utilization of the reactor during the year was by NETL staff. The first half of the year concentrated on the performance of reactor equipment, instrumentation and control systems. The latter half of the year concentrated on the development of two application areas, neutron activation analysis and neutron beam port facilities. One significant research project for construction of a cold neutron source for the radial beam port proceeded throughout the course of the year.

A summary of the reactor utilization for 1993 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 1993
UT-TRIGA Operation

	Q1	Q2	Q3	Q4	Total
<u># of "Key On" Hours</u>					
Operator #1	2.2	11.8	8.1	5.5	27.6
Operator #2	34.3	60.0	16.2	0.0	110.5
testing/maintenance	6.6	1.1	10.6	0.7	19.0
Total hours	43.1	72.9	34.9	6.2	157.1
<u>MW-Hours Energy</u>					
Operator #1	1.9	7.1	5.7	3.8	18.5
Operator #2	4.4	20.3	0.0	0.0	48.8
testing/maintenance	0.0	0.0	1.0	0.5	1.5
Total	16.3	27.4	20.7	4.2	68.6

Figure 3-3 Operating Data 1993

Table 3-5
Summary of Utilization 1993
UT-TRIGA Experiments

	Q1	Q2	Q3	Q4	Total
<u>No. of Samples</u>					
In-core	156	355	248	97	856
Ex-core	2	19	3	0	24
<u>No. of Experiments</u>					
Type A	5	14	5	1	25
Type B	12	10	7	2	31
Other	0	0	1	1	2
Total	17	24	13	4	58

Number of Sample Irradiations

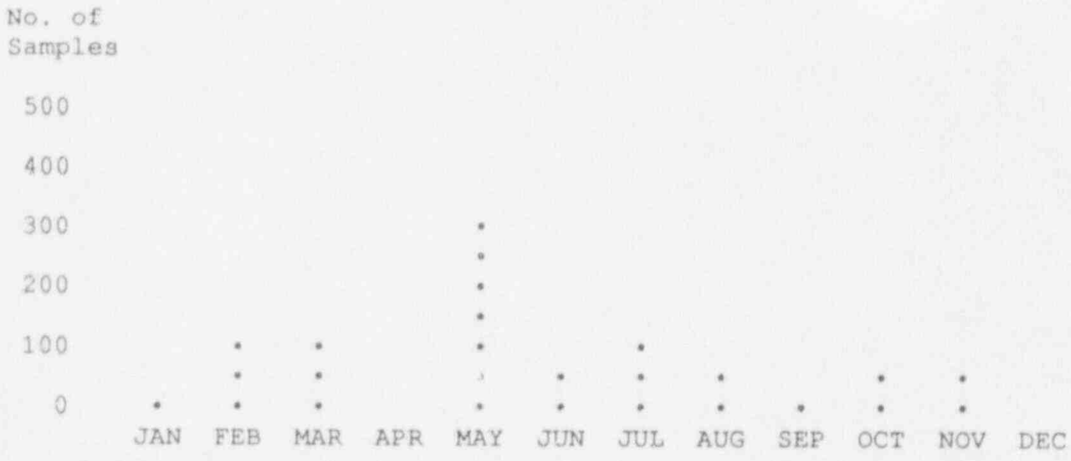

Figure 3-4 Operating Data 1993

3.4 Maintenance

Maintenance in 1993 was routine repair or modifications to equipment. All changes were made to meet or exceed original manufacturers specifications. No significant safety considerations were detected during the maintenance activities.

One repair, a software modification to the control system, was necessary to correct a deficiency in the control rod interlock circuits for pulse mode operation. The safety function of the interlock was not met for specific sequence of pressing the drive switches and mode switch. A revision to the software was made by the manufacturer to correct the condition.

3.5 Facility Changes

One significant experiment authorization became effective during 1993. The experiment authorization was for the installation, test and operation of the Texas Cold Neutron Source. No unreviewed safety question was found during the review of the Safety Analysis Report for the Texas Cold Neutron Source.

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 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 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. Among the functions of the Radiation Safety Committee and Nuclear Reactor Committee was the review of inspections by university personnel. These committees convened at the times listed in Table 3-6.

Table 3-6
Committee Meetings

Radiation Safety Committee	
Spring Term	March 5, 1993
Fall Term	November 18, 1993
Nuclear Reactor Committee	
First Quarter	January 7 & 15, 1993
Second Quarter	April 8, 1993
Third Quarter	July 1, 1993
Fourth Quarter	November 11, 1993

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 17-18, 1993 April 29, 1993
SNM-180	none
L00485(48)	May 26-28, 1993

One violation was found during the inspection process. A violation of the security plan was found and corrective actions taken. No other items of non-compliance were found. The inspection process included a special emphasis on emergency plans and a drill evaluation with local off-site response organizations.

