Kansas State University
TRIGA Mark II Nuclear Reactor Facility

May 1997

DOE/ER/10723--T1

Final Report
Reactor Sharing Contract DE-FG02-80ER10273
Fiscal Years 1980-1995

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DISCLAIMER

Executive Summary:

This report is a final culmination of activities funded through the Department of Energy's (DOE) University Reactor Sharing Program, Grant DE-FG02-80ER10273, during the period 1 July 1980 through 30 June 1995. Progress reports have been periodically issued to the DOE, namely the Reactor Facility Annual Reports C00-2082/2219-7 through C00-2082/10723-21, which are contained as an appendix to this report. Due to the extent of time covered by this grant, summary tables are presented.

Table 1 lists the fiscal year financial obligations of the grant. As listed in the original grant proposals, the DOE grant financed 70% of project costs, namely the total amount spent of these projects minus materials costs and technical support. Thus the bulk of funds was spent directly on reactor operations. With the exception of a few years, spending was in excess of the grant amount.

As shown in Tables 2 and 3, the Reactor Sharing grant funded a immense number of research projects in nuclear engineering, geology, animal science, chemistry, anthropology, veterinary medicine, and many other fields. A list of these users is provided. Out of the average 3000 visitors per year, some groups participated in classes involving the reactor such as Boy Scout Merit Badge classes, teacher's workshops, and summer internships. A large number of these projects met the requirements for the Reactor Sharing grant, but were funded by the University instead.

Table 1: Fiscal Year Financial Record of DOE Grant DE-FG02-80ER10273

Fiscal Year	DOE Grant Amount	Reactor Time (h)	Est. # Samples Run	Cost per Hour	Cost per Sample	Project Costs	Materials Costs	Technical Support	Total Amount Spent
1981	$7,500	92	23	$65	$25	$6,555	$1,000	$1,000	$9,055
1982	$4,000	132	33	$65	$25	$9,405	$1,000	$1,000	$11,905
1983	$4,000	85	21	$65	$25	$6,050	$500	$500	$7,050
1984	$5,500	104	26	$65	$25	$7,410	$500	$500	$8,410
1985	$5,500	107	27	$65	$25	$7,630	$200	$300	$8,103
1986	$5,500	45	11	$65	$25	$3,200	$200	$300	$3,700
1987	$5,500	52	13	$65	$25	$3,705	$200	$300	$4,205
1988	$5,500	90	23	$100	$30	$9,690	$200	$300	$10,190
1989	$7,350	182	46	$100	$30	$19,580	$250	$350	$20,180
1990	$7,350	76	19	$100	$30	$8,170	$250	$350	$8,770
1991	$9,575	82	21	$100	$30	$8,830	$350	$500	$9,680
1992	$7,250	34	9	$100	$30	$3,670	$350	$500	$4,520
1993	$7,250	32	8	$100	$30	$3,440	$400	$700	$4,540
1994	$6,980	68	17	$100	$30	$7,310	$350	$500	$8,160
1995	$5,000	97	24	$100	$30	$10,420	$400	$700	$11,520
Totals	$93,755	1278	321			$115,065	$6150	$8800	$130,015

Table 2: Summary of Reactor Utilization (1 Jul 1980 through 30 Jun 1988)

	Fiscal Year:	1981	1982	1983	1984	1985	1986	1987	1988
a.	Total hours of operation*	398	440	501	401	410	469	441	308
b.	MWh of thermal energy production	30	47	58	36	36	52	43	31
c.	Hours operation at full power	132	207	250	163	223	222	187	125
d.	Operating hours in typical week	8	9	10	8	8	9	9	6
e.	Experiment hours irradiation services	242	284	345	245	254	313	285	152
f.	Nuclear engineering students using reactor for research	60	48	47	52	17	19	16	24
g.	Nuclear engineering graduate students using reactor for research	2	4	4	3	3	3	2	1
h.	KSU academic departments using reactor in instructional programs								
	Nuclear engineering	x	x	x	x	x	x	x	x
	Biology	NR.	NR.	NR.	x	x	x	x	x
	Chemistry	NR.	NR.	NR.	x	x	x	x	x
	History	NR.	NR.	NR.					
	Agricultural and Biological Engineering	NR.	NR.	NR.					
	Animal and Food Science	NR.	NR.	NR.					
i.	KSU academic departments using reactor in research program								
	Nuclear Engineering	x	x	x	x	x	x	x	x
	Mechanical Engineering				x				
	Chemical Engineering						x	x	
	Clothing and Textiles	x	x		x	x	x	x	
	Foods and Nutrition	x	x				x		
	Animal Science and Industry	x	x	x		x	x	x	
	Physics	x	x	x					x
	Chemistry	x	x	x	x	x			
	Geology	x	x	x	x	x	x	x	x
	Anthropology	x							
	Anatomy and Physiology			x					
	Veterinary Medicine		x	x	x				
j.	Outside direct users								
	University of Kansas	x	x	x					
	Purdue University			x					
	Regional Kidney Disease Program					x			
	Kansas Junior Academy of Sciences								x
	National Transportation Safety Board								x
k.	Outside indirect users (Cooperative Geology Research)								
	University of Kansas			x	x	x	x	x	x
	University of Southern California		x						x
	University of Georgia						x	x	
	Delft University	x	x	x	x				
	Louisiana State University						x	x	x
	Kansas Geological Survey	x	x	x	x	x		x	

Fiscal Year:	1981	1982	1983	1984	1985	1986	1987	1988
Canadian Geological Survey	x							
Indian Geological Survey	x	x	x	x				
Justus Liebig University	x							
Wright State University				x	x			
Wichita State University								x
Carleton College								x
University of Missouri (Columbia)					x			
College of Charleston							x	
Brooklyn College				x	x			
Rensselar Polytechnic Institute						x		

*Includes 13 hours per month operations in support of maintenance, surveillance, and testing.

NR. - Not Recorded

Table 3: Summary of Reactor Utilization (1 Jul 1988 through 30 Jun 1996)

	Fiscal Year:	1989	1990	1991	1992	1993	1994	1995	1996
a.	Total hours of operation*	257	370	411	449	299	363	394	309
b.	MWh of thermal energy production	26	26	25	23	13	22	27	24
c.	Hours operation at full power	117	115	125	106	56	87	107	90
d.	Operating hours in typical week	5	7	8	9	**	7	8	6
e.	Experiment hours irradiation services	143	214	259	293	143	207	238	153
f.	Nuclear engineering students using reactor for research	24	21	35	35	34	38	27	30
g.	Nuclear engineering graduate students using reactor for research	3	3	3	3	3	3	2	3
h.	KSU academic departments using reactor in instructional programs								
	Nuclear engineering	x	x	x	x	x	x	x	x
	Biology	x	x	x	x	x		x	x
	Chemistry	x	x	x	x	x	x	x	x
	History					x	x	x	x
	Agricultural and Biological Engineering								x
	Animal and Food Science							x	x
i.	KSU academic departments using reactor in research program								
	Nuclear Engineering	x	x	x	x	x	x	x	x
	Chemical Engineering	x							
	Chemistry			x	x				
	Biology	x							
	Physics	x							
	Geology	x	x	x	x	x	x	x	x
	Anthropology								x
	Veterinary Medicine			x	x		x	x	
j.	Outside direct users								
	Boeing Corporation					x			
	Wolf Creek Nuclear Operating Corp./ANS						x	x	x
	Armed Forces Radiobiology Res. Inst.						x	x	
	SE Kansas Agricultural Experiment Station						x	x	
	Kansas Highway Patrol								x
k.	Outside indirect users (Cooperative Geology Research)								
	University of Kansas	x	x	x		x	x	x	
	Stanford University			x	x				
	Louisiana State University	x	x	x	x				
	Kansas Geological Survey		x	x	x	x	x	x	x
	University of Cincinnati			x					
	University of Nevada-Reno								x
	Wichita State University	x			x	x			
	Baylor University	x	x						
	Carleton College	x							
	Univ. degli Studi della Basilicata						x	x	x

Fiscal Year:	1989	1990	1991	1992	1993	1994	1995	1996
Geoforschungs Zentrum Potsdam						x	x	
Virginia Technical University								x
University of Maine							x	
SUNY at Stony Brook							x	x

*Includes 13 hours per month operations in support of maintenance, surveillance, and testing.

**Utilization low in FY 1993 because of remodeling, console replacement, and cooling system replacement.

Table 5: Visitors to Facility FY 81-88

Fiscal Year	1981	1982	1983	1984	1985	1986	1987	198
a. Participants of workshops or institutes	370	50	412	659	321	79	106	9
b. Private individuals/clubs	256	225	232	448	432	449	724	42
c. Secondary, and junior college students	273	540	469	581	634	888	937	80
d. College and university students	902	1209	907	613	955	541	713	72
e. Open-house participants	1200	1200	1028	850	542	359	508	63
Total	3001	3224	3048	2301	2884	2316	2988	268

Table 6: Visitors to Facility FY 89-96

Fiscal Year	1989	1990	1991	1992	1993	1994	1995	199
a. Participants of workshops or institutes	168	138	120	186	*	145	112	12
b. Private individuals/clubs	480	224	264	626	201	55	343	10
c. Secondary, and junior college students	857	1161	1352	1224	517	535	622	90
d. College and university students	334	393	208	197	189	837	660	64
e. Open-house participants	640	607	892	786	452	605	548	42
Total	2479	2523	2836	3019	1359	2177	2285	219

Summary of Reactor Sharing Users

During the period July 1, 1975 through June 30, 1996 the KSU Nuclear Reactor was used by or for the following persons from institutions other than Kansas State University

Activity	Institution	Researcher
Classroom Instruction	Univ. of Nebraska (Mech. Engg.)	D. A. Alexander
	University of Tulsa (Engg.)	J. D. McCoy
	Kansas State College at Emporia (Secondary Ed.)	Charles Creager
	Marymount College (Chem.)	Sr. Zepherine
	Wamego High School (Chem.)	L. Riblett
		S. Kissick
	Kansas 4-H Discovery Days	L. Lindquist
	American Nuclear Society (High School Teachers)	S. Maycock
Neutron Activation Analysis	Univ. of Kansas (Biophysics)	R. Johnson
		C. M. Beach
		J. Thomas
		D. F. Lan
	Univ. of Kansas (Pharmacology)	S. Bannister
	Univ. of Kansas (Geology)	P. Bickford*
		R. VanSchuus*
		D. Walker*
	Kansas Bureau of Investigation	(Forensic)
	Kansas Geological Survey	Peter Berendsen*
	Kansas Highway Patrol	Jeff Deitz
	Pittsburg State Univ. (Biology)	-
	Univ. of Wisconsin (Geology)	G. Medaris*
	Indian Geological Survey	D. K. Paul*
	Louisiana State Univ. (Geology)	M. Murray*
		M. DiMarco*
		Don Lowe*
		R. Cox*
	Univ. of Southern California (Geology)	J. L. Anderson*
	Delft University	Pieter VanLeeuwen*
	University of Indiana (Geology)	A. Basu*
	Hessisch Geol. Lands.	H. J. Lippert*
	Univ. of Utah (Geology)	W. P. Nash*
	Justus Liebig Univ.	G. Shur*
	Canadian Geological Survey	-
	Purdue University	Dennis Anderson*
	Wright State University	Paul Pushkar*
	Franklin and Marshall College	A. H. Barabas*
	Univ. of Brunswick	S. W. Bachinski*

Cleveland State University	M. Tevesz*
Brooklyn College	S. Bhattacharya*
University of Missouri (Columbia)	K. Shelton*
Regional Kidney Disease Program	C. L. Smith
National Transportation Safety Board	R. Dickens
Kansas Junior Acad. of Sciences	S. Kissick
University of Georgia	M. Roden*
College of Charleston	R. Nusbaum*
Carleton College	S. Boardman*
Wichita State University	G. Sangmor*
	J. Gries*
Baylor University	D. Parker*
University of Cincinatti	M. Suidan
Stanford University	Dennis Bird*
Armed Forces Radiobiology Research Institute	Mark Moore
Univ. degle STudi della Basilicata	Giovanni Mongelli*
Geoforschungs Zentrum Potsdam	Peer Hoth*
University of Maine	Charles Guidotti*
State University of NY (Stony Brook)	Barbara Bock*
Virginia Technical University	Spencer Cotkin*
University of Nevada-Reno	Richard Schweikert*

*In collaboration with R.L. Cullers and J.L. Graf, Jr., of the Geology Department, Kansas State University.

Appendices:
KSU Reactor Facility Annual Reports Fiscal Years 1981-1995

COO-2082/2219-7

KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1980 - June 30, 1981

Richard E. Faw and Timothy M. DeBey

Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66506

July, 1981

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG02-80ER10273
DE-AC02-76ER02219
(Formerly EY-76-C-02-2219)
DE-AC02-76ER02082
(Formerly EY-76-C-02-2082)

Annual Progress Report

1 July 1980 - 30 June 1981

KSU TRIGA Mk II Nuclear Reactor Facility

Department of Nuclear Engineering

Kansas State University

Manhattan, Kansas 66506

1. Introduction

During FY 1981 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element	32 g

Total ^{235}U	3.0 kg
Maximum Power (Steady-State)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Neutron Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator
Ancillary Facilities	Three 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Si-Li), and magnetic-tape data-transfer.

