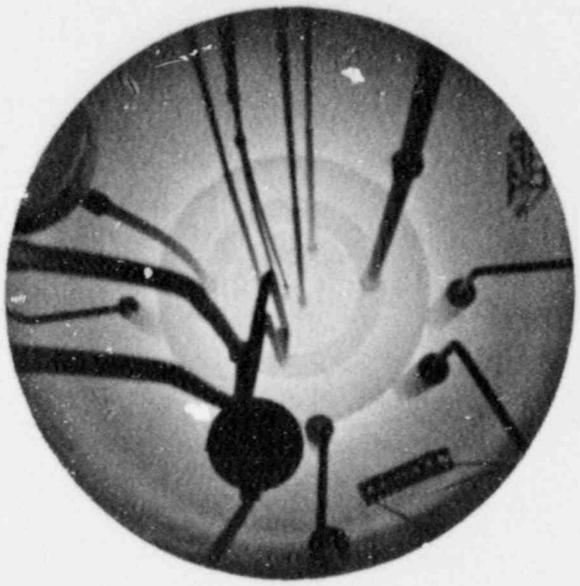


# NUCLEAR REACTOR LABORATORY

# TECHNICAL REPORT

THE UNIVERSITY OF TEXAS

COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

1987 ANNUAL REPORT

of

The University of Texas at Austin
Nuclear Engineering Teaching Laboratory
Taylor Hall Room 104

January 1, 1987 - December 31, 1987

D. E. Klein, Director
512/471-5136
T. L. Bauer, Supervisor
512/471-5787

January 1988

TABLE OF CONTENTS

## List of Tables

# List of Figures

# I. INTRODUCTION

The Nuclear Engineering Teaching Laboratory (NETL) at The University of Texas at Austin prepares an annual report to provide information about program activities. Information in this report satisfies the requirements of the U.S. Nuclear Regulatory Commission (NRC) docket number 50-192 and the U.S. Department of Energy contract number At-(40-1)-3919. The report covers the period from January 1, 1987 to December 31, 1987.

Activities of the NETL program are part of the College of Engineering Department of Mechanical Engineering. Development of the nuclear program by the university began in the years prior to 1960, with the location of most of the program activities in one of the original engineering buildings. Building space in Taylor Hall provides classroom, laboratory and office areas. The nuclear program was the only engineering program still functional by the year 1985 in the building that has become the location of the College of Natural Sciences Department of Computer Science. Building areas are also the location for parts of the University Computation Center and some other university groups.

Most NETL program laboratory activities are at two locations in Taylor Hall. Floor plans of these two laboratory areas, a Nuclear Reactor Laboratory and an Activation Analysis Laboratory, are shown in Figures 1 and 2. The Nuclear Reactor Laboratory is the site of a TRIGA Mark I reactor that operates in steady-state and pulse modes. Power operation of the reactor is at 250 kilowatts steady-state and approximately 250 megawatts pulse. At the time of initial facility acceptance the power level was at 10 kilowatts. The Activation Analysis Laboratory provides gamma spectroscopy systems for analysis of neutron activation reactions. These reactions are products of irradiation experiments in reactor experiment facilities. Data acquisition and analysis is done with high efficiency, high resolution detectors. Intrinsic purity germanium detectors provide radiation detection with automatic control and acquisition systems run by microcomputers.

Other NETL program laboratory activities are at locations in the Engineering Science Building. This building provides a multipurpose facility for several engineering and science programs. A Nuclear Radiation Laboratory provides an experiment facility for flux and energy measurements of neutrons from fusion, fission, and other neutron production reactions. Three sources available are the D-T reaction from a Cockcroft-Walton type accelerator, spontaneous fission reaction from the isotope californium-252 and the alpha-neutron reaction from plutonium-beryllium. Activities of the laboratory include detection, measurement and analysis.

NETL program equipment and materials provide support for different types of facility activities. Supplemental equipment and radioactive materials include a subcritical assembly, gamma irradiator, portable x-ray unit and various isotopic radiation sources. Equipment, instrumentation systems and detection devices for monitoring, measurement and calibration of ionizing radiation are in routine use or available for special applications. Radioactive material inventories contain radioisotope sources for gamma rays, neutron emissions, x-ray excitation, and reference standards for several types of experimental programs.

Development goals of the university and engineering have been the cause of a major change to the NETL program. Initiation of a project to move activities of the NETL program to the Balcones Research Center (BRC) began in October 1983 and should continue into early March 1989. The program move is in response to needs of the main campus for expansion of other educational programs, addition of research facilities, and the development of the research center into a major research site for science and engineering.

A Dismantling and Decommissioning, DDP, Plan (docket 50-192) for the Taylor Hall facility was submitted to the Nuclear Regulatory Commission (NRC) on May 3, 1985. An order to authorize the activities that will lead to the license termination was issued on March 9, 1987. Project plans indicate that the DDP activities will occur in the last quarter of 1988 and first quarter of 1989.

Project authorization to move NETL program activities to the Balcones Research Center (BRC) site was approved by The University of Texas System Board of Regents on October 13, 1983. A submittal for a construction permit and an operation license was made to the Nuclear Regulatory Commission on November 9, 1984. Subsequent to a site visit on January 22 thru 24 a license amendment was requested on February 27, and responses to NRC questions were prepared. The construction permit was issued June 4, 1985.

Preliminary architectural and engineering plans were approved by The University of Texas System Board of Regents on August 8, 1985. Final plans were approved on April 10, 1986 and the bid to a general contractor was awarded on December 4, 1986. CIT Construction Inc. of Stafford, Texas, was specified as the general contractor and start of construction was recorded on February 10, 1987. Facility completion is scheduled for 16-18 months after start of construction.

The Balcones Research Center facility will provide laboratories for the TRIGA reactor, a neutron generator, radiation measurement systems, preparation and processing of radioactive samples, and office space. Although the facility will move the present TRIGA facility and other program activities into a single building at the Research Center, several improvements to the reactor facility will extend facility capability. These include above ground shield structure for access to horizontal beam tubes, and an increase of power and pulse parameters. Plans are to utilize the present fuel and move some other components from the old to the new facility. A few components such as control rod drives will be subject to rework procedures to assure appropriate functional operation. Many components such as reactor structure, instrumentation, and control system will be new components.

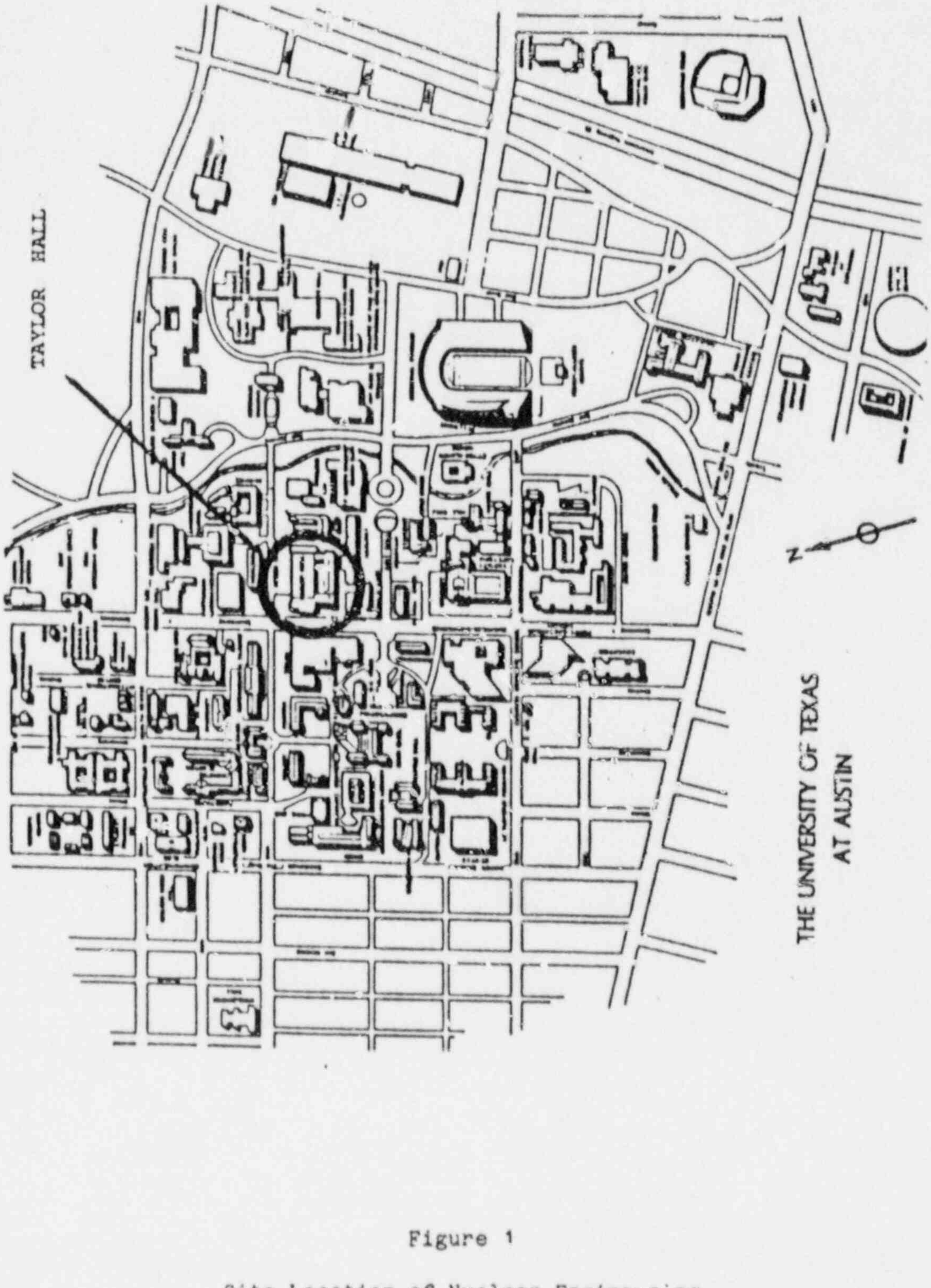
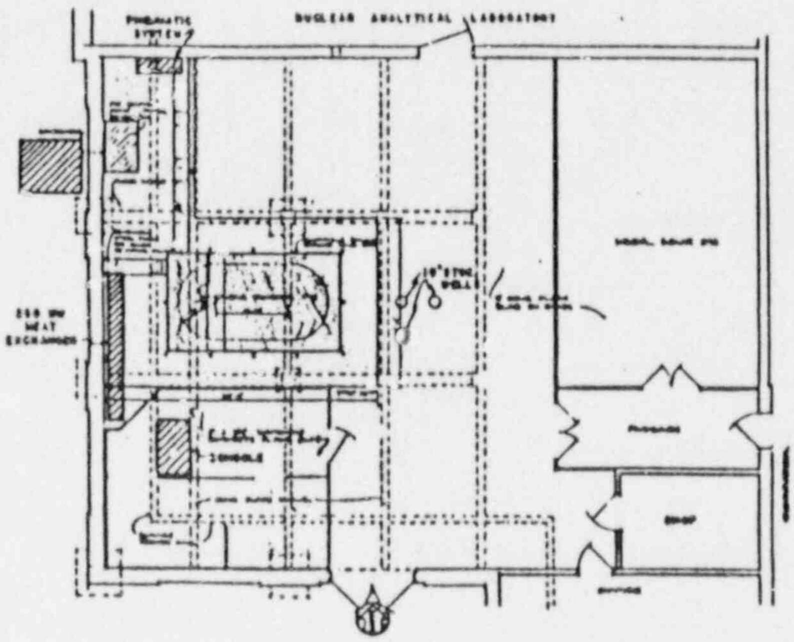