A visit by Region IV administrative officials followed the routing annual inspection. Inspection frequencies are expected to continue at a rate of approximately once a year.

3.7 **Radiation Exposures**

Radiation exposures for personnel, building work areas and areas in the vicinity of the building are shown in the following tables. Table 3-8 lists NETL personnel dose exposure data for the calendar year. Table 3-9 is a list of the Radiation Protection Requirements and Frequencies. Figure 3-5 locates the building internal and external dosimetry sites. Numbers identify the immediate vicinity radiation measurement sites exterior to the building. These sites do not indicate any measurable dose from work within the NETL building. Table 3-10 and Table 3-11 list doses recorded in facility work areas and the immediate area adjacent to the building.

Table 3-8
Annual Summary of Personnel Radiation
Doses Received Within the NETL Reactor Facility

	Personnel	Students	Visitors
Average Annual Dose [1]			
Whole Body	1	M [2]	M
Extremities	26	N/A [3]	N/A
Greatest Individual Dose			
Whole Body	10	M	M
Extremities	180	N/A	N/A
Total Person-mrem for Group			
Whole Body	10	M	M
Extremities	340	N/A	N/A

(1) Dose is in mrem.
(2) "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, 4 mrem for energetic betas, 20 mrem for fast neutrons, and 10 mrem for thermal neutrons.
(3) "N/A" indicates that there was no extremity monitoring conducted or required for the group.

Table 3-9
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/bet counting system. Collect and analyze TRIGA primary water.
As Required	Process and record solid wasted and liquid effluent discharges. Prepare and record radioactive material shipments. Survey and record incoming radioactive materials. Perform and record special radiation survey. Issue radiation work permits and provide health phys: 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 a 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 detect: equipment