3. Personnel

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Timothy M. DeBey
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis
Reactor Operators	N. Dean Eckhoff Victor A Simonis
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Timothy M. DeBey (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Louis W. Ellsworth

4. Reactor Utilization

a.	Total hours of operation*	397.5
	MW-hr produced	30.26
b.	Total hours of operation at full power	131.6
c.	Operating hours in typical week	8
d.	Experiment-hours of irradiation service	241.5
e.	Formal courses using reactor and number of students involved	Radiation Detection Laboratory (17) Reactor Operations Planning (14) Applied Reactor Theory (16) Nuclear Engineering Laboratory (13)
f.	Nuclear engineering graduate students using reactor for thesis work	Robertus Ismuntoyo Greg Nelson
g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Irradiation Services Chemistry Foods and Nutrition Physics Anthropology Animal Science Clothing and Textiles Tours and Demonstrations General Engineering Industrial Engineering Geology Education Chemistry

*Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

h.	Commercial or non-academic utilization	None
i.	Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF)
j.	Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiations for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC02-76ER02082. In FY 1981, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 1406 sample insertions in 1979. Activation analysis required some 3400 gamma-ray spectra. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Nuclear Engineering Projects

Neutron Sensitivity of TLDs: Irradiations were performed to aid in measurement of differing shapes of TLD glow curves following gamma-ray and mixed neutron and gamma-ray exposure. Principal Investigator: G. G. Simons

Trace Elements in NBS Coal Sample: Comparisons were made of neutron activation analyses of a coal sample performed by the National Bureau of Standards and by the KSU Neutron Activation Analysis Laboratory. Principal Investigator: G. G. Simons

Absorption of Iodine on Ion-Exchange Resin: Measurements were made of the collection efficiency for iodine on Dowex MSA-1 Ion-Exchange Resin. Principal investigator: G. G. Simons

Irradiations for Other KSU Researchers

Synthesis of Protein in Cow's Rumen: [Animal Science Department] Flow rates of Ce, Sm, and La were measured to study the synthesis of protein in cow's rumen, including passage of amino acids to the duodenum for absorption. Principal Investigator: Erle Bartly

Chick Tibia Growth: [Foods and Nutrition Department] Tibia development in chicks from one day to six weeks old was investigated as a function of Mn and Zn levels in feed. Principal Investigator: Robert Reeves.

Silicon Analysis: [Physics Department] Sensitivity studies were performed for the neutron activation analysis for silicon in various matrices. Principal Investigator: Basil Curnutte

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the courses "Applied Reactor Theory" required of all senior-level students and "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted exclusively to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of

laboratory requirements: "Principles of Radiative Detection," and "Radiation Detection Laboratory." The reactor is also used in the elective course "Radiation Detection and Measurement."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1981, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendees at energy conferences, DOE Workshops, and NSF workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for 1980 was about 3,000. This includes 273 grade school and high school students; 902 Kansas State University students; an estimated 1,200 persons during Open House; 370 participants of workshops or institutes held at KSU; and 256 private individuals.

6. Summary of Reactor Utilization
Nuclear Engineering Department

	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	8.7	2.6	-
Operator Training and Requalification	0.9	0.1	-
Undergraduate Class Use	34.6	1.7	-
Graduate Class Use	11.8	-	-
Isotope Production (Class Use)	4.8	0.7	42

* Includes full-power hours.

Neutron Activation Analysis			
a. Iodine Mobility Studies	27.5	0.0	329
b. Thermoluminescence Dosimetry	0.2	0.0	65
c. Trace Elements in Coal	1.0	0.0	3
d. Nitrogen Analysis in Wheat	0.3	0.0	2
e. Radiation Safety Studies	0.8	0.0	13
f. Miscellaneous	3.8	1.0	85
Subtotal Activation Analysis	33.6	1.0	495
Subtotal Nuclear Engineering Department	94.4	6.1	537
Other University Departments			
Neutron Activation Analysis			
a. Trace metals in antique silk [Clothing and Textiles]	12.7	1.9	119
b. Bovine metalolism studies [Animal Sciences]	25.3	23.5	506
c. Iodine and chlorine analyses [Chemistry]	1.3	-	9
d. Sensitivity studies for silicon analysis [Physics]	1.6	0.8	10
e. Chick tibia development [Foods and Nutrition]	3.7	2.5	50
f. Trace metal analyses in copper rivits [Anthropology]	1.7	-	26
Subtotal other University Departments	46.3	28.7	720
Outside Users			
Isotope Production [Wamego High School]	0.1	0	1
Neutron Activation Analysis [Administered by Geology Department, KSU]	100.7	96.8	146
Subtotal Outside Users	100.8	96.8	147
Total Reactor Utilization	241.5	131.6	1406

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 Kansas Geological Survey

Studies have continued on the petrology of the Riley County kimberlites in Kansas with the goal of understanding how these kimberlites form and evolve. Project directors are Pieter Berendson of

the Kansas Geological Survey and R. L. Cullers of the Geology Department at Kansas State University. These studies required 60 hours of reactor time during the year.

7.2 Indian Geological Survey

Studies have begun on rare earth elements in Indian iron ores with the goal of determining the rare earth element patterns in the ores and the relationship of the patterns to vertical and horizontal facies within the sedimentary basins in which the ores were deposited. Project directors are D. K. Paul of the Indian Geological Survey and Joseph L. Graph, Jr., of the Geology Department at Kansas State University. During the year, these studies required 3 hours of reactor time.

7.3 Delft University

Studies are being made of the origin of the Urucum iron and manganese deposits in Mato Grosso do Sul in Brazil. The goal of the research is to use rare earth element patterns and other geochemical data to determine the depositional history and environment of the iron-and manganese-rich chemical sediments. Project directors are Pieter Van Leeuwen of Delft University and Joseph L. Graph, Jr., of the Geology Department at Kansas State University. These studies required 13 hours of reactor operation during the year.

7.4 Justus Liebig Univ. and Hessisches Geologisches Landsamt

Studies are in progress on rare earth elements in iron ores from the Lahn-Dill District in Germany. The research goal is to determine rare earth element patterns in the formations, to compare them to patterns of other iron formations, and to relate the pattern to genetic

models. Project directors are Gunter Suhr of Justus Liebig Univ., H. J. Lippert of the Hessisches Geologisches Landsamt and Joseph L. Graf, Jr., of the Geology Department at Kansas State University. During the year, these studies required 15.7 hours of reactor operations.

7.5 Kansas State University

A study has been made of rare earth elements in carbonate rocks and minerals associated with stratabound Pb-Zn deposits in Southeast Missouri. The goal was to use rare earth element patterns as indicators of the history of the solutions responsible for the ore deposits. Project director is Joseph L. Graf, Jr., of the Geology Department at Kansas State University. This study required 9 hours of reactor time.

7.6 Recent Publications

Anderson J. L., R. L. Cullers, and W. R. Van Schmus (1980) Anorogenic metaluminous granite plutonism in the mid-Proterozoic of Wisconsin, U.S.A. Contrib. Mineral. Petrol. 74 311-328.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: Predominately basic and ultrabasic rocks. Chapter 6, in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igeneous rocks of the continental crust: intermediate and silicic rocks; ore petrogenesis. Chapter 7 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Bickford, M. E., J. R. Sides, and R. L. Cullers (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part I: Field, petrographic, and major element data. Jour. of Geophys. Res., in press.

Cullers, R. L., R. J. Koch, and M. E. Bickford (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part II: trace element data. Jour. Geophys. Res., in press.

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3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element	32 g

4. Reactor Utilization

a.	Total hours of operation*	440.4
	MW-hr produced	46.60
b.	Total hours of operation at full power	207.4
c.	Operating hours in typical week	8.5
d.	Experiment-hours of irradiation service	284.4
e.	Formal courses using reactor and number of students involved	Prin. of Radiation Detection (20) Reactor Operations Planning (10) Applied Reactor Theory (11) Nuclear Engineering Laboratory (7)
f.	Nuclear engineering graduate students using reactor for thesis work	Timothy DeBey Jack Higginbotham Shirley Essam Bob Stuewe
g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Chemistry Foods and Nutrition Physics Veterinary Medicine Animal Science Agronomy Clothing and Textiles Tours and Demonstrations General Engineering Industrial Engineering Geology Education Chemistry

*Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

h. Commercial or non-academic utilization	None
i. Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF)
j. Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiations for neutron activation analysis (NAA). THis activity is supported in part by the U.S. Department of Energy under contract DE-AC02-76ER02082. In FY 1982, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 1059 sample insertions in 1982. Activation analysis required some 2500 gamma-ray spectra. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Trace Elements in NBS Coal Sample: Comparisons were made of neutron activation analyses of a coal sample performed by the National Bureau of Standards and by the KSU Neutron Activation Analysis Laboratory. Principal Investigator: G. G. Simons

Trace Elements in Animal Cancers: Trace element concentrations are determined in biological samples extracted form healthy animals and animals exhibiting different phases of cancer. Emphasis is placed upon developing sample collection, preparation and storage procedures; optimizing the INAA

procedure for biological samples; and data acquisition and correlation. This is a joint project of the Nuclear Engineering, Animal Sciences, and Veterinary Medicine Departments. Principal Investigator: G. G. Simons.

Irradiations for Other KSU Researchers

Synthesis of Protein in Cow's Rumen: [Animal Science Department] Flow rates of Ce, Sm, and La were measured to study the synthesis of protein in cow's rumen, including passage of amino acids to the duodenum for absorption. Principal Investigator: Erle Bartly

Chick Tibia Growth: [Foods and Nutrition Department] Tibia development in chicks from one day to six weeks old was investigated as a function of Mn and Zn levels in feed. Principal Investigator: Robert Reeves.

Soybean Root Uptake Studies: The purpose of this research is to identify elements which can be foliar-applied to soybean plants and translocated to the root system, thereby labeling the root system. Once these elements are identified, they will be used to label soybean root systems in an effort to determine inter-row penetration of these roots among genotypes at two soil volumes (deep soil, shallow soil). This information could give an indication of the relative competitive ability of different soybean genotypes. When correlated with yield data, we may be able to determine whether or not there is interaction between the degree of inter-row penetration (competitive ability) and soil volume. If interaction occurs, implications for a soybean breeding program would be that genotypes selected at a location with a deep soil may be poorly adapted in an area with shallow soils. Therefore, genetic improvement for soybean yield in an area of shallow soils may be expediated by selecting genotypes at a location with shallow soils. Principal investigator: W. T. Schapaugh, Jr.

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the courses "Applied Reactor Theory" required of all senior-level students and "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted exclusively to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiative Detection," and "Radiation Detection Laboratory. The reactor is also used in the elective course "Radiation Detection and Measurement."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1982, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendess at energy conferences, DOE Workshops, and NSF workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for 1982 was 3224. This includes 540 grade school and high school students; 1209 Kansas State University students; an estimated 1,200 persons during Open House; 50 participants of workshops or institutes held at KSU; and 225 private individuals. The University students include 469 persons enrolled in chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	28.6	2.7	-
Operator Training and Requalification	0.6	0.1	-
Undergraduate Class Use	38.1	2.4	-
Graduate Class Use	7.2	4.3	22
Isotope Production (Class Use)	0.5	0.0	11
Isotope Production (Research)			
a. Beta-source preparation	32.7	30.0	27
Neutron Activation Analysis			
a. Trace Elements in Coal	0.0	0.0	7
b. Radiation Safety Studies	4.1	1.1	38
c. Miscellaneous	3.1	1.5	29
Subtotal Activation Analysis	7.2	2.6	74
Subtotal Nuclear Engineering Department	104.9	42.1	134
Other University Departments			
Isotope Production (Chemistry)	1.2	0.0	7
Neutron Activation Analysis			
a. Trace metals in antique woods and fabrics [Clothing and Textiles]	0.4	0.0	4
b. Bovine metalolism studies [Animal Sciences]	25.1	21.4	524
c. Iodine and chlorine analyses	1.6	0	12
d. Ion implantation studies [Physics]	2.1	2.0	5
e. Chick tibia development [Foods and Nutrition]	16.2	13.7	142
f. Soybean root-uptake studies [Agronomy]	0.0	0.0	46
g. Trace elements in horse hair [Veterinary Medicine]	0.2	0.0	2
h. Trace elements in animal cancers [Animal Science, Veterinary Medicine & Nuclear Engineering]	1.2	0.2	12
Subtotal other University Departments	48.0	37.3	747
Outside Users			
Neutron Activation Analysis [Administered by Geology Department, KSU]	131.5	128.0	171
Total Reactor Utilization	284.4	207.4	1059

* Includes full-power hours.

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 Kansas Geological Survey

Studies have continued on the petrology of the Riley County kimberlites in Kansas with the goal of understanding how these kimberlites form and evolve. Project directors are Pieter Berendson of the Kansas Geological Survey and R. L. Cullers of the Geology Department at Kansas State University. These studies required about 72 hours of reactor time during the year.

7.2 Indian Geological Survey

Studies are in progress on rare earth elements in Indian iron ores with the goal of determining the rare earth element patterns in the ores and the relationship of the patterns to vertical and horizontal facias within the sedimentary basins in which the ores were deposited. Project directors are D. K. Paul of the Indian Geological Survey and Joseph L. Graph, Jr., of the Geology Department at Kansas State University. During the year, these studies required about 5 hours of reactor time.