Figure 1

Site Location of Nuclear Engineering
Teaching Laboratory

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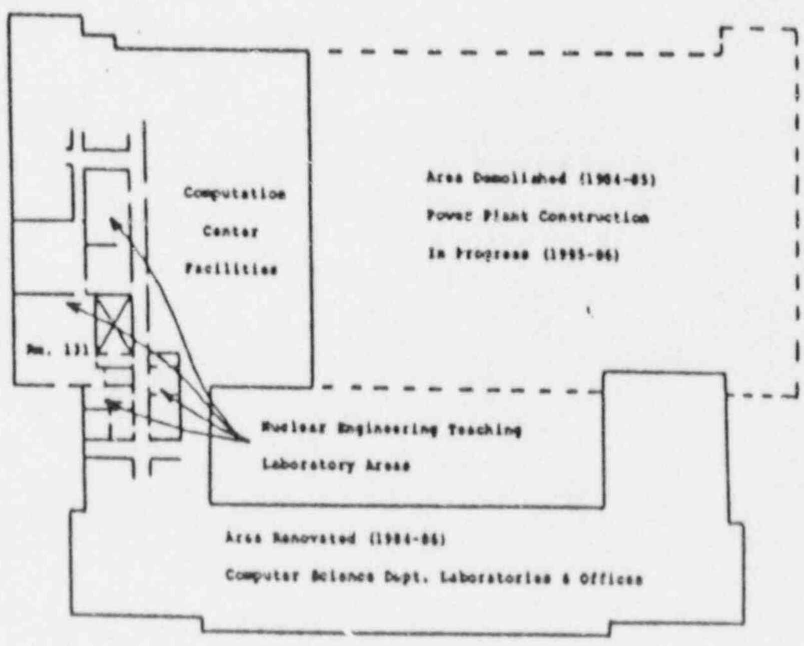



TAYLOR HALL

Figure 2

Floor Plan of Nuclear Engineering Teaching Laboratory

# II. LABORATORY ADMINISTRATION

## A. Organization

The present organizational chart of the NETL program is presented in Figure 3. Budgeted NETL staff funding is provided for a Supervisor/Assistant Director, research associate, technician/operator, operator, and secretary. Budget support is divided into full time positions for supervisor, technician and research associate; half time for an operator; and quarter time for a secretary.

## B. Personnel

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 past year are summarized in Table I.

## C. Standing Committees

Two committees monitor the activities of the NETL programs. The Nuclear Reactor Committee functions through the College of Engineering and the Radiation Safety Committee functions through the Office of the President.

### 1. Nuclear Reactor Committee

The Nuclear Reactor Committee convened to review the activities related to facility operation during each quarter of the calender year. Committee meeting dates were April 16, July 3, October 22 and January 16, 1988. The committee composition is shown in Table 2. Committee responsibilities are the reactor operation, associated facility activities and engineering programs.

### 2. Radiation Safety Committee

The Radiation Safety Committee convened to review radiological safety practices at the university during each academic term. Committee meeting dates were April 8, 1987 and November 12, 1987. The committee composition is shown in Table 2. Committee responsibilities are the activities of university research programs that utilize radiation source materials.