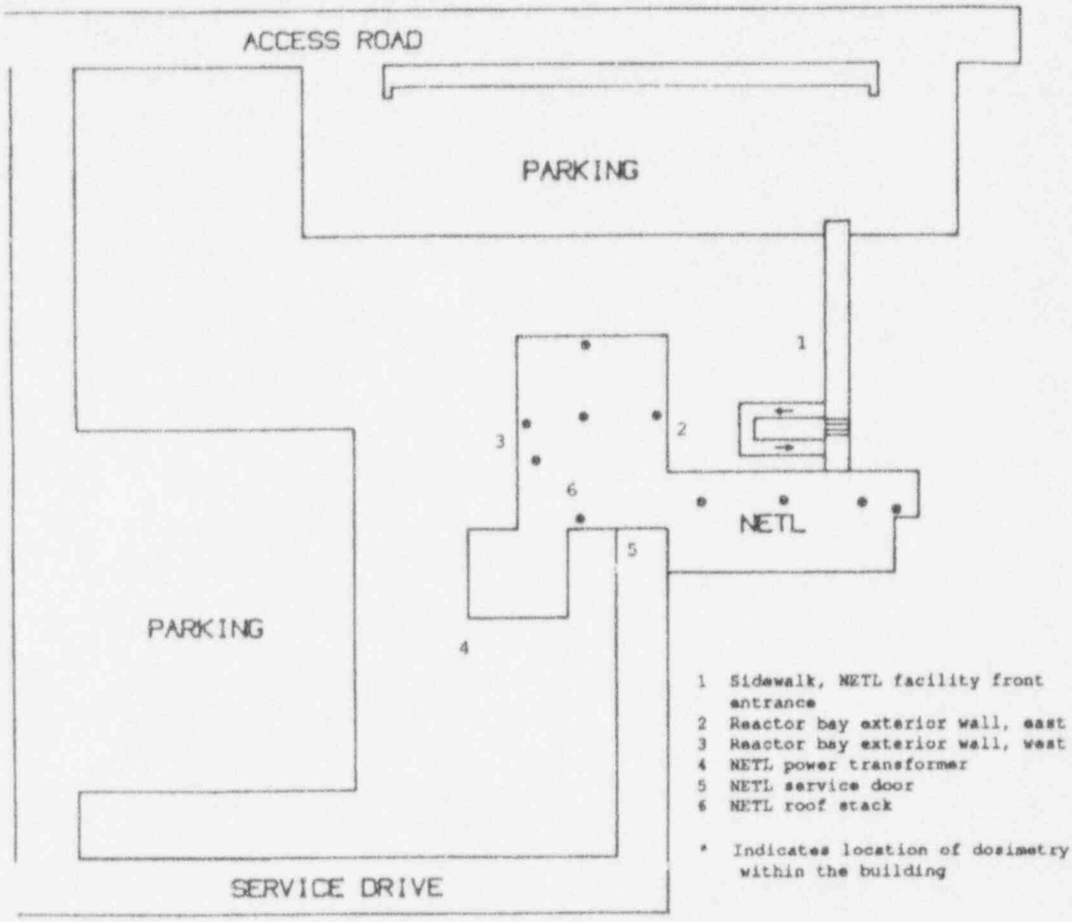

Figure 3-5 Environmental TLD Locations

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 facility front entrance	00156	M[2]
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) Dose is in mrem.

(2) "M" indicates that each of the dosimeters during the period was below vendor's minimum measurable quantity of 10 mrem for x- and gamma rays, 40 mrem for energetic betas. 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 location.

Table 3-11
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	210[2]	M
Reactor Bay, East Wall	00168	20	M
Reactor Bay, West Wall	00169	430	M
Water Treatment Room	00170	1090	M
Reactor Pool Area, Roof	00171	10	M
Shield Area, Room 1.102	00172	610	M
Sample Processing, Room 3.102	00173	M	N/A[3]
Gamma Spectroscopy Lab, 3.112	00174	30	N/A
Radiation Experiment Lab, 3.106	00175	M	N/
Reception Area, 2.102	00176	M	N/A

(1) Dose is in mrem.

(2) "M" indicates that each of the dosimeters during the period was below 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. The total recorded dose equivalent values 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. These dose equivalent values do not represent radiation exposure through and exterior wall directly into an unrestricted area.

(3) "N/A" indicates that there was no neutron monitoring at that location.

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	0.429	1.80	227.1	1288.0(3)
Reactor Bay South	0.012	0.03	<MDA(2)	<MDA(2)
Reactor Bay East	0.128	0.42	222.2	932.0(3)
Reactor Bay West	0.289	1.50	13.0	13.0
Reactor Pool Deck (third floor)	0.014	0.018	19.0	72.0
NETL Facility				
NAA Sample Processing (Rm 3.102	0.03	0.5	55.7	520.0(3)
NAA Sample Counting (Rm 3.112)	0.03	1.25	4.4	4.4
Health Physics Laboratory	0.07	0.5	3.5	5.2
RAM Storage (Rm 1.102)	0.44	1.5	16.2	28.6
Neutron Generator (Rm 1.102)	0.09	0.7	<MDA(2)	<MDA(2)
Waste Storage (Rm 1.108)	0.143	1.5	8.3	25.3

(1) Measurements made with a Bicron Microrem portable survey meter.
(2) MDA for the G-5000 low level alpha-beta radiation counting system is 2.49 dpm/100 cm^2 beta.
(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 effluent releases to the air, to the sanitary sewer and disposals of radioactive materials are shown on the following pages. 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, 1993)	Total Quantity of Argon-41 Release (microCuries)	Average Concentration at Point of Release ($microCurie/cm^3$)	Fraction of Technical Specifications[2] (%)
January	46	4.58E-12	.000229
February	283000	2.81E-08	1.40
March	360000	3.57E-08	1.79
April	1400	1.38E-10	.00692
May	256000	2.54E-08	1.27
June	382000	3.79E-08	1.89
July	169000	1.68E-08	.840
August	217000	2.15E-08	1.08
September	2700	2.68E-10	.0134
October	2750	2.73E-10	.0136
November	20300	2.01E-09	.101
December			
ANNUAL VALUE	1690000	1.38E-08	0.69

(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 is 2.00E-6 $microCurie/cm^3$.

Table 3-14
Monthly Summary of Liquid Effluent Releases to the Sanitary Sewer From the NETL Reactor Facility

Date of Discharge (Month, 1992)	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

Table 3-15
Monthly Summary of Solid Waste Transfers for Disposal

Date of Discharge (Month, 1992)	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	23.4	9.70 E-05

Releases to the sanitary sewer are done from waste hold up tanks at irregular intervals. To date no releases have been made.

Radioactive waste disposal of solids are shown in Table 3-15. The inventory of material in Table 3-15 represents the disposal of parts of the pool and shield of the Taylor Hall TRIGA installation and the disposal of radioactive components of the pool structure. The total activity sent to disposal was 97 microcuries primarily of the isotope cobalt-60, and europium-152. Radioactive materials were mostly aluminum plate, concrete rubble, and fragments of steel rebar. All material was sent to as low specific activity (LSA) waste. No disposals were made from the Balcones Research Center site.