7.3 Delft University

Studies are being made of the origin of the Urucum iron and manganese deposits in Mato Grosso do Sul in Brazil. The goal of the research is to use rare earth element patterns and other geochemical data to determine the depositional history and environment of the iron-and manganese-rich chemical sediments. Project directors are Pieter Van Leeuwen of Delft University and Joseph L. Graph, Jr., of the Geology Department at Kansas State University. These studies required about 14 hours of reactor operation during the year.

7.4 University of Kansas

Studies have commenced on determination of geochronological and geochemical properties of the Wet Mountain region of southern Colorado. Project directors are M. E. Bickford of the Geology Department at the University of Kansas and R. L. Cullers of the Geology Department at Kansas STate University. During the year, the studies required about 36 hours of reactor operation.

7.5 University of Southern California (Los Angeles)

An investigation has begun on trace elements in the Whipple Mountain region of Southern California. Principal investigators are Lawford Anderson of the Geology Department at the University of Southern California, and R. L. Cullers of the Geology Department at Kansas State University. During the year, the investigation required about 4 hours of reactor operation.

7.6 Recent Publications

Anderson, J. L., R. L. Cullers, and W. R. Van Schmus (1980) Anorogenic metaluminous granite plutonism in the mid-Proterozoic of Wisconsin, U.S.A. Contrib. Mineral. Petrol. 74 311-328.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: Predominately basic and ultrabasic rocks. Chapter 6 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: intermediate and silicic rocks; ore petrogenesis. Chapter 7 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Bickford, M. E., J. R. Sides, and R. L. Cullers (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part I: Field, petrographic, and major element data. Jour. of Geophys. Res., in press.

Cullers, R. L., R. J. Koch, and M. E. Bickford (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part II: trace element data. Jour. Geophys. Res., in press.

Graph, Joseph L. and Bill Richards (1981) Rare Earth Elements in Hydrothermal Carbonates Associated with Breccia-Filling and Replacement, Pb-Zn-Cu Sulfide Deposits in Dolomite Host Rock, Viburnum Trend, Missouri. South Central Geological Society of America.

Val Leeuwen, Pieter, and Joseph L. Graph (1981) Geochemical Evidence Regarding the Formation of Manganese and Iron Deposits in the Urucum Region, Matto Grosso do Sul, Brazil. South Central Geological Society of America.

COO-2082/2219-9

KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1982 - June 30, 1983

Victor A. Simonis, Richard E. Faw, and Jack F. Higginbotham

Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66506

July, 1983

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG02-80ER10723
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DE-AC02-76ER02082
(Formerly EY-76-C-02-2082)

Annual Progress Report

1 July 1982 - 30 June 1983

KSU TRIGA Mk II Nuclear Reactor Facility

Department of Nuclear Engineering

Kansas State University

Manhattan, Kansas 66506

1. Introduction

During FY 1983 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element	32 g

Total ^{235}U	3.0 kg
Maximum Power (SteadyOState)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Neutron Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator
Ancillary Facilities	Three 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Si-Li), and magnetic-tape data-transfer.

3. Personnel

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Jack F. Higginbotham
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis Victor A. Simonis
Reactor Operators	N. Dean Eckhoff
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Jack F. Higginbotham (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a.	Total hours of operation*	500.8
	MW-hr produced	58
b.	Total hours of operation at full power	250.4
c.	Operating hours in typical week	9.6
d.	Experiment-hours of irradiation service	344.8
e.	Formal courses using reactor and number of students involved	Prin. of Radiation Detection (20) Reactor Operations Planning (10) Applied Reactor Theory (11) Nuclear Engineering Laboratory (7)
f.	Nuclear engineering graduate students using reactor for thesis work	Timothy DeBey Jack Higginbotham Donald Mei Bob Stuewe
g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Chemistry Physics Veterinary Medicine Animal Science Tours and Demonstrations General Engineering Industrial Engineering Geology Education Chemistry
h.	Commercial or non-academic utilization	None
i.	Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF)

*Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

Irradiations for Other KSU Researchers

Synthesis of Protein in Cow's Rumen: [Animal Science Department] Flow rates of Ce, Sm, and La were measured to study the synthesis of protein in cow's rumen, including passage of amino acids to the duodenum for absorption. Principal Investigator: the late Erle Bartley

Soybean Root Uptake Studies: The purpose of this research is to identify elements which can be foliar-applied to soybean plants and translocated to the root system, thereby labeling the root system. Once these elements are identified, they will be used to label soybean root systems in an effort to determine inter-row penetration of these roots among genotypes at two soil volumes (deep soil, shallow soil). This information could give an indication of the relative competitive ability of different soybean genotypes. When correlated with yield data, we may be able to determine whether or not there is interaction between the degree of inter-row penetration (competitive ability) and soil volume. If interaction occurs, implications for a soybean breeding program would be that genotypes selected at a location with a deep soil may be poorly adapted in an area with shallow soils. Therefore, genetic improvement for soybean yield in an area of shallow soils may be expediated by selecting genotypes at a location with shallow soils. Principal investigator: W. T. Schapaugh, Jr.

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the courses "Applied Reactor Theory" required of all senior-level students and "Reactor Operations Planning," a laboratory course devoted exclusively

to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted exclusively to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection," and "Radiation Detection Laboratory". The reactor is also used in the elective course "Radiation Measurement Systems."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1983, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendess at energy conferences, DOE Workshops, and NSF workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for 1983 was 3048. This includes 469 grade school and high school students; 907 Kansas State University students; an estimated 1,028 persons during Open House; 412 participants of workshops or institutes held at KSU; and 232 private individuals. The University students include 475 persons enrolled in chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	2.9	1.4	-
Operator Training and Requalification	0.4	0.0	-
Undergraduate Class Use	64.4	1.6	16
Graduate Class Use	11.9	0.2	4
Isotope Production (Class Use)	0.3	0.0	7
Isotope Production (Research)			
a. Beta-source preparation	36.7	36.1	22
Neutron Activation Analysis			
a. Trace Elements in Coal	66.8	62.4	120
b. Radiation Safety Studies	0.7	0.3	6
c. Miscellaneous	3.0	0.6	14
Subtotal Activation Analysis	70.2	63.3	140
Subtotal Nuclear Engineering Department	187.1	102.6	189
Other University Departments			
Isotope Production (Chemistry)	2.2	0.0	18
Neutron Activation Analysis			
a. Bovine metabolism studies [Animal Sciences]	4.5	4.0	121
b. Soybean root-uptake studies [Agronomy]	0.0	0.0	832
c. Trace elements in horse hair [Veterinary Medicine]	7.6	7.0	15
d. Trace elements in animal cancers [Animal Science, Veterinary Medicine & Nuclear Engineering]	7.3	4.7	48
e. Trace elements in minerals [Geology]	51.0	49.5	102
Subtotal other University Departments	72.6	65.2	1136
Outside Users			
Neutron Activation Analysis [Administered by Geology Department, KSU]	85.1	82.6	170
Total Reactor Utilization	344.8	250.4	1495

* Includes full-power hours.

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 Kansas Geological Survey

Studies have continued on the petrology of the Riley County kimberlites in Kansas with the goal of understanding how these kimberlites form and evolve. Project directors are Pieter Berendson of the Kansas Geological Survey and R. L. Cullers of the Geology Department at Kansas State University. These studies required about 4 hours of reactor time during the year.

7.2 Indian Geological Survey

Studies are in progress on rare earth elements in Indian iron ores with the goal of determining the rare earth element patterns in the ores and the relationship of the patterns to vertical and horizontal facias within the sedimentary basins in which the ores were deposited. Project directors are D. K. Paul of the Indian Geological Survey and Joseph L. Graph, Jr., of the Geology Department at Kansas State University. During the year, these studies required about 8 hours of reactor time.

7.3 Delft University

Studies are being made of the origin of the Urucum iron and manganese deposits in Mato Grosso do Sul in Brazil. The goal of the research is to use rare earth element patterns and other geochemical data to determine the depositional history and environment of the iron-and manganese-rich chemical sediments. Project directors are Pieter Van Leeuwen of Delft University and Joseph L. Graph, Jr., of the Geology Department at Kansas State University. These studies required about 12 hours of reactor operation during the year.

7.4 University of Kansas

Studies have commenced on determination of geochronological and geochemical properties of the Wet Mountain region of southern Colorado. Project directors are M. E. Bickford of the Geology Department at the University of Kansas and R. L. Cullers of the Geology Department at Kansas STate University. During the year, the studies required about 40 hours of reactor operation.

7.5 University of Southern California (Los Angeles)

An investigation has begun on trace elements in the Whipple Mountain region of Southern California. Principal investigators are Lawford Anderson of the Geology Department at the University of Southern California, and R. L. Cullers of the Geology Department at Kansas State University. During the year, the investigation required about 16 hours of reactor operation.

7.6 Recent Publications

Anderson, J. L., R. L. Cullers, and W. R. Van Schmus (1980) Anorogenic metaluminous granite plutonism in the mid-Proterozoic of Wisconsin, U.S.A. Contrib. Mineral. Petrol. 74 311-328.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: Predominately basic and ultrabasic rocks. Chapter 6 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: intermediate and silicic rocks; ore petrogenesis. Chapter 7 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Bickford, M. E., J. R. Sides, and R. L. Cullers (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part I: Field, petrographic, and major element data. Jour. of Geophys. Res., in press.

Cullers, R. L., R. J. Koch, and M. E. Bickford (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part II: trace element data. Jour. Geophys. Res., in press.

Graph, Joseph L. and Bill Richards (1981) Rare Earth Elements in Hydrothermal Carbonates Associated with Breccia-Filling and Replacement, Pb-Zn-Cu Sulfide Deposits in Dolomite Host Rock, Viburnum Trend, Missouri. South Central Geological Society of America.

Val Leeuwen, Pieter, and Joseph L. Graph (1981) Geochemical Evidence Regarding the Formation of Manganese and Iron Deposits in the Urucum Region, Matto Grosso do Sul, Brazil. South Central Geological Society of America.

Cullers, R. L. and Graf, J. (1983) Rare-earth elements in igneous rocks of the continental crust: predominately basic and ultrabasic rocks: in Rare-Earth Geochemistry, Chp. 6 (ed. by P. Henderson), Elsevier, IN PRESS.

Cullers, R. L., and Graf, J. (1983) Rare-earth elements in igneous rocks of the continental crust: predominately basic and ultra-basic rocks: in Rare-Earth Geochemistry, Chp. 7 (ed. by P. Henderson), Elsevier, IN PRESS.

Cullers, R. L., Mullenax, J, DiMarco, M., and Nordeng, S. (1982) The trace element content and petrogenesis of kimberlites in Riley County, Kansas, U.S.A.: American Mineralogist, 67, 223-233.

VanSchmus, W. R., Harrower, K. L., Anderson, J. L. and Cullers, R. L., (1979) Age and composition of a Precambrian rapakivi pluton from the subsurvace of Nebraska and Kansas: submitted to Geol. Soc. American.

Other Publications

Cullers, R. L. (1981) The geology of Colorado and vicinity: Field Guide for the Kansas Universities Geology Field Camp, 78 pp.

Cullers, R. L. (1979) Laboratory Guide for the study of rocks: Lab Guide for Mineralogy-Petrology, 54 pp.

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1983 - June 30, 1984

Victor A. Simonis, Richard E. Faw, and Jack F. Higginbotham

Department of Nuclear Engineering
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Manhattan, Kansas 66506

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THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG02-80ER10723
DE-AC02-76ER02219
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DE-AC02-76ER02082
(Formerly EY-76-C-02-2082)

Annual Progress Report

1 July 1983 - 30 June 1984

KSU TRIGA Mk II Nuclear Reactor Facility

Department of Nuclear Engineering

Kansas State University

Manhattan, Kansas 66506

1. Introduction

During FY 1984 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element	32 g

Total ^{235}U	3.0 kg
Maximum Power (SteadyOState)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Neutron Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator
Ancillary Facilities	Two 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Si-Li), and magnetic-tape data-transfer.

3. Personnel

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Jack F. Higginbotham
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis Victor A. Simonis
Reactor Operators	N. Dean Eckhoff Michael A. Bigelow
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Jack F. Higginbotham (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a.	Total hours of operation*	400.8
	MW-hr produced	36.3
b.	Total hours of operation at full power	162.4
c.	Operating hours in typical week	8.0
d.	Experiment-hours of irradiation service	244.8
e.	Formal courses using reactor and number of students involved	Prin. of Radiation Detection (6) Reactor Operations Planning (12) Applied Reactor Theory (14) Nuclear Engineering Laboratory (4)
f.	Nuclear engineering graduate students using reactor for thesis work	Jack Higginbotham Donald Mei Kevin Stansbury
g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Chemistry Physics Veterinary Medicine Animal Science Tours and Demonstrations General Engineering Industrial Engineering Geology Education Chemistry
h.	Commercial or non-academic utilization	None
i.	Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF)

*Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

j. Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiations for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC02-76ER02082. In FY 1984, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 321 sample insertions in 1984. Activation analysis required approximately 1400 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Trace Elements in NBS Coal Sample: Comparisons were made of neutron activation analyses of a coal sample performed by the National Bureau of Standards and by the KSU Neutron Activation Analysis Laboratory. Principal Investigator: G. G. Simons

Trace Elements in Animal Cancers: Trace element concentrations are determined in biological samples extracted form healthy animals and animals exhibiting different phases of cancer. Emphasis is placed upon developing sample collection, preparation and storage procedures; optimizing the INAA procedure for biological samples; and data acquisition and correlation. This is a joint project of the Nuclear Engineering, Animal Sciences, and Veterinary Medicine Departments. Principal Investigator: G. G. Simons.