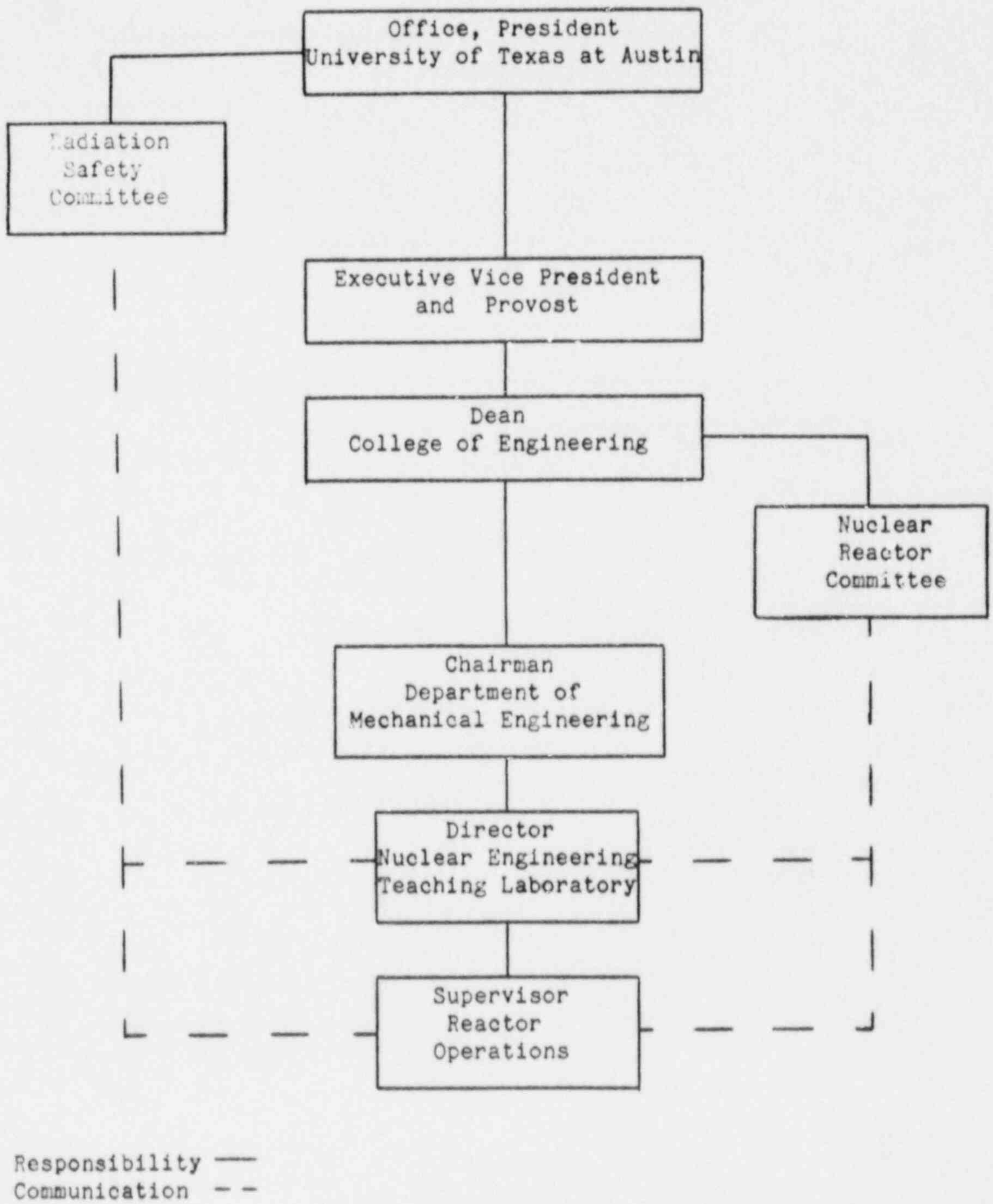



Figure 3

Organization Chart of the Nuclear Engineering Teaching Laboratory

Table 1
Administration and Committees

## Administration

The University of Texas System Board of Regents

| | | |
|---|---|---|
| Chairman | | Jess Hay |
| Vice Chairman | | R.B. Baldwin III |
| Vice Chairman | | S.H. Ratliff |
| Executive Secretary | | A.H. Dilly |
| Member (1987) | Member (1989) | Member (1991) |
| J.S. Briscoe | R.B. Baldwin III | J.S. Blanton |
| B.B. Milburn | Jess Hay | S.H. Ratliff |
| T.B. Rhodes | Mario Yzaguirre | Bill Roden |
| Chancellor | | Hans Mark |

The University of Texas at Austin

| | |
|---|---|
| President (app. 9/1/85) | William H. Cunningham |
| Executive Vice President and Provost (app. 9/1/85) | Gerhard J. Fonken |
| Dean of the College of Engineering | Earnest F. Gloyna (rem: 8/31/87)<br>Herbert H. Woodson (app: 9/1/87) |
| Chairman of Department of Mechanical Engineering | Grady H. Rylander (rem: 8/31/87)<br>John R. Howell (app: 9/1/87) |

## Nuclear Reactor Committee

| | |
|---|---|
| Chairperson: | H. L. Marcus (app: 9/1/77) |
| Member: | N. E. Hertel (app: 4/1/79) |
| Member: | D. E. Klein (app: 9/1/77) |
| Member: | J. O. Ledbetter (app: 9/1/71) |
| Member: | L. Rabenberg (app: 9/1/87) |
| Member, student: | R. D. Manteufel (app: 9/1/85) |
| Ex officio member: | T. L. Bauer (app: 6/1/78) |
| Ex officio member: | H. W. Bryant (app: 11/1/73) |
| Ex officio member: | E. F. Gloyna (app: 4/1/70, 8/31/87) |
| Ex officio member: | H. H. Woodson (app: 9/1/87) |
| Ex officio member: | H. G. Rylander (app:9/1/76, 8/31/87) |
| Ex officio member: | J. R. Howell (app: 9/1/87) |

## Radiation Safety Committee

| | |
|---|---|
| Chairperson: | E. L. Sutton (app: 9/1/84) |
| Member: | K. J. Caskey (app: 9/1/83) |
| Member: | G. W. Hoffman (app: 9/1/84) |
| Member: | D. E. Klein (app: 9/1/83) |
| Member: | S. A. Monti (app: 9/1/85) |
| Member: | L. O. Morgan (app: 4/1/75) |
| Ex officio member: | H. W. Bryant (app: 11/1/73) |
| Ex officio member: | W. H. Cunningham (app: 9/1/85) |

Table 2
Personnel

## Facility Personnel

Staff

| | |
|---|---|
| Director | D.E. Klein |
| Assistant Director/Supervisor | T.L. Bauer |
| Research Associate | F.Y. Iskander |
| Nuclear Technical Specialist | M.G. Krause |
| Technical Secretary | D.L. Wood |
| Laboratory Research Assistant | R. Clements |
| Laboratory Research Assistant | L. Polohlopek |
| Laboratory Research Assistant | K. Israels |

## Support Personnel

Safety Personnel

| | |
|---|---|
| Safety Coordinator | H.W. Bryant |
| Radiation Safety Specialist | L.W. Hamlin |

## Researchers

College of Engineering

| | | |
|---|---|---|
| T.L. Bauer | Nuclear Reactor Lab. | |
| F.Y. Iskander | Neutron Activation Lab. | Research Associate |
| N.E. Hertel | Nuclear Radiation Lab. | Assoc. Prof. |

University Departments

| | | |
|---|---|---|
| E.M.B. Sorenson | Pharmacy | Assoc. Prof. |
| J.H. Freeland | Home Economics | Assoc. Prof. |

## Students

| | Engineering | University |
|---|---|---|
| Graduate Assistants | R. Hartley | F. Behmardi |
| | D. Smith | D. Durbin |
| | A. Patterson-Hine | H. Lo |
| | R. Savage | |
| | R. Manteufel | |
| | A. Heger | |
| Student Assistants | R. Clements | |
| | L. Polchlopek | |
| | K. Israels | |

D. Report to the College of Engineering

Each year the Reactor Committee provides a report to the Dean of the College of Engineering describing activities of the committee and a review or assessment of the operation of specific portions of the NETL program concerning the reactor and other radiation producing equipment. Harris Marcus, Reactor Committee Chairman, summarized the activities during this period saying:

There are two sets of minutes for this years quarterly meetings. Docket 50-192 deals with the ongoing operation in Taylor Hall and Docket 50-602 deals with the construction of the new facility at Balcones Research Center. The specific items of interest are the following:

1. A major portion of the effort in the program was again associated with continuing the development of a new reactor facility at Balcones Research Center as well as for decommissioning arrangements of the existing facility. Plans have progressed in an orderly manner and have been coordinated with NRC personnel. A contract award for the new facility was made December 4, 1986. On March 9, 1987 authorization for dismantling the Taylor Hall facility was received from the Nuclear Regulatory Commission.

2. For another year the reactor remained operating efficiently while construction and destruction continued all around it. The level of reactor activity for the year was comparable to previous years. Recently, additional neutron activation studies have been initiated with an increase in reactor usage. This was accomplished in spite of the very heavy additional work load associated with the new facility and setting up the dismantling of the old reactor.

It is imperative that the personnel involved with the Nuclear Engineering Teaching Reactor be given full support during the construction phase to make sure that the construction problems are satisfactorily solved. In addition, the necessary resources for dismantling must be made available.

I recommend the committee be reappointed for the coming year and that Lew Rabenberg (ME) be added to the committee and Randy Manteufel be the student member. 1986-87 was again a busy and fruitful year for the NETL.

Note: Bids for the facility at the Balcones Research Center were opened October 21, 1986 and award of the general contract was approved December 4, 1986. The University of Texas System Board of Regents entered into a contract with CIT Construction Inc. of Stafford, Texas. Total project cost for the proposed facility was \$5,452,560. An additional \$408,140 is being held in reserve for dismantling activities at the Taylor Hall facility. Authorized total cost is \$5,860,700.

# III. LABORATORY DEVELOPMENT

## A. Organization

Dr. Dale E. Klein continued as the Director and Dr. Thomas L. Bauer continued as Reactor Supervisor/Assistant Director during the past year.

The only changes made in the facility staff during the 1987 calendar year were in the area of part time student research assistants. Kenneth Israels and Lester Polchlopek assisted in various laboratory activities during the summer with Mr. Polchlopek continuing in the Fall. Bob Clements resigned in September to take employment elsewhere.

The Nuclear Reactor Committee remained unchanged with the exception of the appointment of one additional member. Nolan Hertel, a reactor committee member is on leave for the academic year 87-88. New personnel were appointed to the following university administrative positions: Dean of the College of Engineering, and Chairman of the Department of Mechanical Engineering. Dr. H.H. Woodson has assumed the role of acting Dean of the College of Engineering. Dr. J.R. Howell has been appointed chairman of the Department of Mechanical Engineering.

## B. Nuclear Engineering Teaching Laboratory

The Nuclear Engineering Teaching Laboratory is part of the Nuclear Engineering Program at The University of Texas.

The Nuclear Engineering Teaching Laboratory's central feature is a Mark I TRIGA thermal fission reactor. Originally licensed by the Atomic Energy Commission to operate at 10 kw in 1963, the nuclear reactor and the associated laboratory equipment have been updated over the past years and the research capabilities of the Laboratory are now more diverse. In 1968, the facility license was amended to allow the TRIGA reactor to operate at a steady state power level of 250 kw which increased experimental capabilities.

Other radiation producing devices maintained by the Laboratory are a 750 curie Co-60 irradiator, vertical neutron beam tube, subcritical assembly, industrial x-ray source, 14 MeV neutron generator, and several isotopic neutron sources. Different types of radiation detection devices provide the capacity to monitor or analyze the various radiation sources.

One of the functions of the nuclear reactor and its associated equipment has been to teach and demonstrate the fundamentals of reactor operation. Another function has been the demonstration of specific applications of nuclear technology. Several organized classes routinely utilize the reactor facility and a few others use the facility on an infrequent basis. Courses utilizing the reactor and associated facilities are listed in Table 3. Classes, organizations and groups are provided tours or demonstrations of the reactor and its associated experimental facilities. Approximately 925 persons were admitted into the reactor facility during the past year.