Irradiations for Other KSU Researchers

Bone Coring Tool Analysis: [Chemistry Department] The purpose of this research is to determine if bone coring tools are contaminating human bone samples. An irradiated coring tool is used to obtain a human bone sample. An analysis is then performed on the bone sample to check for possible contamination. Principal investigator: Clifton Meloan

Comparative Analysis of Degraded Silk: [Clothing, Textiles and Interior Design Department] The purpose of this research is to characterize the physical morphology and chemical composition of naturally aged and experimentally degraded silk as compared to new silk.

The purpose of the neutron activation analysis portion of the project is to identify metallic salts that may have been absorbed by the historic silks. Such salts were applied to silk as weighting agents and are causal factors in silk degradation. Therefore, it is necessary to identify which aged silk samples are weighted and which are unweighted. Because weighting agents may also interfere with other analytical methods, it is important to identify the metallic salts present. Principal investigator: Barbara Reagan

Nitrogen Update Studies: [Horticulture Department] The purpose of this research is to identify elements in evergreens, specifically those elements present in pine needles. This information could then be used to determine the nitrogen uptake in specific types of evergreens. Principal investigator: David Hensley

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the courses "Applied Reactor Theory" required of all senior-level students and "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted exclusively to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection," and "Radiation Detection Laboratory". The reactor is also used in the elective course "Radiation Measurement Systems."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1983, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendess at energy conferences, DOE Workshops, and NSF workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for 1984 was 2301. This includes 581 grade school and high school students; 613 Kansas State University students; an estimated 850 persons during Open House; 659 participants of workshops or institutes held at KSU; and 448 private individuals. The University students include 410 persons enrolled in chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	4.5	2.7	-
Operator Training and Requalification	6.4	2.1	-
Undergraduate Class Use	62.6	1.8	14
Graduate Class Use	5.9	0.5	0
Isotope Production (Class Use)	0.1	0.0	1
Isotope Production (Research)			
a. Beta-source preparation	0.2	0.0	1
b. N16-Source preparation	2.0	0.3	0
Neutron Activation Analysis			
a. Trace Elements in Coal	0.3	0.3	2
b. Radiation Safety Studies	0.1	0.0	2
c. Miscellaneous	8.9	5.9	28
Subtotal Activation Analysis	9.3	6.2	32
Subtotal Nuclear Engineering Department	91.0	13.6	48
Other University Departments			
Isotope Production (Chemistry)	2.3	0.0	13
Neutron Activation Analysis			
a. Bone coring tool analysis [Chemistry]	4.3	3.2	8
b. Comparative analysis of degraded silk [Clothing, Textiles and Interior Design]	34.5	34.5	47
c. Trace elements in horse hair [Veterinary Medicine]	3.1	3.0	4
d. Nitrogen uptake studies [Horticulture]	4.5	4.3	18
e. Trace elements in minerals [Geology]	32.4	32	62
Subtotal other University Departments	81.1	77	152
Outside Users			
Neutron Activation Analysis [Administered by Geology Department, KSU]	72.7	71.8	121
Total Reactor Utilization	244.8	162.4	321

* Includes full-power hours.

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 Kansas Geological Survey

Studies have continued on the petrology of the Riley County kimberlites in Kansas with the goal of understanding how these kimberlites form and evolve. Project directors are Pieter Berendson of the Kansas Geological Survey and R. L. Cullers of the Geology Department at Kansas State University. These studies required about 8 hours of reactor time during the year.

7.2 University of Kansas

Studies have commenced on determination of geochronological and geochemical properties of the Wet Mountain region of southern Colorado. Project directors are M. E. Bickford of the Geology Department at the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, the studies required about 44 hours of reactor operation.

Studies are in progress on the trace elements in volcanic ash from Missouri. Principal investigators are M. E. Bickford of the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, these studies required about 4 hours of reactor time.

7.3 University of Southern California (Los Angeles)

An investigation has begun on trace elements in the Whipple Mountain region of Southern California. Principal investigators are Lawford Anderson of the Geology Department at the University of Southern California, and R. L. Cullers of the Geology Department at Kansas State University. During the year, the investigation required about 4 hours of reactor operation.

7.4 Wright State University

Studies are in progress on the trace elements in igneous rocks. Principal investigators are P. Pushkar of Wright State University and R. L. Cullers of the Geology Department at Kansas State University. During the year, these studies required about 8 hours of reactor time.

7.5 U.S. - India Cooperative Project

Studies are in progress on the trace elements and isotopic geochemistry of volcanic and plutonic rocks from the Son-Narmada-Tapti lineament zone in central India. The principal investigators are S. Bhattacharya and at Brooklyn College and S. Chaudhuri of the Geology Department at Kansas State University. During the year, the investigation required about 4 hours of reactor operation.

7.6 Recent Publications

Anderson, J. L., R. L. Cullers, and W. R. Van Schmus (1980) Anorogenic metaluminous granite plutonism in the mid-Proterozoic of Wisconsin, U.S.A. Contrib. Mineral. Petrol. 74 311-328.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: Predominately basic and ultrabasic rocks. Chapter 6 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: intermediate and silicic rocks; ore petrogenesis. Chapter 7 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

Bickford, M. E., J. R. Sides, and R. L. Cullers (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part I: Field, petrographic, and major element data. Jour. of Geophys. Res., in press.

Cullers, R. L., R. J. Koch, and M. E. Bickford (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part II: trace element data. Jour. Geophys. Res., in press.

Graph, Joseph L. and Bill Richards (1981) Rare Earth Elements in Hydrothermal Carbonates Associated with Breccia-Filling and Replacement, Pb-Zn-Cu Sulfide Deposits in Dolomite Host Rock, Viburnum Trend, Missouri. South Central Geological Society of America.

Val Leeuwen, Pieter, and Joseph L. Graph (1981) Geochemical Evidence Regarding the Formation of Manganese and Iron Deposits in the Urucum Region, Matto Grosso do Sul, Brazil. South Central Geological Society of America.

Cullers, R. L. and Graf, J. (1984) Rare-earth elements in igneous rocks of the continental crust: predominately basic and ultrabasic rocks: in Rare-Earth Geochemistry, Chp. 7 (ed. by P. Henderson), Elsevier, 237-274.

Cullers, R. L., and Graf, J. (1984) Rare-earth elements in igneous rocks of the continental crust: intermediate and silicic rock; ore petrogenesis: in Rare-Earth Geochemistry, Chp. 8 (ed. by P. Henderson), Elsevier, 275-316.

Cullers, R. L., Mullenax, J, DiMarco, M., and Nordeng, S. (1982) The trace element content and petrogenesis of kimberlites in Riley County, Kansas, U.S.A.: American Mineralogist, 67, 223-233.

VanSchmus, W. R., Harrower, K. L., Anderson, J. L. and Cullers, R. L., (1979) Age and composition of a Precambrian rapakivi pluton from the subsurvace of Nebraska and Kansas: submitted to Geol. Soc. American.

Cullers, R. L., Berendsen, P., Ramnikrishnan, S., and Griffin, T. (1984) Geochemistry and petrogenesis of lamproites, Late Cretaceous age, Woodson County, Kansas, U.S.A.: Geochemica et Cosmochimica Acta, IN PRESS.

Graf, J. L. (1984) Effects of Mississippi Valley-type mineralization on the REE Patterns of Carbonate rocks and minerals, Viburnum Trend, southeast Missouri: Journal of Geology, 92, 307-324.

Graf, J. L. (1984) Rare earth element distributions in carbonate rocks and minterals from the Tri-State district, Missouri-Kansas-Oklahoma: Abstracts, G.S.A. 1984 Annual Meeting, Reno, Nevada, 523.

Alcott, L. J., and Graf, J. L. (1984) Rare earth element distributions within limestones and dolostones of the Bonneterre Formation in the vicinity of the Viburnum Trend, southeast Missouri: Abstracts, G.S.A. 1984 Annual Meeting, Reno, Nevada, 427.

Other Publications

Cullers, R. L. (1981) The geology of Colorado and vicinity: Field Guide for the Kansas Universities Geology Field Camp, 78 pp.

Cullers, R. L. (1979) Laboratory Guide for the study of rocks: Lab Guide for Mineralogy-Petrology, 54 pp.

COO-2082/2219-11

KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1984 - June 30, 1985

Richard E. Faw and Jack F. Higginbotham

Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66506

July, 1985

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG02-80ER10723
DE-AC02-76ER02219

Annual Progress Report

1 July 1984 - 30 June 1985

KSU TRIGA Mk II Nuclear Reactor Facility

1. Introduction

During FY 1985 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	107
Average Enrichment	18 percent
^{235}U per Element	34 g
Total ^{235}U	3.7 kg
Maximum Power (Steady-State)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$

Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Neutron Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator
Ancillary Facilities	Three 4096-channel multi-parameter pulse height analyzers with Ge-Li solid-state detectors, and magnetic-tape data-transfer.

3. Personnel

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Jack F. Higginbotham
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis Victor A. Simonis
Reactor Operators	N. Dean Eckhoff Michael A. Bigelow
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Jack F. Higginbotham (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a. Total hours of operation*	409.6
MW-hr produced	35.9
b. Total hours of operation at full power	222.9
c. Operating hours in typical week	8.0
d. Experiment-hours of irradiation service	253.6

*Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

e. Formal courses using reactor and number of students involved	Prin. of Radiation Detection (10) Reactor Op'n. Laboratory (7) Chemistry I (501) Rad. Safety in the Res. Lab (12)
f. Nuclear engineering graduate students using reactor for thesis work	Jack Higginbotham Donald Mei Kevin Stroh
g. Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Chemistry Physics Animal Science Clothing, Textiles and Interior Design Tours and Demonstrations General Engineering Industrial Engineering Geology Education Chemistry
h. Commercial or non-academic utilization	None
i. Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF)
j. Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiations for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC02-76ER02082. In FY 1985, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 701 sample insertions in 1985. Activation analysis required approximately 2600 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Irradiations for Nuclear Engineering Researchers

Beta-Particle and Mixed Beta-Gamma Source Production: The purpose of this research is to design and evaluate a beta-particle spectrometer which will incorporate active gamma-ray discrimination. The radiation sources are required to complete the evaluation of the spectrometer. Principal investigator: G. G. Simons.

Nitrogen-16 Source Preparation:

The purpose of this research is to utilize the fast-neutron activation of ^{16}O to produce a ^{16}N radiation source. This source will be used to study the response of radiation survey instruments and personnel dosimeters to high energy gamma rays.

Irradiations for Other KSU Researchers

Comparative Analysis of Degraded Silk: [Clothing, Textiles and Interior Design Department] The purpose of this research is to characterize the physical morphology and chemical composition of naturally aged and experimentally degraded silk as compared to new silk.

The purpose of the neutron activation analysis portion of the project is to identify metallic salts that may have been absorbed by the historic silks. Such salts were applied to silk as weighting agents and are causal factors in silk degradation. Therefore, it is necessary to identify which aged silk samples are weighted and which are unweighted. Because weighting agents may also interfere with other analytical methods, it is important to identify the metallic salts present. Principal investigator: Barbara Reagan.

Feedstuff Metabolism in Beef Cattle: [Animal Science Department] The object of this study is to compare the rate of passage of cracked corn, tagged with ceric ammonium nitrate, and cottonseed hulls, tagged with lanthanum nitrate, for two breeds of cattle. Neutron activation analysis will be used to quantify cerium and lanthanum concentrations in intestinal fluid samples removed from the cattle. Principal investigator: Jack Riley.

Halogen Determination in Water Purification Resins: [Chemistry Department] The purpose of this project is to determine the bromine concentration ratio in a water purification resin developed at Kansas State University. Principal investigator: Jack Lambert.

Non-Radioactive Isotopic Labeling of Animal Hair: [Department of Clothing and Textiles] This project is aimed at determination of the feasibility of tagging animal hair with known isotopes to allow for later

identification of the animal or of cloth woven from the animal's hair. The neutron activation analysis portion of the project deals with identification of suitable isotopes and concentrations. Principal investigator: Randall Bresee.

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the courses "Applied Reactor Theory" required of all senior-level students and "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted exclusively to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection." The reactor is also used in the elective course "Radiation Measurement Systems." Graduate Research Assistants in the Chemistry and Biology Department make use of the reactor in the class "Radiation Safety in the Research Laboratory."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1985, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendess at energy conferences, DOE Workshops, and NSF workshops, (5) the general public at Open House sessions,

and (6) general interest groups. The total number of persons touring the reactor for 1985 was 2884. This includes 634 grade school and high school students; 955 Kansas State University students; 542 persons during Open House; 321 participants of workshops or institutes held at KSU; and 432 private individuals. The University students include 501 persons enrolled in chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	6.5	1.5	-
Operator Training and Requalification	3.9	0.3	-
Undergraduate Class Use	12.8	0.2	12
Isotope Production (Research)			
a. Beta-source preparation	24.1	24.1	8
b. N16-Source preparation	6.1	0.0	0
c. Undergraduate class use	0.4	0.0	14
Neutron Activation Analysis			
a. Analysis of Food Products	4.4	4.4	35
b. Radiation Safety Studies	0.5	0.0	12
c. Analysis of Carbon Combustion	4.0	4.0	1
Subtotal Activation Analysis	27.7	27.1	59
Subtotal Nuclear Engineering Department	81.5	53.2	93
Other University Departments			
Isotope Production			
a. Chemistry Department	0.4	0.0	12
b. Biology Division	0.1	0.0	3
c. Geology Department	4.0	4.0	1
d. Miscellaneous	0.3	0.1	2
Neutron Activation Analysis			
a. Feedstuff Metabolism [Animal Science]	14.3	14.0	269
b. Comparative analysis of degraded silk [Clothing, Textiles and Interior Design]	19.5	18.7	28
c. Animal Hair Analysis [Clothing, Textiles and Interior Design	15.6	15.6	44
d. Halogens in Resins [Chemistry]	8.6	8.3	20
e. Trace elements in minerals [Geology]	21.0	21.0	41
Subtotal other University Departments	83.8	81.7	420
Outside Users (Neutron Activation Analysis)			
[Administered by Geology Department, KSU]	88.3	88.0	188
Blood serum analysis [for Regional Kidney Disease Program]	18.8	18.7	11
Total Reactor Utilization	253.6	222.9	701

* Includes full-power hours.

Joseph L. Graf, Jr., of the Geology Department at Kansas State University. During the year, the investigation required about 12 hours of reactor operation.

7.4 Wright State University

Studies are in progress on the trace elements in igneous rocks. Principal investigators are P. Pushkar of Wright State University and R. L. Cullers of the Geology Department at Kansas State University. During the year, these studies required about 6 hours of reactor time.

7.5 U.S. - India Cooperative Project

Studies are in progress on the trace elements and isotopic geochemistry of volcanic and plutonic rocks from the Son-Narmada-Tapti lineament zone in central India. The principal investigators are S. Bhattacharya and at Brooklyn College and S. Chaudhuri of the Geology Department at Kansas State University. During the year, the investigation required about 12 hours of reactor operation.

7.6 Regional Kidney Disease Program, Hennepin County Medical Center

The purpose of this research is to investigate the feasibility of quantitative determination of selenium in samples of dried human blood. Trace quantities of selenium are thought to be important in intestinal function. Principal investigators: C. L. Smith, M.D., Hennepin County Medical Center, and G. G. Simons, Professor of Nuclear Engineering, Kansas State University.

7.7 Recent Publications

Cullers, R. L. (1981) The geology of Colorado and vicinity: Field Guide for the Kansas Universities Geology Field Camp, 78 pp.

Cullers, R. L. (1979) Laboratory Guide for the study of rocks: Lab Guide for Mineralogy-Petrology, 54 pp.

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Bickford, M. E., J. R. Sides, and R. L. Cullers (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part I: Field, petrographic, and major element data. Jour. of Geophys. Res.

Cullers, R. L., R. J. Koch, and M. E. Bickford (1981) Chemical evolution of magmas in the Proterozoic terrane of the St. Francois Mountains, southeastern Missouri, U.S.A., Part II: trace element data. Jour. Geophys. Res.

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Val Leeuwen, Pieter, and Joseph L. Graph (1981) Geochemical Evidence Regarding the Formation of Manganese and Iron Deposits in the Urucum Region, Matto Grosso do Sul, Brazil. South Central Geological Society of America.

Cullers, R. L. and Graf, J. (1984) Rare-earth elements in igneous rocks of the continental crust: predominately basic and ultrabasic rocks: in Rare-Earth Geochemistry, Chp. 7 (ed. by P. Henderson), Elsevier, 237-274.

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Cullers, R. L., Robinson, B., Jennings, D., Carlson, R., and Barrett, T. (1985) Rareearth element and mineralogic changes in size fractions of soils and sediment during weathering of the San Isabel batholith, Wet Mountains, U.S.A.: Geological Society of America Abstracts, 17, 155.

Berendsen, P., Cullers, R. K., Mansker, W. 1., and Cole, G. P. (1985) Late Cretaceous Kimberlite and Lamproite occurrences in eastern Kansas, U.S.A.: Geological Society of America Abstracts, 17, 151.

Cullers, R. L., Berendsen, P., Ramnikrishnan, S., and Griffin, T. (1985) Geochemistry and petrogenesis of lamproites, Late Cretaceous age, Woodson Countay, Kansas, U.S.A.,: Geochimica et Cosmochemica Acta, 49, 1383-1402

COO-2082/2219-12

KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1985 - June 30, 1986

Richard E. Faw and Jack F. Higginbotham

Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66506

July, 1986

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG02-80ER10723
DE-AC02-76ER02219

1. Introduction

During FY 1986 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element Total ^{235}U	32 g 3.0 kg
Maximum Power (SteadyOState)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$

Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Neutron Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator
Ancillary Facilities	Two 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Si-Li), and magnetic-tape data-transfer.

3. Personnel

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Jack F. Higginbotham
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis Victor A. Simonis
Reactor Operators	N. Dean Eckhoff Michael A. Bigelow Jeffrey L. Daniels David J. Whitfill
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Jack F. Higginbotham (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a. Total hours of operation*	469.3
MW-hr produced	51.7
b. Total hours of operation at full power	221.9
c. Operating hours in typical week	9.0
d. Experiment-hours of irradiation service	313.3

*Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

e. Formal courses using reactor and number of students involved	Prin. of Radiation Detection (7) Reactor Operations Planning (12) Chemistry I (341) Radiation Safety in the Res. Lab (10)
f. Nuclear engineering graduate students using reactor for thesis work	Jack Higginbotham Donald Mei Kevin Stroh
g. Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Chemistry Chemical Engineering Veterinary Medicine Animal Science Clothing, Textiles and Interior Design Foods and Nutrition Tours and Demonstrations General Engineering Industrial Engineering Geology Education Chemistry
h. Commercial or non-academic utilization	None
i. Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF) Beta/Gamma Spectroscopy (DOE)
j. Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiations for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC02-76ER02082. In FY 1986, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 806 sample insertions in 1986. Activation analysis required approximately 2900 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Beta-Particle and Mixed Beta-Gamma Source Production: The purpose of this research is to design and evaluate a beta-particle spectrometer which will incorporate active gamma-ray discrimination. The radiation sources are required to complete the evaluation of the spectrometer. Principal investigator: G. G. Simons.

Nitrogen-16 Source Preparation:

The purpose of this research is to utilize the fast-neutron activation of ^{16}N to produce a ^{16}N radiation source. This source will be used to study the response of radiation survey instruments and personnel dosimeters to high energy gamma rays. Principal Investigator: G. G. Simons.

Irradiations for Other KSU Researchers

Feedstuff Metabolism in Beef Cattle: [Animal Science Department] The goal of this research is determination of the effects of theionophore lasalocid

on feed intake, digestibility, and weight change of cattle. Ytterbium in the aqueous chloride form was used as a label for neutron activation analysis of esophageally collected samples (for intake determination) and fecal samples. Principal investigator: Bob Cochran.

Non-Radioactive Isotopic Labeling of Animal Hair: [Department of Clothing and Textiles] This project is aimed at determination of the feasibility of tagging animal hair with known isotopes to allow for later identification of the animal or of cloth woven from the animals hair. The neutron activation analysis portion of the project deals with identification of suitable isotopes and concentrations. Principal investigator: Randall Bresee.

Controlled Release of Pesticides on Stored Grain: [Chemical Engineering Department] This research has the goal of developing a controlled-release pesticide through encapsulation of the pesticide in a polymer matrix. Under specific test is the pesticide Chlorpyrifos-methyl in the biopolymer Xanthan. Neutron activation analysis for chlorine is used to determine the retention of the pesticide over periods up to six months in stored grain. Principal Investigator: L. T. Fan

Silica Gel Analysis: [Chemical Engineering Department] This project was in support of research into the sol-gel process. Neutron activation analysis was applied to determine if the gel composition and retention of sodium and chlorine in borosilicate gels. Principal Investigator: John Schlup.

$NaVO_3$ Gel Analysis: [Chemical Engineering Department] This project was in support of research into the sol-gel process. Neutron activation was applied to determination of the gel composition and retention of sodium and chlorine in sodium vanadate gels. Principal Investigator: John Schlup.

Blood Serum Analysis: [Pathology Department (Veterinary Medicine)] The objective of this work is evaluation of the use of stable isotopes of iron

and chromium as biological tracers for iron and erythrocytes, as applied to the study of two erythrocyte-related diseases of horses. Principal Investigator: Joe Smith.

Analysis of Processed Chicken: [Department of Foods and Nutrition] This project deals with determination of Cu, Fe, Mn, Na, and Zn in processed chicken. Principal Investigator: Jean Craig.

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the courses "Applied Reactor Theory" required of all senior-level students and "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted exclusively to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection." The reactor is also used in the elective course "Radiation Measurement Systems." Graduate Research Assistants in the Chemistry and Biology Department make use of the reactor in the class "Radiation Safety in the Research Laboratory."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1986, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public

officials, (3) 4-H groups, (4) symposia attendess at conferences, DOE Workshops, and NSF workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for 1986 was 2316. This includes 888 grade school and high school students; 541 Kansas State University students; 359 persons during Open House; 79 participants of workshops or institutes held at KSU; 296 private individuals, and 153 members of professional and civic organizations. The University students include 341 persons enrolled in chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

Studies have commenced on determination of geochronological and geochemical properties of the Wet Mountain region of southern Colorado. Project directors are M. E. Bickford of the Geology Department at the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, the studies required about 5 hours of reactor operation.

Studies are in progress on the trace elements in volcanic ash from Missouri. Principal investigators are M. E. Bickford of the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, these studies required about 4 hours of reactor time.

7.2 University of Georgia

This work involves neutron activation analysis in the study of the weathering of igneous rocks in Georgia. Project directors are M. Roden of the University of Georgia and R. L. Cullers of the Geology Department at Kansas State University. During the year, this work required 31 hours of reactor time.

7.4 Renssylaer Polytechnic Institute

This is a study of rare earths in the Gem Park Igneous Complex. It employs neutron activation analysis in an investigation of the origins of carbonatites, pyroxenites, and gabgrus at Glen Park, Colorado. Principal investigators are Mary Roden of R.... Polytechnnic Institute and R. L. Cullers of the Geology Department at Kansas State Univetrsity. About 4 hours of reactor time were required during the year.

7.5 Louisiana State University

This project is concerned with the 3.5 billion year old Duffer formation in Australia. Neutron activation analysis is used in determination of the elemental contents of the oldest sedimentary rocks in the world with the goal of determining element mobility during alteration and, ultimately, the origin of the igneous rocks that weathered to produce the sediments. Principal investigators are Mike DiMarco of Louisiana State University and R. L. Cullers of the Geology Department at Kansas State University. During this first year of the project, about 8 hours of reactor time were required.

7.6 Recent Publications

Anderson, J. L., R. L. Cullers, and W. R. Van Schmus (1980) Anorogenic metaluminous granite plutonism in the mid- Proterozoic of Wisconsin, U.S.A. Contrib. Mineral. Petrol. 74 311-328.

Cullers, R. L. and J. Graf (1981) Rare earth elements in igneous rocks of the continental crust: Predominately basic and ultrabasic rocks. Chapter 6 in Rare-earth Geochemistry (ed. by P. Henderson), Elsevier, in press.

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Graph, Joseph L. and Bill Richards (1981) Rare Earth Elements in Hydrothermal Carbonates Associated with Breccia-Filling and Replacement, Pb-Zn-Cu Sulfide Deposits in Dolomite Host Rock, Viburnum Trend, Missouri. South Central Geological Society of America.

Val Leeuwen, Pieter, and Joseph L. Graph (1981) Geochemical Evidence Regarding the Formation of Manganese and Iron Deposits in the Urucum Region, Matto Grosso do Sul, Brazil. South Central Geological Society of America.

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Graf, J. L. (1984) Effects of Mississippi Valley-type mineralization on the REE Patterns of Carbonate rocks and minerals, Viburnum Trend, southeast Missouri: Journal of Geology, 92, 307-324.

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Alcott, L. J., and Graf, J. L. (1984) Rare earth element distributions within limestones and dolostones of the Bonneterre Formation in the vicinity of the Viburnum Trend, southeast Missouri: Abstracts, G.S.A. 1984 Annual Meeting, Reno, Nevada, 427.

Other Publications

Cullers, R. L. (1981) The geology of Colorado and vicinity: Field Guide for the Kansas Universities Geology Field Camp, 78 pp.

Cullers, R. L. (1979) Laboratory Guide for the study of rocks: Lab Guide for Mineralogy-Petrology, 54 pp.

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1986 - June 30, 1987

Richard E. Faw and Jeffrey L. Daniels

Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66506

July, 1987

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG02-80ER10723
DE-AC02-76ER02219

1. Introduction

During FY 1987 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element Total ^{235}U	32 g 3.0 kg
Maximum Power (Steady-State)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$
Special Facilities	Rotary Speciman Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Neutron Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator

Ancillary Facilities	Two 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li, Si-Li and Ge), and magnetic-tape data-transfer.