The use, operation, regulation and inspection of the Nuclear Engineering Teaching Laboratory is controlled by the United States Nuclear Regulatory Commission, the Nuclear Reactor Committee of The University of Texas, the Director of the Nuclear Engineering Teaching Laboratory, the Radiation Safety Committee and the Texas Department of Health Division of Radiation Control.

C. Neutron Activation Analysis Laboratory

The Neutron Activation Analysis Laboratory has provided nuclear analytical support for individual projects ranging from student project support for classes to measurements for faculty research projects. Student project support is in the areas of engineering, chemistry, physics, geology, biology, zoology, and other areas. Research project support includes elemental measurements for environmental and investigative research projects. Scientific articles based upon the results of sponsored and non sponsored research by this laboratory have been published or accepted for publication in several journals and proceedings, and have been presented at conferences at the state, national and international level.

Radiation measurement systems available include gamma ray spectroscopy with two HpGe detectors coupled to a microcomputer controlled acquisition and analysis system, Si(Li) detector and multichannel analyzer for X-ray measurements, alpha-beta proportional counter, scintillation detectors, neutron detectors and associated electronic modules to accomplish several types of standard nuclear measurements. An important function of the laboratory is to support various research applications with the neutron activation analysis method or other techniques related to nuclear radiation measurements.

D. Nuclear Radiation Laboratory

The Nuclear Radiation Laboratory is utilized by staff and students of the Nuclear Engineering Program at The University of Texas at Austin. The laboratory is located in an area of the Engineering Science Building. A 14 MeV Texas Nuclear neutron generator is the main feature of the laboratory. Three californium-252 neutron sources are also available for use. The facility, with installed shielding, provides an area where students and staff can perform experiments utilizing not only the high energy neutrons from the neutron generator but fission spectrum neutrons from Cf252. In addition to the neutron generator and the californium sources, other smaller radioactive sources are also used within the confines of the Nuclear Radiation Laboratory.

Table 3

Courses Utilizing the Reactor and Associated Facilities

| Course Number | Course Description |
|---|---|
| **Mechanical Engineering Department** | |
| ME 361F | Introductory Nuclear Laboratory - studies in radioactive decay, activation, detection and measurement. |
| ME 361G | Reactor Operations - studies in nuclear reactor parameters, instrumentation characteristics and regulation. |
| ME 377K | Projects in Mechanical Engineering - individual study and experiment projects for undergraduates. |
| ME 389R | Nuclear Engineering Laboratory - studies for graduate students in nuclear methods in measurement and analysis. |
| ME S389R | Special projects course for nuclear engineering laboratory studies as a summer course for foreign students. |
| ME 397 | Current Studies in Engineering - special projects course for graduate study of selected topics. |
| **Additional Courses in Other Departments** | |
| GEO 388L | Isotope Geology - graduate course |
| CH 376K | Advanced Analytical Chemistry - senior level course in instrumental and analytical methods. |
| CE 390L | Environmental Analysis - graduate course in civil engineering |
| PHR 370K | Nuclear Pharmacy - senior level course in measurement and analysis methods with nuclear pharmaceuticals. |

## IV. Facility Operations Summary

### A. Operating Experience

During the period no significant deviations from normal operating conditions were observed. Pulse reactor operation remained suspended. Established operating procedures and other required procedures remained unchanged.

Licensed activities were performed by three persons with Senior Operator Permits, T.L. Bauer, M.G. Krause and R. Clements. Operating activities were in support of reactor operations, nuclear engineering, sample irradiations, research and education or demonstrations. No new experiments were proposed or approved. Excluding operation for demonstration, instruction, routine surveillance, or isotope production, the major experiment performed was neutron activation to support various research activities. Maintenance during the period consisted primarily of routine equipment repair and adjustments.

### B. Reactor Shutdowns

Reactor shutdowns (scrams) occurring during the reporting period are summarized in Table 4, categorized according to the type of initiating event. Safety system scrams are protective actions to shutdown the reactor that are caused by the proper operation of the safety system but are not the result of an operator error or an intentional action of the operator. Operator error scrams are the result of judgement errors or procedural errors. Instrument and power failure scrams are protective actions that result from loss of safety system function. Intentional scrams are operator initiated scrams such as tests. Manual action scrams are classified either safety or intentional as determined by the cause of the manual scram action. Inadvertent scrams are all unintentional shutdowns of the reactor by the protective action of the safety system. Table 5 compares the number of inadvertent shutdowns during this reporting period to previous reporting periods.

Table 4

Reactor Safety System
(scrams)

| | |
|---|---|
| Safety System | 0 |
| Operator Error | 1 |
| Instrument Error | 1 |
| Power Failure | 0 |
| Subtotal | 2 |
| Intentional | 6 |
| Total | 8 |

Table 5

Safety System Events
(inadvertent)

| | | | | | |
|---|---|---|---|---|---|
| | | 1971 | 13 | 1981 | 7 |
| | | 1972 | 6 | 1982 | 6 |
| 1963 | 10 | 1973 | 10 | 1983 | 6 |
| 1964 | 9 | 1974 | 4 | 1984 | 5 |
| 1965 | 3 | 1975 | 7 | 1985 | 2 |
| 1966 | 4 | 1976 | 5 | 1986 | 9 |
| 1967 | 3 | 1977 | 9 | 1987 | 2 |
| 1968 | 11 | 1978 | 11 | | |
| 1969 | 15 | 1979 | 12 | | |
| 1970 | 11 | 1980 | 7 | | |

Table 6

Performance Data 1987

Reactor Operation Hours, Fuel Burn-up and Irradiated Samples

| Quarter | Reactor Operation (hours) | Total Burn-up Fuel (kwhrs) | Samples Irradiated (number) |
|---|---|---|---|
| First | 90.2 | 6169 | 192 |
| Second | 77.5 | 15349 | 442 |
| Third | 60.1 | 13066 | 418 |
| Fourth | 66.1 | 9202 | 342 |
| Total | 293.9 | 43786 | 1394 |

Notes:

(1) Reactor operation hours record the console key on time or the time power is applied to the rod control system.

(2) One full power hour is 250 kilowatt-hours.

(3) Samples that are irradiated in the experimental facilities of the reactor such as the RSR, PNT or CT.

Table 7
Annual Utilization Data

| Year | Reactor Operation (hours) | Total Burn-up Fuel (kwhrs) | Samples Irradiated (number) |
|---|---|---|---|
| 1967 | 154.5 | 846 | 265 |
| 1968 | 342.6 | 28168 | 2449 |
| 1969 | 260.8 | 49985 | 1452 |
| 1970 | 222.0 | 36477 | 1640 |
| 1971 | 262.5 | 53912 | 2990 |
| 1972 | 222.8 | 48389 | 1946 |
| 1973 | 318.6 | 45794 | 1347 |
| 1974 | 226.5 | 27641 | 778 |
| 1975 | 207.0 | 204[illegible]0 | 363 |
| 1976 | 135.7 | 11312 | 468 |
| 1977 | 139.3 | 7509 | 164 |
| 1978 | 171.9 | 26870 | 178 |
| 1979 | 311.6 | 72616 | 1568 |
| 1980 | 184.1 | 11760 | 150 |
| 1981 | 258.5 | 18165 | 330 |
| 1982 | 247.6 | 16150 | 294 |
| 1983 | 260.2 | 24028 | 477 |
| 1984 | 179.6 | 24806 | 667 |
| 1985 | 139.9 | 18607 | 473 |
| 1986 | 183.1 | 18660 | 633 |
| 1987 | 293.9 | 43785 | 1394 |
| Total | 4722.7 | 605931 | 20026 |

Note:

(1) Data for 1967 includes all data recorded for previous operation at 10 kW from 1963-1967.

(2) Operation power of 250 kilowatts was initiated in 1968.

C. Utilization

Reactor utilization data for this reporting period is summarized in Table 6. A summary of reactor utilization since initial criticality is shown in Table 7. Bar graphs comparing annual burnup and quantities of samples irradiated since initial criticality are shown in Figures 4 and 5.

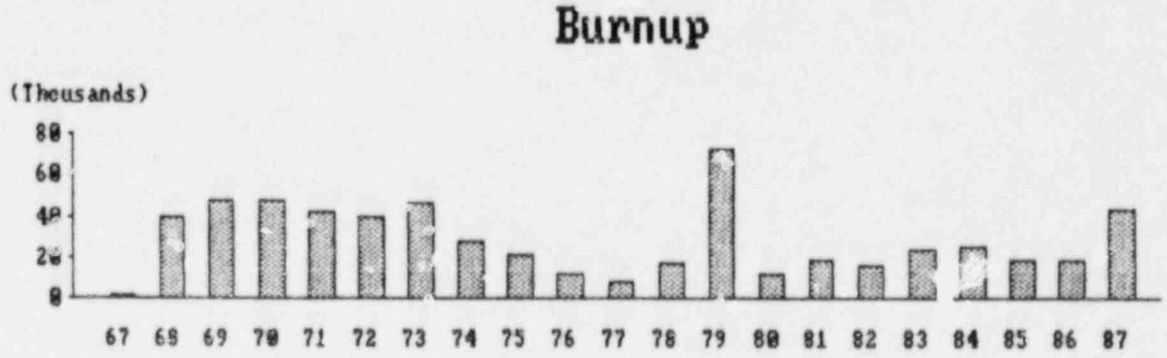
D. Maintenance

During this reporting period maintenance consisted primarily of routine repair and adjustment.