3. Personnel (30 Jun 87)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Jeffrey L. Daniels
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis David J. Whitfill
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Jeffrey L. Daniels (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a.	Total hours of operation*	440.5
	MW-hr produced	52.6
b.	Total hours of operation at full power	187.3
c.	Operating hours in typical week	8.8
d.	Experiment-hours of irradiation service	284.5
e.	Formal courses using reactor and number of students involved	Prin. of Radiation Detection (7) Reactor Operations Planning (14) Chemistry I (396) Radiation Safety in the Res. Lab (12)
f.	Nuclear engineering graduate students using reactor for thesis work	Jack Higginbotham Richard Weiner

*Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Animal Science Biology Chemistry Chemical Engineering Clothing, Textiles & Interior Design Grain Science Engineering Technology Tours and Demonstrations Chemistry Education General Engineering Geology Industrial Engineering Landscape Architecture
h.	Commercial or non-academic utilization	None
i.	Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF) Beta/Gamma Spectroscopy (DOE)
j.	Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC02-76ER02082. In FY 1987, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 942 sample insertions in FY 1987. Activation analysis required approximately 3400 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Beta-Particle and Mixed Beta-Gamma Source Production: The purpose of this research is to design and evaluate a beta-particle spectrometer which will incorporate active gamma-ray discrimination. The radiation sources are required to complete the evaluation of the spectrometer. Principal investigator: G.G. Simons.

Nitrogen-16 Source Preparation:

The purpose of this research is to utilize the fast-neutron activation of ^{16}N to produce a ^{16}N radiation source. This source will be used to study the response of radiation survey instruments and personnel dosimeters to high energy gamma rays. Principal Investigator: G.G. Simons

Irradiations for Other KSU Researchers

Feedstuff Metabolism in Beef Cattle: [Animal Science Department] The goal of this research is determination of the effects of theionophore lasalocid on

feed intake, digestibility, and weight change of cattle. Ytterbium in the aqueous chloride form was used as a label for neutron activation analysis of esophageally collected samples (for intake determination) and fecal samples. Principal investigator: Bob Cochran.

Non-Radioactive Isotopic Labeling of Animal Hair: [Department of Clothing and Textiles] This project is aimed at determination of the feasibility of tagging animal hair with known isotopes to allow for later identification of the animal or of cloth woven from the animals' hair. The neutron activation analysis portion of the project deals with identification of suitable isotopes and concentrations. Principal investigator: Randall Bresee.

Controlled Release of Pesticides on Stored Grain: [Chemical Engineering Department] This research has the goal of developing a controlled-release pesticide through encapsulation of the pesticide in a polymer matrix. Under specific test is the pesticide Chlorpyrifos-methyl in the biopolymer Xanthan. Neutron activation analysis for chlorine is used to determine the retention of the pesticide over periods up to six months in stored grain. Principal Investigator: L. T. Fan

Silica Gel Analysis: [Chemical Engineering Department] This project was in support of research into the sol-gel process. Neutron activation analysis was applied to determination of the gel composition and retention of sodium and chlorine in borosilicate gels. Principal Investigator: John Schlup.

$NaVO_3$ Gel Analysis: [Chemical Engineering Department] This project was in support of research into the sol-gel process. Neutron activation was applied to determination of the gel composition and retention of sodium and chlorine in sodium vanadate gels. Principal Investigator: John Schlup.

Iodine Resin Studies: [Division of Biology] This is a broad-based study of the biocidal activity of Triocide and Pentacide resin-iodide demand-type

disinfectants on bacteria, virus, and protozoa. Neutron activation analysis is applied to the determination of iodine concentrations. Principal Investigator: L. R. Fina

Effect of Liquid Binders on Microingredients Segregation and Premix Dustiness: [Grain Science and Industry] Liquid binders have been used both to stabilize a premix and to provide more powder to be absorbed by carriers. The project objective is to determine the effects of adding soybean oil, mineral oil, and animal fat at different levels as liquid binders on dust reduction and particle segregation during post-mixer handling. NAA is used to assay the uniformity of dispersion of trace minerals and vitamins. Principal Investigator: R. R. McEllhiney

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the course "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection" and "Nuclear Engineering Concepts." The reactor is also used in the elective course "Radiation Measurement Systems." Graduate Research Assistants in the Chemistry and Biology Department make use of the reactor in the class "Radiation Safety in the Research Laboratory."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1987, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for 1987 was 2988. This includes 301 grade school and junior high school students, 636 high school students; 713 Kansas State University students; 508 persons during Open House; 106 participants of workshops or institutes held at KSU; 286 private individuals, 206 in general-interest campus tours, and 232 members of professional and civic clubs and organizations. The University students include 396 persons enrolled in chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	1.5	1.3	0
Operator Training and Requalification	0.7	0.1	0
Undergraduate Class Use	37.5	2.5	14
Other Class Use	5.6	3.2	2
Isotope Production (Research)			
a. Beta-source preparation	3.7	2.5	26
b. Undergraduate class use	1.6	1.4	5
Neutron Activation Analysis			
a. Radiation Safety Studies	0.7	0.2	24
b. Miscellaneous	5.0	4.5	42
Subtotal Nuclear Engineering Department	56.3	15.7	113
Other University Departments			
Isotope Production			
a. Chemistry Department	0.5	0.0	12
b. Biology Division	0.1	0.0	1
Neutron Activation Analysis			
a. Feedstuff Metabolism [Animal Science]	2.0	2.0	4
b. Animal Hair Analysis [Clothing, Textiles and Interior Design]	56.9	56.9	281
c. Grain Science	94.9	40.2	340
d. Trace elements in minerals [Geology]	4.0	4.0	14
e. Silica-Gel Analysis [Chemical Engineering]	8.8	8.2	18
f. $NaVO_3$-Gel Analysis [Chemical Engineering]	0.7	0.2	11
g. Polymer/Pesticide Analysis [Chemical Engineering]	0.1	0.0	1
h. Biology Division	1.6	1.6	27
i. Iodine Resin Disinfectants [Division of Biology]	6.6	6.5	32
Subtotal other University Departments	176.2	119.8	741
Outside Users			
Neutron Activation Analysis [Administered by Geology Department, KSU]	52.0	52.0	88
Total Reactor Utilization	284.5	187.3	942

*Includes full-power hours.

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

Studies have commenced on the analysis of volcanic rocks in the western United States in order to determine their evolution. Project directors are Douglas Walker of the Geology Department at the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, the studies required 4 hours of reactor operation.

Studies are in progress on the petrology of Kimberlites and periodites in Kansas. Principal investigators are P. Berendson of the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, these studies required 8 hours of reactor time.

7.2 University of Georgia

This work involves neutron activation analysis in the study of the weathering of igneous rocks in Georgia. Project directors are M. Roden of the University of Georgia and R. L. Cullers of the Geology Department at Kansas State University. During the year, this work required 4 hours of reactor time.

7.3 Louisiana State University

This project is concerned with the 3.5 billion year old Duffer formation in Australia. Neutron activation analysis is used in determination of the elemental contents of the oldest sedimentary rocks in the world with the goal of determining element mobility during alteration and, ultimately, the origin of the igneous rocks that weathered to produce the sediments. Principal investigators are Mike DiMarco of Louisiana State University and R. L. Cullers of the Geology Department at Kansas State University. During this second year of the project, 8 hours of reactor time were required.

7.4 College of Charleston

Geochemical studies have commenced involving examining intrusive rocks in the Honduras. Principal Investigators are Robert Nusbaum of the College of Charleston (South Carolina) and R. L. Cullers of the Geology Department at Kansas State University. During this first year of the project, 28 hours of reactor time were required.

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1987 – June 30, 1988

Richard E. Faw and Jeffrey L. Daniels

Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66506

July, 1988

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG07-80ER10723
DE-AC07-76ER02082

1. Introduction

During FY 1988 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor–Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R–88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless–Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element Total ^{235}U	32 g 3.0 kg
Maximum Power (Steady–State)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady–State)	10^{13} $cm^{-2}s^{-1}$
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column

	Two Radial Beam Ports One Tangential Beam Port One Fast–Neutron Beam Port Bulk–Shielding Tank In–Core LiDO Fast–Neutron Generator
Ancillary Facilities	Two 4096–channel multi–parameter pulse height analyzers with solid state detectors (Ge–Li, Si–Li and Ge), and magnetic–tape data–transfer.

3. Personnel (30 Jun 88)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Jeffrey L. Daniels
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis David J. Whitfill
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Jeffrey L. Daniels Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a.	Total hours of operation[1] MW–hr produced	308 31.0
b.	Total hours of operation at full power	124.6
c.	Operating hours in typical week	6.0
d.	Experiment–hours of irradiation service	152.0

[1]Total hours of operation includes experiment–hours plus an estimated thirteen hours per month for pre–experiment operations and reactivity balances.

e. Formal courses using reactor and number of students involved	Nuclear Engineering Concepts (19) Reactor Operations Planning (5) Chemistry I (410) Radiation Safety in the Res. Lab (18)
f. Nuclear engineering graduate students using reactor for thesis work	Jack Higginbotham Richard Weiner
g. Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Animal Science Biology Chemistry Grain Science Tours and Demonstrations Chemistry Education General Engineering Geology
h. Commercial or non-academic utilization	None
i. Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF) Beta/Gamma Spectroscopy (DOE)
j. Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE–AC07–76ER02082. In FY 1988, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 673 sample insertions in FY 1988. Activation analysis required approximately 2400 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Beta–Particle and Mixed Beta–Gamma Source Production: [Nuclear Engineering] The purpose of this research is to design and evaluate a beta–particle spectrometer which will incorporate active gamma–ray discrimination. The radiation sources are required to complete the evaluation of the spectrometer. Principal investigator: G.G. Simons.

Iodine Resin Studies: [Division of Biology] This is a broad–based study of the biocidal activity of Triocide and Pentacide resin–iodide demand–type disinfectants on bacteria, virus, and protozoa. Neutron activation analysis is applied to the determination of iodine concentrations. Principal Investigator: L. R. Fina

Effect of Liquid Binders on Microingredients Segregation and Premix Dustiness: [Grain Science and Industry] Liquid binders have been used both to stabilize a premix and to provide more powder to be absorbed by carriers. The project

objective is to determine the effects of adding soybean oil, mineral oil, and animal fat at different levels as liquid binders on dust reduction and particle segregation during post–mixer handling. NAA is used to assay the uniformity of dispersion of trace minerals and vitamins. Principal Investigator: R. R. McEllhiney

Effects of Neutron Irradiation on Superconductor Properties: [Physics Department] Effects of neutron irradiation were studied for superconductors consisting of oxides of yttrium or europeum, barium and copper. Moderate increases were found in critical currents with no measurable decreases in transition temperatures. Principal investigator: Michael T. O'Shea.

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the course "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory course devoted to use of the Reactor, is required of all candidates for advanced degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements. "Principles of Radiation Detection" and "Nuclear Engineering Concepts." The reactor is also used in the elective course "Radiation Measurement Systems." Graduate Research Assistants in the Chemistry and Biology Department make use of the reactor in the class "Radiation Safety in the Research Laboratory."

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1988, lectures, tours, and demonstrations have been provided for (1) high school and college classes, both local and regional, (2) public officials, (3) 4–H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for 1988 was 2681. This includes 114 junior high school students, 688 high school students; 729 Kansas State University students; 638 persons during Open House; 91 participants of workshops or institutes held at KSU; 233 private individuals, 125 persons in general–interest campus tours, and 63 members of professional and civic clubs and organizations. The university students include 410 persons enrolled in chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises. The high school students include 568 prospective university students for whom special tours were arranged.

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

Studies are in progress on the analysis of volcanic rocks in the western United States in order to determine their evolution. Project directors are Douglas Walker of the Geology Department at the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, the studies required 16 hours of reactor operation.

Studies are in progress on the petrology of Kimberlites and periodites in Kansas. Principal investigators are P. Berendson of the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University.

7.2 University of Southern California

Work has resumed on studies of trace elements in the granitic rocks of the Whipple Mountains. Principal investigators are J. L. Anderson of the University of Southern California and R. L. Cullers of the Geology Department at Kansas State University. During the year, the studies required 16 hours of reactor time.

7.3 Louisiana State University

This project is part of a study of the composition of precambrian metashales in the southwestern United States. In order to determine the source and techtonic environment of these shales, their compositions will be compared to those of known source and environment. Principal investigators are Don Lowe and Ronadh Cox of Louisiana State University and R. L. Cullers of the Geology Department at Kansas State University. During the year, 28 hours of reactor operations were required for this project.

7.4 Carleton College

This project involves studies of the compositions of amphibolites and granite greisses in metamorphic rocks in the Salida, Colorado area in order to determine their origin and petrogenesis. Principal investigators are Shelby Boardman of Carleton College and R. L. Cullers of the Geology Department at Kansas State University. During the year, the project required 4 hours of reactor operations.

7.5 Wichita State University

This project involves studies of trace elements in metamorphic rocks in order to determine their origin. Principal investigators are John Gries and Sam Sangmor of Wichita State University and R. L. Cullers of the Geology Department at Kansas State University. During the year, the project required 8 hours of reactor operations.

7.6 National Transportation Safety Board

This study was undertaken to assist in the determination of the cause of an airplane crash. Trace elements were determined in two specimens of wreckage in order to ascertain whether the specimens had a common origin. Principal investigators were Bob Dickens of the Safety Board and Richard Faw of the Nuclear Engineering Department at Kansas State University. The study required 4.2 hours of reactor operations.

7.7 Kansas Junior Academy of Sciences

This study was undertaken in support of the Kansas Junior Academy of Sciences program for high–school students. It involved studies of trace elements in foliage from shade and ornamental trees and the variability with site, season, and

species. Principal investigators were Sharon Kissick of Wamego High School and Richard Faw of the Nuclear Engineering Department at Kansas State University. The study required 18.3 hours of reactor operations during the year.

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Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix, Stainless-Steel Clad
Number of Fuel Elements	91
Average Enrichment	17 percent
^{235}U per Element Total ^{235}U	32 g 3.0 kg
Maximum Power (Steady-State)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port

	One Fast–Neutron Beam Port Bulk–Shielding Tank In–Core LiDO Fast–Neutron Generator
Ancillary Facilities	Three 4096–channel multi–parameter pulse height analyzers with solid state detectors (Ge–Li and Ge), and magnetic–tape/disk data–transfer.

3. Personnel (30 Jun 89)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Jeffrey L. Daniels
Radiation Safety Officer	John P. Lambert
Senior Reactor Operators	J. Kenneth Shultis David J. Whitfill
Reactor Operators	Matthew Burger John Kirkland
Reactor Safeguards Committee	N. Dean Eckhoff (ex officio) John P. Lambert (ex officio) Jeffrey L. Daniels Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a. Total hours of operation[1]	340.3
MW–hr produced	26.4
b. Total hours of operation at full power	115.7
c. Operating hours in typical week	6.5
d. Experiment–hours of irradiation service	184.3

[1]Total hours of operation includes experiment–hours plus an estimated thirteen hours per month for pre–experiment operations and reactivity balances.

e. Formal courses using reactor and number of students involved	Nuclear Engineering Concepts (19) Reactor Operations Planning (7) Chemistry I (275) Radiation Safety in the Res. Lab (11) Principles of Radiation Detection (1) Graduate Problems in Nuclear Engg. (3)
f. Nuclear engineering graduate students using reactor for thesis work	Yuni Dewarajara Hossein Zamani
g. Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Biology Irradiation Services Biology Chemistry Electrical Engineering Tours and Demonstrations Chemistry Education General Engineering Geology
h. Commercial or non–academic utilization	None
i. Nature of research being done for DOE, or other Federal agencies	Rare earth element assay in mineral specimens (NSF) Beta/Gamma Spectroscopy (DOE)
j. Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principal use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE–AC07–76ER02082. In FY 1989, irradiations were provided to (1) faculty, undergraduate and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and nearby states.

There were 308 sample insertions in FY 1989. Activation analysis required approximately 1200 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in Section 7.

Silica Uptake in Grasses: [Biology] The purpose of this study is to investigate the uptake of silicon in grasses as a function of nitrogen concentration in the nutrient medium. Uptake is examined by using a Si–31 tracer prepared using the nuclear reactor. Principal investigators are Christopher C. Smith and Peter P. Wong, Professors of Biology.

Trace Elements in Foliage: [Nuclear Engineering] This is a study of the variation of trace element concentrations in oak leaves with species, season, specimen, and site. Its purpose is to provide baseline information for a study of the effect of stress on trace element concentrations. The principal investigator is Richard E. Faw, Professor of Nuclear Engineering.

5.2 University Education

The second major use of the KSU TRIGA is for undergraduate and graduate instruction.

Standard laboratory experiments using the Reactor are carried out in the course "Reactor Operations Planning," a laboratory course devoted exclusively to use of the reactor and required of all undergraduate students. The graduate course "Nuclear Reactor Laboratory," also a laboratory

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	25.0	3.8	0
Operator Training and Requalification	8.3	0.4	0
Undergraduate Class Use	26.8	2.7	6
Graduate Class Use	0.0	0.0	3
Other Class Use	4.6	1.3	1
Neutron Activation Analysis			
a. Trace Elements in Foliage	14.1	5.5	11
b. Miscellaneous	0.7	0.0	7
Subtotal Nuclear Engineering Department	79.5	13.7	28
Other University Departments			
Isotope production & Irradiation Services			
a. Chemistry Department	2.1	0.0	21
b. Semiconductor Studies [Electrical Engg.]	8.7	8.0	70
c. Silicon Studies [Biology]	2.0	2.0	3
d. Geology Department	0.0	0.0	1
Neutron Activation Analysis			
a. Trace elements in minerals [Geology]	24.0	24.0	65
Subtotal other University Departments	36.8	34.0	159
Outside Users			
Neutron Activation Analysis			
a. Geology Department [administered by KSU]	68.0	68.0	120
Subtotal Outside Users	68.0	68.0	120
Total Reactor Utilization	184.3	115.7	308

*Includes full power hours

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

Studies continue on the petrology of Kimberlites and periodites in Kansas. Principal investigators are P. Berendson of the University of Kansas and R. L. Cullers of the Geology Department at Kansas State University. During the year, the studies required 8 hours of reactor operation.

7.2 Louisiana State University

This project is part of a study of the composition of precambrian metashales in the southwestern United States. In order to determine the source and techtonic environment of these shales, their compositions will be compared to those of known source and environment. Principal investigators are Don Lowe and Ronadh Cox of Louisiana State University and R. L. Cullers of the Geology Department at Kansas State University. During the year, 24 hours of reactor operations were required for this project.

7.3 Carleton College

This project involves studies of the compositions of amphibolites and granite greisses in metamorphic rocks in the Salida, Colorado area in order to determine their origin and petrogenesis. Principal investigators are Shelby Boardman of Carleton College and R. L. Cullers of the Geology Department at Kansas State University. During the year, the project required 20 hours of reactor operations.

7.4 Wichita State University

Igneous rocks formed in different geological environments have different compositions. Correspondingly, sediments formed by weathering of these igneous rocks should have diagnostic

compositions. This hypothesis is to be tested in order to determine tectonic enviornments in ancient rocks. Principal investigators are John Gries and Sam Sangmor of Wichita State University and R. L. Cullers of the Geology Department at Kansas State University. During the year, the project required 8 hours of reactor operations.

7.5 Baylor University

The compositions of selected volcanic rocks in Texas are being examined in order to determine the evolution of magma formations. Principal investigators are Don Parker of the Geology Department at Baylor University and R. L. Cullers of the Geology Department at Kansas State University. Eight hours of reactor operations were required during the year.

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1989 - June 30, 1990

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July, 1990

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG07-80ER10723
DE-AC07-76ER02082

During FY 1990 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and the understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic Triga Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix Stainless Steel Clad
Number of Core Positions	91
Average Enrichment	17 percent
^{235}U per Element Total ^{235}U	32 g 3.0 kg
Maximum Power (Steady-State)	250 Kw (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} $cm^{-2}s^{-1}$
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Piercing Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator

Ancillary Facilities	Three 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Ge), and magnetic-tape/disk data-transfer.

3. Personnel (30 Jun 90)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	David J. Whitfill
Radiation Safety Officer	John P. Lambert
Senior Reactor Operator	John K. Shultis
Reactor Operators	Matthew J. Burger John C. Kirkland
Reactor Safeguards Committee	Norman D. Eckhoff (ex officio) John P. Lambert (ex officio) David J. Whitfill (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a. Total Hours of operation[1] Mwh produced	369.7 26.2
b. Total hours of operation at full power	114.8
c. Operating hours in a typical week	7.1
d. Experiment-hours of irradiation service	213.7
e: Formal courses using reactor and number of students involved	Nuclear Engineering Concepts (17) Reactor Operations Laboratory (6) Chemistry I (83) Radiation Safety in the Res. Lab (17) Principles of Radiation Detection (20) Graduate Problems in Nuclear Engg. (5)
f. Nuclear engineering graduate students using reactor for thesis work	Ahmed Nejmaour Hossein Zamani Yuni Dewarajara

[1]Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

g. Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Biology Irradiation Services Biology Chemistry Electrical Engineering Tours and Demonstrations Chemistry Education Geology General Engineering University for Man
h. Commercial or non-academic utilization	Rare earth element assay in mineral specimens (NSF) Beta/Gamma Spectroscopy (DOE)
j. Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principle use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC07-76ER02082. In FY 1990, irradiations were provided to (1) faculty, undergraduate, and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and its nearby states.

There were 387 sample insertions in FY 1990. Activation analysis required approximately 1500 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in section 7.

Trace Elements in Foliage: [Nuclear Engineering] This is a study of trace element concentrations in oak leaves with species, season, specimen, and site. Its purpose is to provide baseline information for a study of the effect of stress on trace element concentrations. The principle investigator is Richard E. Faw, Professor of Nuclear Engineering.

Trace Elements in Rocks: [Geology] This is a study of the trace elements from the host rocks for Lead-Zinc deposits from samples taken from southeastern Missouri, and Iron-Manganese deposits from samples taken from Brazil and Bolivia. The principal investigator is Joseph Graf, Professor of Geology.

5.2 University Education

The second major use of the KSU TRIGA reactor is for graduate and undergraduate instruction.

Standard laboratory experiments using the reactor are carried out in the course "Reactor Operations Laboratory", a laboratory course devoted exclusively to the use of the reactor and required of all undergraduate students. The graduate course Nuclear Engineering Laboratory", also a laboratory course devoted to the use of the reactor, is required for all candidates for advance degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection", and "Nuclear Engineering Concepts". The reactor is also used in the elective course "Radiation Measurement Systems". Graduate Research Assistants in the Chemistry and

Biology Departments make use of the reactor in the course "Radiation Safety in the Research Laboratory".

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1990, lectures, tours, and demonstrations have been provided for (1) high school and college students, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for FY 1990 was 2524. This includes 307 elementary and junior high school students, 248 high school and junior college students, 393 Kansas State University students, 138 participants in workshops or institutes held at KSU, 195 general interest campus tours, and professional and civic clubs, and 29 individuals on walk-in tours. In addition, there with 607 during Open House, 457 during Engineering Awareness day, and 150 during parents day. The university students includes 145 persons enrolled in Chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	46.1	2.9	0
Operator Training and Requalification	8.5	2.3	0
Undergraduate Class Use	22.6	1.2	16
Graduate Class Use	0.3	0.0	5
Other Class Use	5.2	3.2	0
Neutron Activation Analysis			
a. Trace Elements in Foliage	35.4	16.1	152
b. Miscellaneous	10.8	5.1	34
Subtotal Nuclear Engineering Department	128.9	30.8	207
Other University Departments			
Isotope Production & Irradiation Service			
a. Chemistry Department	0.8	0.0	9
Neutron Activation Analysis			
a. Trace Elements in minerals [Geology]	8.0	8.0	24
Subtotal Other University Departments	8.8	8.0	33
Outside Users			
Neutron Activation Analysis			
a. Geology Department [administered by KSU]	76.0	76.0	147
Subtotal Outside Users	76.0	76.0	147
Total Reactor Utilization	213.7	114.8	387

*Includes full-power hours

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

Studies continue on the petrology and periodites in Kansas. Principal investigators are Pieter Berendsen of the University of Kansas, Lawrence, Kansas, and Robert L. Cullers of the Geology Department at Kansas State University. During the year, the studies required 16 hours of reactor operation.

7.2 Louisiana State University

This project is part of a study of the composition of precambrian metashales in the southwestern United States. In order to determine the source and tectonic environment of these shales, their compositions will be compared to those of known sources and environments. The principal investigators in this project are Don Lowe and Ronadh Cox of Louisiana State University, Baton Rouge, Louisiana, and Robert L. Cullers of the Geology Department at Kansas State University. During the year, this project consumed 36 hours of reactor operation.

7.3 Baylor University

The compositions of selected volcanic rocks in Texas are being examined in order to determine the evolution of magma formations. Principal investigators in this research are Don Parker of Baylor University, Waco, Texas, and Robert Cullers of the Geology Department at Kansas State University. Research in this project required 12 hours of reactor operation this year.

7.4 University of Kansas

The compositions of the Texaco core from Washington County, Kansas is being investigated from the precambrian continental rift deposits. Principal investigators for this project are Pieter Berendsen of the University of Kansas, Lawrence, Kansas, and Robert L. Cullers of the Geology Department of Kansas State University. 16 hours of reactor operation were required this year for the research in this project.

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AT

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1990 - June 30, 1991

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Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG07-80ER10723
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During FY 1991 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and the understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic Triga Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix Stainless Steel Clad
Number of Core Positions	91
Average Enrichment	17 percent
^{235}U per Element	32 g
Total ^{235}U	3.0 kg
Maximum Power (Steady-State)	250 Kw (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} cm^{-2} s^{-1}
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Piercing Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator

Ancillary Facilities	Three 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Ge),and magnetic-tape/disk data-transfer.

3. Personnel (30 Jun 91)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Matthew J. Burger
Radiation Safety Officer	John P. Lambert
Senior Reactor Operator	John K. Shultis David J. Whitfill John C. Kirkland
Reactor Safeguards Committee	Norman D. Eckhoff (ex officio) John P. Lambert (ex officio) Matthew J. Burger (ex officio) Gale G. Simons Richard E. Faw Herbert C. Moser Patrick Richard

4. Reactor Utilization

a.	Total Hours of operation[1] Mwh produced	410.5 24.6
b.	Total hours of operation at full power	125.2
c.	Operating hours in a typical week	8.0
d.	Experiment-hours of irradiation service	254.5
e.	Formal courses using reactor and number of students involved	Nuclear Engineering Concepts (17) Reactor Operations Laboratory (8) Chemistry I (114) Principles of Radiation Detection (8) Graduate Problems in Nuclear Engg. (2)
f.	Nuclear engineering graduate students using reactor for thesis work	Ahmed Nejmaour Hossein Zamani Jeffrey Deist

[1]Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Biology Chemistry Chemical Engineering Tours and Demonstrations Chemistry Geology General Engineering University for Man
h.	Commercial or non-academic utilization	Rare earth element assay in mineral specimens (NSF) Heavy element assay in Soils (EPA)
j.	Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principle use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC07-76ER02082. In FY 1991, irradiations were provided to (1) faculty, undergraduate, and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and its nearby states.