E. Facility Changes

Operation of the reactor in the pulse mode remains discontinued until the operation characteristics of the compensated chamber as related to pulsing is established. This evaluation is not planned since current activities of the facility do not require pulsing and no pulsing is planned before moving to the new facility at BRC.

No other facility changes were made during this reporting period.




Annual Burnup versus Operation Year

Figure 4

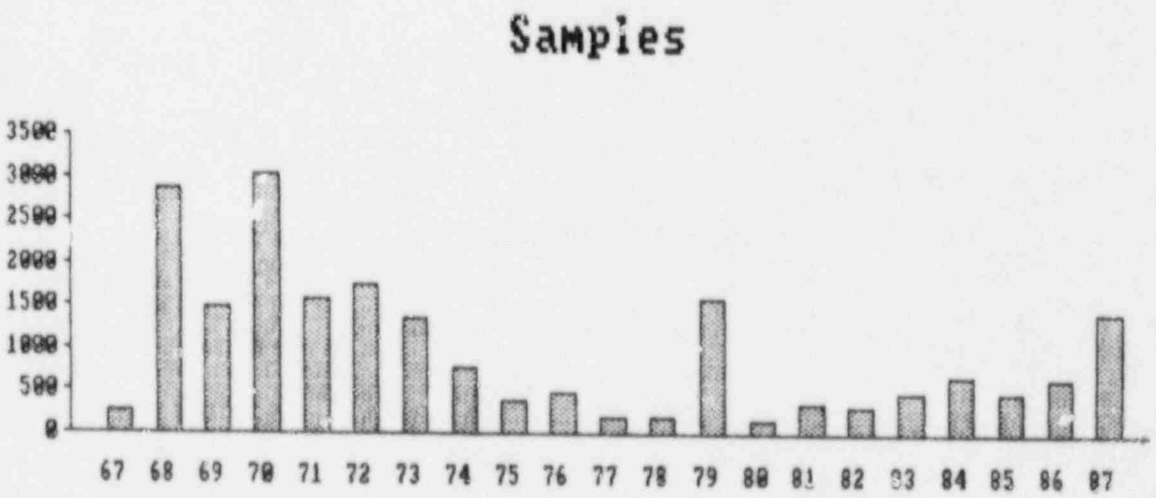



Figure 5

Samples Irradiated versus Year

F. Radiation Exposures

A summary of radiation exposures during this reporting period to facility personnel, students, and visitors is shown in Table 8. The average exposure per individual and the greatest exposure per individual for each group is summarized in Table 9. No exposures in excess of the limits of 10CFR20 occurred during this period.

G. Area Radiation Surveys

An annual summary of the normal radiation levels measured in the laboratory is shown in Table 10. The results of routine surface and pool water contamination surveys are summarized in Table 11. Environmental surveys performed outside the laboratory are summarized in Table 12.

H. Radioactive Effluents

1. Gaseous Wastes

Gaseous discharge during the reporting period is limited to leakage of Ar41 from the reactor laboratory. The total estimated amount of radioactivity released was calculated based on experimental data. A summary of the calculated radioactive gaseous discharges during the reporting period is presented in Table 13.

An estimate of the release volume is calculated from the product of the monthly number of full power hours operated during the period and the effective air leakage rate. Although air leakage from the laboratory is restricted, an effective air change rate of two per hour (.36 $m^3$/sec) is assumed. The total activity released is calculated as the product of the volume released and the equilibrium concentration of Ar41 in the laboratory, measured at $4x10^{-8}$ $\mu Ci/cm^3$.

The release point concentration is determined as the product of the equilibrium Ar41 concentration in the laboratory, the effective air leakage rate, release point (0.14 sec/$m^3$), and the actual full power hours operated divided by the total number of hours in the reporting period. The percent of the maximum permissible concentration (MPC) is the release point concentration divided by the MPC for Ar41 ($4x10^{-8}$ $\mu Ci/cm^3$) in unrestricted areas.

2. Liquid Waste

No liquid radioactive waste was discharged during the reporting period. Efforts are made to avoid liquid waste disposal by appropriate evaporation or absorption techniques for small volumes and purification by resin treatment for large volumes.

3. Solid Waste

The activity and amounts of solid waste discharged during the reporting period are summarized in Table 14. All solid waste materials were packaged and shipped, along with radioactive waste generated in other departments, by the Safety Office. Waste shipments are performed by Texas Nuclear, Austin, Texas.

Table 8

Summary of Personnel Radiation Exposures

| Range of Exposure in REM | Number of Individuals | | |
|---|---|---|---|
| | Staff | Students | Visitors |
| No measurable exposure | 5 | 18 | 857 |
| Measurable exposure less than 0.1 | 3 | 4 | 68 |
| 0.1 - 0.25 | 0 | 0 | 0 |
| 0.25 - 0.5 | 0 | 0 | 0 |
| 0.5 - 0.75 | 0 | 0 | 0 |
| 0.75 - 1.0 | 0 | 0 | 0 |

Table 9

Radiation Exposure Groups

| Group | Exposure per Individual in mrem Average | Greatest |
|---|---|---|
| Staff | 13 | 50 |
| Students | < 10 | 20 |
| Visitors | < 10 | < 10 |

Table 10

Laboratory Radiation Levels

| Location | Average (mR/hr) | Maximum (mR/hr) |
|---|---|---|
| Control Console Area<br>10 ft. from core axis<br>6 ft. above pool | 7x10^-3 | 3x10^-2 |
| Water System Area<br>12 ft. from core axis<br>4 ft. above pool | 2x10^-2 | 1x10^-1 |
| Above Core<br>0 ft. from core axis<br>16 ft. above pool | 2x10^-1 | 3x10^-1 |

Table 11

Laboratory Contamination Levels

| Location | Average | Maximum |
|---|---|---|
| Floors | 19 dpm | 162 dpm |
| Surfaces | 18 dpm | 39 dpm |
| Pool Water | 130 pCi/l | 293 pCi/l |

Table 12

Environmental Surveys

| Location | Average | Maximum |
|---|---|---|
| 1 | .01 mR/hr | .01 mR/hr |
| 2 | .01 mR/hr | .01 mR/hr |
| 3 | .02 mR/hr | .03 mR/hr |
| 4 | .01 mR/hr | .01 mR/hr |
| 5 | .01 mR/hr | .01 mR/hr |
| 6 | .01 mR/hr | .01 mR/hr |
| 7 | 14 pCi/l | 63 pCi/l |

Table 13

Mc 'thly Gaseous Waste Discharge
(ARGON-41)

| MONTH | EFPH (HRS) | VOLUME (M^3) | ACTIVITY ( Ci) | REL. CONC. ( Ci/CM^3) x10-12 | % MPC |
|---|---|---|---|---|---|
| 1 | 7.86 | 10187 | 407 | 22 | 0.054 |
| 2 | .37 | 480 | 19 | 1 | 0.003 |
| 3 | 16.44 | 21306 | 852 | 45 | 0.114 |
| 4 | 11.88 | 15396 | 616 | 33 | 0.082 |
| 5 | 23.80 | 30845 | 1234 | 66 | 0.164 |
| 6 | 25.82 | 33328 | 1333 | 71 | 0.178 |
| 7 | 12.11 | 15698 | 628 | 33 | 0.084 |
| 8 | 24.05 | 31169 | 1247 | 66 | 0.166 |
| 9 | 16.10 | 20866 | 835 | 44 | 0.111 |
| 10 | 12.11 | 15693 | 628 | 33 | 0.084 |
| 11 | 12.74 | 16511 | 660 | 35 | 0.088 |
| 12 | 11.96 | 15499 | 620 | 33 | 0.083 |

Monthly Gaseous Waste Discharge
(gas or particulate)

| Month | Isotope | Total Release ( Ci) | (m^3) | Point of Release Concentration (pCi/m^3) | Percent of Maximum (> 20%) |
|---|---|---|---|---|---|
| Jan | none | | | | |
| Feb | none | | | | |
| Mar | none | | | | |
| Apr | none | | | | |
| May | none | | | | |
| Jun | none | | | | |
| Jul | none | | | | |
| Aug | none | | | | |
| Sep | none | | | | |
| Oct | none | | | | |
| Nov | none | | | | |
| Dec | none | | | | |
| Total | -- | | | | |

Table 14

Monthly Liquid Waste Discharge

| Month | Isotope | Total Release ( Ci) | (m^3) | Point of Release Concentration (pCi/m^3) | Percent of Maximum (%) |
|---|---|---|---|---|---|
| Jan | - | | | | |
| Feb | - | | | | |
| Mar | - | | | | |
| Apr | - | | | | |
| May | - | | | | |
| Jun | - | | | | |
| Jul | - | | | | |
| Aug | - | | | | |
| Sep | - | | | | |
| Oct | - | | | | |
| Nov | - | | | | |
| Dec | - | | | | |

Table 15

Monthly Solid Waste Disposal

| Month | Isotope | Total Release ( Ci) | (ft^3) | Form Chemical/Physical | Remarks |
|---|---|---|---|---|---|
| Jan | - | | | | |
| Feb | - | | | | |
| Mar | - | | | | |
| Apr | $H^3$ | $6853X10^3$ | 3 | Targets & Paper | From N. Generator |
| May | - | | | | |
| Jun | - | | | | |
| Jul | - | | | | |
| Aug | - | | | | |
| Sep | - | | | | |
| Oct | - | | | | |
| Nov | - | | | | |
| Dec | - | | | | |

## V. Laboratory Inspections

### A. NRC Inspections

No NRC inspections took place during the calender year for the R-92 Reactor Facility License.

No NRC inspections took place during the calender year for the SNM-180 special nuclear material license.

A license renewal for the SNM-180 license date May 19, 1987 extends the license to May 31, 1992.

### B. TDH Inspection November 23-24, 1987

The inspection consisted of a review of activities and radioactive materials used at The University of Texas at Austin as authorized by TDH License.

# VI. Public Service Activities

## A. Summer High School Science Teacher Symposium

The NETL staff organizes and supervises an annual two week symposium designed to familiarize high school science teachers with the theory and technology associated with energy resources today. Graduate college course credit is given to all participants who successfully complete the course. The program is funded by various electric utility companies in Texas. Approximately thirty (30) teachers attend the symposium every year.

## B. Lectures and Presentations

On numerous occasions during 1987 the NETL staff talked to various organizations about subjects including but not limited to: "Nuclear Reactor Safety," "Nuclear Engineering and Society," "Research and Development of Energy Resources," and "Energy and the Environment."

## C. Reactor Facility Tours

During 1987, 925 persons visited the laboratory. The largest group visiting the laboratory were persons attending the Texas Energy Science Symposium. Numerous high school students also toured the facility during an event called The World of Engineering, designed to recruit students into the field of Engineering. Students from several local high schools and students from several non engineering related college courses visited the facility. Numerous college engineering related classes and several student engineering organizations also toured the facility. Safety personnel such as Austin Fire Department, UT Police Department, UT Safety Office and the Texas Department of Health also visited the facility to remain familiar with the laboratory and emergency response procedures unique to the facility.

## D. Fuel Transfer Cask Loan

A three element transfer cask was obtained as part of the fuel element acquisition from the Northrup Corporation. The donated cask is designed for standard elements of TRIGA fuel and is to be available for loan to other university reactor programs. A container to ship the empty cask is also available. Charges for the cask use will apply only to shipment costs.

## VII. Research Activities

The staff and users of the Nuclear Engineering Teaching Laboratory perform research, as both sponsored and non sponsored projects, in several different areas. Equipment and personnel are provided by the laboratory to supplement the research efforts of facility users, that include students, faculty and others. The following section lists research projects active during the calendar year. Major research funding or grants are presented in Table 16 for users of the facility.

A. Fuel Assistance

Sponsor: U.S. Department of Energy

Personnel: Dale Klein, NETL
Thomas L. Bauer, NETL

Description:

The U.S. Department of Energy has provided research support by providing reactor fuel cycle assistance for the currently operating reactor core at The University of Texas at Austin TRIGA reactor.

B. Summer Science Teachers Symposium

Sponsor: Electric Utility Companies of Texas

Personnel: Dale Klein, NETL

The Electric Utility Companies of Texas have sponsored Summer High School Science Teachers Symposium, a program designed to familiarize these teachers with the theory and technology of energy sources.

C. Texas Energy Science Symposium

Sponsor: Texas Atomic Energy Research Foundation

Personnel: Dale Klein, NETL
Orlan Ihms, Texas Utilities Electric Company

The Texas Atomic Energy Foundation has sponsored a symposium for outstanding high school science students for over 25 years. The program is intended to encourage students to pursue careers in the sciences or engineering. Yearly attendance for the 4 day symposium consists of about 250 students and 150 high school science teachers.

Table 16

Research Funding

| | | |
|---|---|---|
| Department of Energy<br>Fuel Assistance Program | ------ | |
| New Nuclear Engineering Teaching Laboratory<br>(includes D&D for existing facility) | | 5,860,700 |
| Electric Power and the Environment<br>6/87 - 8/87 | 20,000 | |
| Texas Energy Science Symposium<br>6/87-8/87 | 22,000 | |
| National Science Foundation<br>9/85 - 8/87 | 141,626 | |
| Sandia National Laboratories<br>2/85 - 9/87 | 90,000 | |
| Sandia National Laboratories<br>4/87 - 1/90 | 131,000 | |
| Texas Parks and Wildlife Department<br>8/31/87 | 25,400 | |
| Texas Parks and Wildlife Department | 23,000 | |
| Subtotal | | 453,026 |
| TOTAL | | 6,313,726 |

Heat Transfer and Friction Factor Analysis for Artificially Roughened Surfaces

Sponsor: Center for Energy Studies
National Science Foundation
University Research Institute

Personnel: Dale Klein, NETL
J. Parker Lamb, Mech. Eng.
Mike Krause, NETL
Michael Michael, Mech. Eng.

Description:

The proposed research is to determine the heat transfer and friction characteristics for surfaces with discrete roughness geometry. Two major aspects are to be examined in that this is both an experimental and an analytical investigation. Values of R(h+) and G(h+) in the universal velocity and temperature profiles will be examined. New experimental techniques have been developed at The University of Texas at Austin to measure local heat transfer values surrounding discrete roughness elements. A test assembly to examine artificially roughened surfaces is being designed. In addition, a new analytical method has also been developed to determine R(h+) and G(h+) values without making detailed velocity and temperature profile measurements. Analytical predictions will be made utilizing fundamental parameters in boundary layer theory coupled with the latest information on rough surfaces using integral techniques. Results from the experimental and analytical methods will be compared in order to gain insight as to the dominant mechanism involved for the use of discrete rough surfaces. This research has fundamental application for heat transfer augmentation.

Pressure Drop and Heat Transfer Measurements of Liquid Metal Flowing in a Packed Bed Under the Influence of a Magnetic Field

Sponsor: Center for Fusion Engineering
Texas Atomic Energy Research Foundation

Personnel: Dale Klein, NETL
Jon McWhirter
George Avlonitis, Mech. Eng.
Mike Crawford, Mech. Eng.

Description:

The flow of electrically conducting fluids through porous media in the presence of a magnetic field has recently begun to generate significant interest due to potential applications for fusion reactors. This study is designed to examine the pressure drop and heat transfer from a liquid metal (NaK) flowing through a packed bed of stainless steel spheres under the influence of a transverse magnetic field. Results of this investigation should have direct applications on the design of fusion breeder blankets using liquid metal flowing around spheres of fertile material.

Thermal Analysis of Nuclear Shipping Containers

Sponsor: Sandia National Laboratories

Personnel: Randy Manteufel
Dale E. Klein

Description:

The thermal analysis of shipping containers to be used in the transport of spent nuclear fuel is an important safety issue. Sandia National Laboratories has been involved in safety issues for the transport of nuclear material for many years. The University of Texas at Austin (NETL) has been involved in the specific issues of thermal analysis of these containers for several years. The current project is intended to benchmark a thermal analysis computer code (Q/TRAN) and pre and post processing software PATRAN-G using four standard model problems. Comparisons will be made with other applicable codes currently available at UT (including HEATING 5). Sensitivity studies will be performed to further evaluate Q/TRAN's suitability for thermal analysis. Enhancements, if any, that will increase the current capabilities of the software will be suggested and developed if feasible.

Application of COBRA for shipping Cask Analysis

Sponsor: Sandia National Laboratories

Personnel: Randy Manteufel, Mechanical Engineering
Dale Klein, NETL

Description:

A thermal hydraulic computer code, COBRA, has been applied for both steady state and transient analysis. Previous research at The University of Texas at Austin involved the modification of the COBRA code and created a new version COBRA*GCFR 4P/UT. The current research is directed towards modifying COBRA*GCFR 4P/UT so that it may be applied to transient conditions for shipping cask analysis. One specific modification will be to develop a more sophisticated model for analyzing radiation heat transport. Results using this code will be compared with the results from Q-TRAN and HEATING-6 where possible. In addition, recommendations will be made regarding COBRA's use for dry storage analyses.

Transportation Analysis of Spent Fuel & High Level Wastes

Sponsor: Nuclear Engineering Teaching Laboratory
Personnel: Danny Smith, NETL
Dale Klein, NETL
Thomas L. Bauer, NETL

Description:

The current methodology (i.e., overall plan for analysis which integrates discrete computer codes and other computational elements) for analysis of high-level waste and spent fuel transportation is not directed toward minimizing radiation exposure but rather is an attempt to demonstrate minimum compliance with statutory and regulatory requirements. The current models (i.e., algorithms and computer codes) exhibit deficiencies and the thesis to be examined for this work is that more representative and credible models can be developed for radioactive waste transportation analyses and those models can be integrated into a methodology that allows selection of routes resulting in minimum radiation exposure. This work will also examine options for cost-effective enhancement of transportation operations with the intent of minimizing public and occupational exposure to radiation as well as exposure to radiation and non-radiation transportation risks (recognizing that elimination of risk is neither possible nor necessary but that achievement of exposures as low as reasonably achievable, ALARA, is prudent).

Neutron Transport Studies: Neutron Multiplication by Beryllium

Sponsor: National Science Foundation

Personnel: Nolan E. Hertel, Center for Fusion Engineering

Description:

The use of beryllium as a neutron multiplier is central to the current fusion breeder design. Recent measurements of beryllium neutron multiplication and reevalutions of beryllium nuclear data indicate that the multiplying performance of beryllium previously has been overestimated, possibly by as much as 25%. If beryllium's performance as a neutron multiplier has indeed been overestimated even by as much as 10%, the direction of the fusion breeder program in the United States might well change. It is tantamount to the current fusion breeder concepts that the issue of beryllium neutron multiplication be resolved. Therefore, an experiment using a spherical shell of beryllium is being proposed.

The beryllium experiment has been designed to measure multiplication resulting from DT, DD, PuBe, and 252Cf neutron sources being placed in a spherical shell. By doing so the sensitivity of the multiplication to spectral shape can be observed. In addition, the use of these four sources helps to simulate the effect of neutron source degradation in a fusion reactor. The neutron multiplication will be obtained directly from summing weighted Bonner ball measurements of the neutron leakage. The neutron multiplication obtained in this manner will provide a number which tests the capability of the current beryllium nuclear data to calculate total neutron multiplication.

Measurement of Nutrional and Other Elements in Bread

Sponsor: Nuclear Engineering Teaching Laboratory
Food Research Center, University of Idaho

Personnel: F.Y. Iskander
K.R. Davis

Description:

Egyptian bread samples were collected from several locations across the country. Cereal and other components used for bread making depend on location (city, village or nomad). The objective of the study is to determine the concentration of nutritional elements in the different bread samples and to study a possible correlation between the iron content of bread and cases of iron deficient anemia.

Comparison Between Imported and Locally Manufactured Baby Food in Nigeria

Sponsor: Nuclear Engineering Teaching Laboratory
Dept. of Chemistry, University of IFE, Nigeria

Personnel: F.Y. Iskander
O.I. Asubiojo

Description:

The concentration of nutritional, probably nutritional and toxic trace elements in baby food locally produced in Nigeria were compared to imported brands. Based on the total element content no significant difference was observed between local and imported baby foods. However, mineral bio-availability from the different brands may vary.

New Method for the Determination of Iodine Value by Instrumental Neutron Activation Analysis

Sponsor: Nuclear Engineering Teaching Laboratory

Personnel: F.Y. Iskander

Description:

Measuring the degree of unsaturation for oils and fats, as expressed by iodine value (I.V.), is an important step in the production of shortenings and margarine fats. Measuring I.V. is also of great importance to detect adulteration of vegetable oils with highly saturated animal fats and mineral oils. Early methods for the determination of I.V. depend on mixing a halogenating agent with the oil sample for a certain period of time, then titrating the residual unreacted halogenating agent. Most of these methods require preparation of special reagents, large sample size, and handling of corrosive or toxic chemicals. In addition, a long time (up to 48 hours) is required to prepare fresh reagents before starting the analysis.

A new microanalytical method has developed to measure the I.V. of oils and fats. Bromine vapor was used to saturate the ethylenic double bond in the oil samples. The quantity of Br reacted was determined by instrumental neutron activation analysis (INAA). The analysis of 50 samples was completed in 75-100 minutes (compared to several days by other methods).

Determination of Selenium. A quality assurance project to evaluate the minimum detection limit.

Sponsor: Department of Parks and Wildlife, State of Texas

Personnel: T. L. Bauer
F.Y. Iskander

Description:

The Department of Parks and Wildlife for the State of Texas is interested in determining the concentration of selenium, in fish, in several lakes across the state. To evaluate the quality of analysis, the department requested the participant laboratory to analyze a number of biological material for selenium content. No significant variation was observed between the results reported from NETL and the certified values (except for one sample). Results of the analysis were intended to provide quality assurance information to the department on the measurement methods performed by several laboratories.

Selenium and Other Metals in Fish Tissues

Sponsor: Department of Parks and Wildlife, State of Texas

Personnel: T.L. Bauer
F.Y. Iskander

Description:

Tissue from muscle and liver of fish samples from several Texas lakes are analyzed for several elements known to be toxic. Elements of interest are selenium, arsenic, mercury and zinc. This measurement is part of an environmental program for the State to examine the conditions of waters subject to certain types of power plant or industrial effluent releases.

## VIII. Publications From the Nuclear Engineering Teaching Laboratory

Ph.D. Dissertations

1. R.D. O'Dell, "The Angular Thermal Neutron Spectrum in the Vicinity of the Interface Between Two Media", Ph.D. Dissertation, The University of Texas at Austin, 186 pp., January 1965.

2. B.E. Thompson, Sr., "Cryogenic Neutron Spectra Measurements Across a Discontinuity in Temperature and Properties", Ph.D. Dissertation, The University of Texas at Austin, 149 pp., January 1965.

3. M.G. Stevenson, "Investigations on the Macroscopic Nodal Approach to Space-dependent Nuclear Reactor Kinetics", Ph.D. Dissertation, The University of Texas at Austin, 203 pp., August 1968.

4. P.J. Rodriguez, "Time and Energy Dependent Neutron Distribution in a Pulsed Multiplying Medium", Ph.D. Dissertation, The University of Texas at Austin, 205 pp., January 1969.

5. F.A. Rodriguez-Gonzalez, "Application of Neutron Activation Analysis to the Study of Interstitial Solid Solution of Oxygen in Niobium and in Niobium-Titanium Alloys", Ph.D. Dissertation, The University of Texas at Austin, 131 pp., August 1970.

6. G.D. Atkinson, Jr., "Nondestructive Uranium Assay by Delayed Gamma Ray Analysis Following Californium- 252 Neutron Interrogation", Ph.D. Dissertation, The University of Texas at Austin, 183 pp., August 1971.

7. G.D. Bouchey, "The Optimization of Nuclear Systems", Ph.D. Dissertation, The University of Texas at Austin, 231 pp., August 1971.

8. J.B. Whitworth, "The Development and Application of a Systematic Approach to Elemental Analysis in Forensic Investigations", Ph.D. Dissertation, The University of Texas at Austin, 223 pp., December 1971.

9. J. Freim, "Theoretical and Experimental Evaluation of Nuclear Data and Calculation Techniques for Fusion Reactor Blanket Design", Ph.D. Dissertation, The University of Texas at Austin, 210 pp., December 1972.

10. D.G. Anderson, "Fission Product Mass-Yield Measurements from Intermediate Energy Neutron Fission of Plutonium-239 and Plutonium-241", Ph.D. Dissertation, The University of Texas at Austin, 125 pp., December 1972.

11. J.R. Deen, "Measurement of Fission Product Yields from Thorium-232 in a Californium-252 Fission Neutron Spectrum", Ph.D. Dissertation, The University of Texas at Austin, 141 pp., May 1973.

12. T.A. Parish, "Neutronic and Photonic Analyses of Simulated Fusion Reactor Blankets Containing Thorium and Natural Uranium", Ph.D. Dissertation, The University of Texas at Austin, 329 pp., January 1974.

13. J.H. Vanston, Jr., "Use of the Partitive Analytical Forecasting (PAF) Technique for Analysis of the Effects of Various Funding and Administrative Strategies on Nuclear Fusion Power Plant Development", Ph.D. Dissertation, The University of Texas at Austin, 459 pp., January 1974.

14. E.M.B. Sorensen, "Thermal Effects on the Biological Magnification of Arsenic in Green Sunfish, Lepomis Cyanellus", Ph.D. Dissertation, The University of Texas at Austin, 233 pp., May 1974.

15. S.P. Nichols, "Application of the Partitive Analytical Forecasting (PAF) Technique to the United States Controlled Thermonuclear Research Effort," Ph.D. Dissertation, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, December 1975.

16. C.T. Rombough, "The Total Energy Investment in Nuclear Power Plants", Ph.D. Dissertation, The University of Texas at Austin, January 1975.

17. J.L. MacDonald, "Investigation of Pattern Recognition Techniques for the Identification of Splitting Surfaces in Monte Carlo Particle Transport Calculations", Ph.D. Dissertation, The University of Texas at Austin, August 1975.

18. S.A. Hodge, "Determination of Friction Factors and Heat Transfer Coefficients for Flow Past Artificially Roughened Surfaces", Ph.D. Dissertation, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, December 1979.

19. Y. Yang, "Heat Transfer Through A Randomly Packed Bed of Spheres by the Monte Carlo Method", Ph.D. Dissertation, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, December 1981.

20. M.M. Razzaque, "Finite Element Analysis of Combined Mode Heat Transfer, Including Radiation in Gray Participating Media", Ph.D. Dissertation, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1982.

21. G.F. Polansky, "A Finite Element Analysis of Incompressible Laminar and Turbulent Flow with Heat Transfer past Irregular Surfaces", Ph.D. Dissertation, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1983.

22. T.L. Sanders, "Magnetohydraulic Flow Through a Packed Bed of Electrically Conducting Spheres", Ph.D. Dissertation, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1985.

23. R.D. Smith, "Routing and Scheduling of Radioactive Material Shipments", Ph.D. Dissertation, Mechanical Engineering Department, The University of Texas at Austin, August 1987.

Masters Thesis

1. K.L. Gilbert, "Neutron Flux Mapping of a Subcritical Reactor Core with a Polyethylene Reflector", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 61 pp., June 1961.

2. T.T. Doss, "Neutron Density Distribution in an Unreflected Subcritical Reactor Core", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 63 pp., June 1961.

3. J.M. Norwood, "The Point Source Transport Solution for the Position and Velocity Dependent Neutron Distribution in a Spherical Body of Non-Multiplying Material", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 75 pp. June 1962.

4. R.W. Reed, "Effect of a Cadmium Control Rod on the Neutron Density in a Subcritical Reactor", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 85 pp., August 1962.

5. P. Berananda, "Neutron Flux Distribution of a Subcritical Reactor Core with a Graphite Reflector", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 40 pp., January 1962.

6. T.A. Fredericks, "Thermal Neutron Flux Distribution Due to a Plane Wave Source in an Unreflected Reactor Assembly", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 107 pp., August 1963.

7. D.G. Martin, "Film Detector for a Neutron Spectrometer", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, June 1963.

8. M.L. West II, "Flux Decay Rate in a Reflected Subcritical Reactor", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 55 pp., August 1963.

9. R.S. Kolflat, "An Experimental Approach to the Study of Nucleonic Fundamentals", Masters Thesis, Mechanical Engineering (Nuclear

Engineering) Department, The University of Texas at Austin, 190 pp., May 1965.

10. J.B. Whitworth, "A Cryogenic Irradiation Device for the TRIGA Mark I Nuclear Reactor", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 52 pp., January 1967.

11. D.A. Pullen, "A Rod Oscillator Design and Zero Power Transfer Function Measurement for a TRIGA Mark I Reactor," Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, January 1967.

12. G.F. Malan, "Transfer Function Analysis of Temperature and Xenon Feedback in Coupled-Core Nuclear Reactor Systems", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 69 pp., August 1967.

13. F.H. Antunez-Castillo, "Gamma Radiation Dosimetry Techniques and Application to Mapping of The University of Texas Cobalt-60 Irradiation Facility", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 60 pp., September 1968.

14. R. Valiente, "Neutron Radiography with The University of Texas TRIGA Nuclear Reactor", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, August 1968.

15. J.A. Villalobos, "A Study of Gamma Radiation Dosimetry Techniques and Application to Radiation Field Mapping", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, January 1969.

16. M.A. Zuniga, "Delayed Neutron Counting Technique for Uranium Determination", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, January 1969.

17. G.D. Atkinson, Jr., "Investigation of the Dynamic Behavior of a Two-Region Subcritical Reactor", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, January 1969.

18. M. Gallardo, "Trace Elements in Six Quartz Samples by Nondestructive Neutron Activation Analysis Technique", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, January 1969.

19. F.G. Pasos, "Nondispersive X-Ray Fluorescence Analysis using a Lithium Drifted Germanium Detector", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, 54 pp., January 1969.

20. D.G. Jopling, "The Politics of Nuclear Reactor Siting", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, December 1970.

21. A.H. Urdaneta, "A Programmed Associative Analyzer", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, December 1960.

22. K.R. Waid, "Solid State Radiation Detection Devices: Fabrication, Techniques and Application to Nuclear Engineering", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, January 1970.

23. V.H. Chanto, "Neutron Activation Analysis of Chlorine and Bromine in Some Haliburton-Bancroft Rocks and Minerals", Masters Thesis, Physics (Nuclear Engineering) Department, The University of Texas at Austin, January 1970.

24. R.J. Gramatges-Figueras, "Neutron Waves in Cylindrical Geometries for a Subcritical Reactor", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 98 pp., May 1970.

25. E. Oelkers, Jr., "A Learning Method for Identification of Nuclear Reactor Point Dynamics", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 165 pp., August 1970.

26. J.R. Owen, "Calculation of Resonance Integrals Using the Intermediate Resonance Approximation", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 140 pp., January 1970.

27. C.T. Rombough, "Application of Queueing Theory to closed-Loop Computer-Reactor Control Systems", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 78 pp., December 1970.

28. A.H.U. Bohorquez, "A Programmed Associative Analyzer", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 98 pp., December 1970.

29. J.J. Chromik, "Experimental Determination of the Neutron Flux in The University of Texas Californium- 252 Irradiation Facility", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 85 pp., December 1971.

30. M.B. Owen, "Fuel Management Using Dynamic Programming", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 59 pp., May 1972.

31. C.E. Brauer, "Thermal Neutron Radiography with a Lithium-Lead Collimator-Filter", Masters Thesis, Mechanical Engineering

(Nuclear Engineering) Department, The University of Texas at Austin, 64 pp., May 1972.

32. J.L. MacDonald, "Heuristic Learning Control for Nuclear Reactors", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 137 pp., August 1972.

33. S.G. Barbee, "Neutronic Calculations in a Simulated Fusion Reactor Blanket", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 259 pp., November 1972.

34. D.M. Williams, "Identification of Thermal Feedback Parameters for a TRIGA Mark I Reactor", Masters Thesis, Electric Engineering Department, The University of Texas at Austin, 53 pp., December 1972.

35. L.D. Hansborough, "Overall Tritium Considerations for Controlled Thermonuclear Reactors", Masters Thesis, The University of Texas at Austin, 154 pp., May 1973.

36. M.E. Senglaub, "Cross Section Studies Based on the Statistical Model", Masters Thesis, The University of Texas at Austin, 109 pp., August 1973.

37. S.P. Nichols, "Experimental Determination of Neutron Fermi Age from Californium-252 Fission Spectrum to Cadmium Covered Indium Resonance in a Graphite Medium", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 101 pp., January 1974.

38. Thomas L. Bauer, "Discrimination of Uranium-235 and Plutonium-239 by Cyclic Activation and Delayed Gamma Ray Analysis Using Californium-252 as a Neutron Interrogation Source", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 178 pp., August 1974.

39. Olan D. Thompson, "Optimization of Shipping Containers for Radioisotopic Neutron Sources", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, 30 pp., (August 1974).

40. J.W. Davidson, "A Cost-Benefit Analysis for Partitioning Strategies Involved in High-Level Nuclear Waste Management", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1975.

41. J.P. Percy, "Experimental Determination of Local Convective Heat Transfer Coefficients Over a Ribbed Surface", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1979.

42. G.A. Taylor, "The Analysis of the Grid Spacer Pressure and Temperature Effects in SAGAPO", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, August 1979.

43. D.D. Hsu, "Determination of the Relative Toxicities of the Fission Products Produced in the Transmutation of Actinide Wastes", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, December 1979.

44. M.A. Ross, "Electrical Power Generation and Process Heat Application for Coal Gasification and Liquefaction Using a Very-High Temperature and Gas-Cooled Reactor", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1980.

45. T.L. Sanders, "An Alternative Numerical Method for the Steady State and Transient Thermal-Hydraulic Analysis of Gas-Cooled Fast Breeder Reactor Arrays", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1981.

46. J.E. Hamann, "Thermal Analysis of a Spent Fuel Railcar Shipping Cask in an Engulfing Fire", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1983.

47. M. Ally, "Preconcentration Method for the Determination of Uranium, Thorium and Transition Elements Using X-Ray Fluorescence and Activation Analysis", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1983.

48. A. Patterson-Hine, "Characterization of the Effects of Continuous Salt Processing on the Performance of Molten Salt Fusion Breeder Blankets", Masters Thesis, Mechanical Engineering (Nuclear Engineering) Department, The University of Texas at Austin, May 1984.

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March 29, 1988

Director of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Sir:

Enclosed are twelve (12) copies of the calendar year 1987 Annual Report. These are being submitted according to 10 CFR Section 50.59.

Sincerely,

Thomas L. Bauer

Dr. Thomas L. Bauer
Assistant Director
Nuclear Engineering
Teaching Laboratory

TLB:dlw
Enclosure

cc: Dr. Dale Klein

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