There were 284 sample insertions in FY 1991. Activation analysis required approximately 1100 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in section 7.

Trace Elements in Rocks: [Geology] This is a study of the trace elements from the host rocks for Lead-Zinc deposits from samples taken from southeastern Missouri, and Iron-Manganese deposits from samples taken from Brazil and Bolivia. The principal investigator is Joseph Graf, Professor of Geology.

Iodine in Lettuce: [Biology] This is a study of the iodine concentration in lettuce plants grown hydroponically in a nutrient solution kept free of microorganisms by circulation through a base resin loaded with polyiodide anions. Principal investigator is George Marchin of the Division of Biology.

Iodine in Bacteria: [Biology] This project involves determination of iodine attached to bacteria, in association with studies of water purification systems. Principal investigator is Louis Fina, Professor of Biology.

Oxygen in Superconductors: [Chemical Engineering] This project involves determination of oxygen in superconducting compounds by activation of ^{18}O. Principal investigator is John Schlup, Professor of Chemical Engineering.

Trace Elements in LiF: [Nuclear Engineering] This project involves determination of Al, Mg, and Ti in order to characterize and correlate properties of thermoluminescent dosimeters. Principal investigator is H.J. Donnert, Professor of Nuclear Engineering.

Uranium and Thorium in Phosphate Ores: [Nuclear Engineering] This project involves study of ores from Morocco and determination of uranium by activation to ^{239}U and ^{239}Np and thorium by activation to ^{233}Th and ^{233}Pa. Principal investigator is H. J. Donnert, Professor of Nuclear Engineering.

Heavy Metals in Soils: [Nuclear Engineering] This project involves determination of heavy metals and pathfinder elements in soil samples from the mining regions around Butte, Montana and Galena, Kansas. The principal investigator is Richard E. Faw, Professor of Nuclear Engineering

5.2 University Education

The second major use of the KSU TRIGA reactor is for graduate and undergraduate instruction.

Standard laboratory experiments using the reactor are carried out in the course "Reactor Operations Laboratory", a laboratory course devoted exclusively to the use of the reactor and required of all undergraduate students. The graduate course "Nuclear Engineering Laboratory", also a laboratory course devoted to the use of the reactor, is required for all candidates for advance degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection", and "Nuclear Engineering Concepts". The reactor is also used in the elective course "Radiation Measurement Systems". Graduate Research Assistants in the Chemistry and Biology Departments make use of the reactor in the course "Radiation Safety in the Research Laboratory".

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1991, lectures, tours, and demonstrations have been provided for (1) high school and college students, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for FY 1991 was 2836. This includes 340 elementary and junior high school students, 130 high school and junior college students, 208 Kansas State University students, 120 participants in workshops or institutes held at KSU, 79 general interest campus tours, and professional and civic clubs, 402 members of scouting groups, and 185 individuals on walk-in tours. In addition, there were 542 during Open House, 480 during Engineering Awareness day, and 350 during parents day. The university students includes 145 persons enrolled in Chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	39.1	0.4	0
Operator Training and Requalification	32.4	7.0	0
Undergraduate Class Use	25.8	0.4	6
Graduate Class Use	0.0	0.0	0
Other Class Use	22.0	0.1	0
Neutron Activation Analysis			
a. Uranium in phosphate minerals	1.7	1.2	4
b. Additives in TLD materials	5.8	4.1	9
c. Heavy elements in soils	12.3	12.0	40
d. Miscellaneous	2.0	1.5	4
Subtotal Nuclear Engineering Department	141.1	26.7	63
Other University Departments			
Isotope Production & Irradiation Service			
a. Chemistry Department	1.7	0.0	37
Neutron Activation Analysis			
a. Trace Elements in minerals [Geology]	4.0	4.0	8
b. Iodine in lettuce [Biology]	15.2	0.0	36
c. ^{18}O determination [Chemical Engineering]	2.4	0.2	4
d. Iodine in demineralizer elutant [Biology]	12.0	12.0	6
Subtotal Other University Departments	35.3	16.2	91
Outside Users			
Neutron Activation Analysis			
a. Geology Department [administered by KSU]	76.0	76.0	147
b. University of Cincinnati	6.5	6.1	24
Subtotal Outside Users	82.5	82.1	157
Total Reactor Utilization	258.9	125.0	311

*Includes full-power hours

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

Studies continue on the petrology and periodites in Kansas. Principal investigators are Pieter Berendsen of the University of Kansas, Lawrence, Kansas, and Robert L. Cullers of the Geology Department at Kansas State University. During the year, the studies required four hours of reactor operation.

7.2 University of Kansas

The compositions of the Texaco core from Washington County, Kansas is being investigated from the precambrian continental rift deposits. Principal investigators for this project are Pieter Berendsen of the University of Kansas, Lawrence, Kansas, and Robert L. Cullers of the Geology Department of Kansas State University. Four hours of reactor operation were required this year for the research in this project.

7.3 Louisiana State University

This project is part of a study of the composition of precambrian metashales in the southwestern United States. In order to determine the source and tectonic environment of these shales, their compositions will be compared to those of known sources and environments. The principal investigators in this project are Don Lowe and Ronadh Cox of Louisiana State University, Baton Rouge, Louisiana, and Robert L. Cullers of the Geology Department at Kansas State University. During the year, this project consumed 24 hours of reactor operation.

7.4 Stanford University

This project involves examination of the evolution of basalts in E. Greenland to test the hypothesis that the pegmatic rocks ar formed by partial meeting of the solid basaltic rocks. The principal investigators are Dennis Bird of Stanford University and Robert L. Cullers of the Geology Department at Kansas State University. During the year, 16 hours of reactor operations were required for the project.

7.5 Kansas Geological Survey

This project involves studies of the petrology and Chemical composition of Keweenawan-rift sediments from Kansas to Wisconsin. Principal investigators are Peter Berendsen of the Kansas Geological Survey and Robert L. Cullers of the Geology Department at Kansas State University. During the year, this project required 24 hours of reactor operations.

7.6 University of Cincinnati

This project involved determination of trace heavy metals in activated carbon of coal origin. Principal investigators is Dr. M. Suidan of the Civil and Environmental Engineering Department at the University of Cincinnati. The project required 6.5 hours of reactor operations.

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AT

KANSAS STATE UNIVERSITY

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1991 - June 30, 1992

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July, 1992

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG07-80ER10723
DE-AC07-76ER02082

During FY 1992 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and the understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic Triga Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix Stainless Steel Clad
Number of Core Positions	91
Average Enrichment	17 percent
^{235}U per Element	32 g
Total ^{235}U	3.0 kg
Maximum Power (Steady-State)	250 Kw (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} cm^{-2} s^{-1}
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Piercing Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator

Ancillary Facilities	Four 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Ge),and magnetic-tape/disk data-transfer.

3. **Personnel (30 Jun 92)**

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Matthew J. Burger
Radiation Safety Officer	John P. Lambert
Senior Reactor Operator	John K. Shultis John C. Kirkland
Reactor Operator	Brendan Ryan Quinton S. Lies
Reactor Safeguards Committee	Norman D. Eckhoff (ex officio) John P. Lambert (ex officio) Matthew J. Burger (ex officio) Gale G. Simons Richard E. Faw Clifton Meloan Patrick Richard

4. Reactor Utilization

a.	Total Hours of operation[1] Mwh produced	449.1 23.0
b.	Total hours of operation at full power	105.9
c.	Operating hours in a typical week	8.6
d.	Experiment-hours of irradiation service	293.1
e.	Formal courses using reactor and number of students involved	Nuclear Engineering Concepts (15) Reactor Operations Laboratory (6) Chemistry I (162) Nuclear Engineering Laboratory (5) Graduate Problems in Nuclear Engg. (9) Radiation Safety with Research Laboratory (15)
f.	Nuclear engineering graduate students using reactor for thesis work	Ahmed Nejmaoui Hossein Zamani Jeffrey Deist

[1]Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Biology Chemistry Chemical Engineering Tours and Demonstrations Chemistry Geology General Engineering University for Man
h.	Commercial or non-academic utilization	Rare earth element assay in mineral specimens (NSF) Heavy element assay in Soils (EPA)
j.	Anticipated changes in utilization	No significant changes

5. Summary of Reactor Services

5.1 Service Irradiations

A principle use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC07-76ER02082. In FY 1992, irradiations were provided to (1) faculty, undergraduate, and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and its nearby states.

There were 417 sample insertions in FY 1992. Activation analysis required approximately 1100 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in section 7.

Iodine in Bacteria: [Biology] This project involves determination of iodine attached to bacteria, in association with studies of water purification systems. Principal investigator is Louis Fina, Professor of Biology.

Oxygen in Superconductors: [Chemical Engineering] This project involves determination of oxygen in superconducting compounds by activation of ^{18}O. Principal investigator is John Schlup, Professor of Chemical Engineering.

Uranium and Thorium in Phosphate Ores: [Nuclear Engineering] This project involves study of ores from Morocco and determination of uranium by activation to ^{239}U and ^{239}Np and thorium by activation to ^{233}Th and ^{233}Pa. Principal investigator is H. J. Donnert, Professor of Nuclear Engineering.

Heavy Metals in Soils: [Nuclear Engineering] This project involves determination of heavy metals and pathfinder elements in soil samples from the mining regions around Butte, Montana and Galena, Kansas. The principal investigator is Richard E. Faw, Professor of Nuclear Engineering

5.2 University Education

The second major use of the KSU TRIGA reactor is for graduate and undergraduate instruction.

Standard laboratory experiments using the reactor are carried out in the course "Reactor Operations Laboratory", a laboratory course devoted exclusively to the use of the reactor and required of all undergraduate students. The graduate course "Nuclear Engineering Laboratory", also a laboratory course

devoted to the use of the reactor, is required for all candidates for advance degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection", and "Nuclear Engineering Concepts". The reactor is also used in the elective course "Radiation Measurement Systems". Graduate Research Assistants in the Chemistry and Biology Departments make use of the reactor in the course "Radiation Safety in the Research Laboratory".

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1992, lectures, tours, and demonstrations have been provided for (1) high school and college students, both local and regional, (2) public officials, (3) 4-H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for FY 1992 was 3019. This includes 633 elementary and junior high school students, 80 high school and junior college students, 197 Kansas State University students, 186 participants in workshops or institutes held at KSU, 112 in general interest campus tours, and professional and civic clubs, 178 members of scouting and 4-H groups, and 224 individuals on walk-in tours. In addition, there were 786 during Open House, 511 during Engineering Awareness Days, and 112 during Parents' Day. The university students include 162 persons enrolled in Chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	59.2	0.1	0
Operator Training and Requalification	20.3	0.6	0
Undergraduate Class Use	20.0	0.0	6
Graduate Class Use	28.8	4.5	12
Other Class Use	28.1	1.4	7
Neutron Activation Analysis			
a. Uranium in phosphate minerals	1.9	0.0	3
b. Heavy elements in soils	67.6	56.6	256
c. Miscellaneous	2.4	0.5	6
Subtotal Nuclear Engineering Department	228.3	63.7	290
Other University Departments			
Isotope Production & Irradiation Service			
a. Chemistry Department	0.5	0.0	15
Neutron Activation Analysis			
a. ^{18}O determination [Chemical Engineering]	5.0	0.0	16
b. Iodine in demineralizer elutant [Biology]	25.3	8.2	34
Subtotal Other University Departments	30.8	8.2	65
Outside Users			
Neutron Activation Analysis			
a. Geology Department [administered by KSU]	34.0	34.0	62
Total Reactor Utilization	293.1	105.9	417

*Includes full-power hours

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 Louisiana State University

Elemental contents of oldest sedimentary rocks in the world, located in Australia. Principal Investigators for this project are Mike DiMarco, LSU, and Robert L. Cullers of the Department of Geology, Kansas State University. During the year, the studies required four hours of reactor operation.

7.2 Wichita State University

Igneous rocks formed in different geological environments have different compositions. Correspondingly, sediments formed by weathering of these igneous rocks should have diagnostic compositions. This hypothesis is to be tested in order to determine tectonic environments in ancient rocks. Principal investigators for this project are John Gries and Sam Sangmor, Wichita State University, and Robert L. Cullers of the Geology Department of Kansas State University. Fifteen hours of reactor operation were required this year for the research in this project.

7.3 Kansas Geological Survey

This project involves studies of the petrology and Chemical composition of Keweenawan-rift sediments from Kansas to Wisconsin. Principal investigators are Pieter Berendsen of the Kansas Geological Survey and Robert L. Cullers of the Geology Department at Kansas State University. During the year, this project required 11 hours of reactor operations.

7.4 Stanford University

This project involves examination of the evolution of basalts in E. Greenland to test the hypothesis that the pegmatic rocks are formed by partial meeting of the solid basaltic rocks. The principal investigators are Dennis Bird of Stanford University and Robert L. Cullers of the Geology Department at Kansas State University. During the year, 4 hours of reactor operations were required for the project.

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AT

KANSAS STATE UNIVERSITY

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1992 - June 30, 1993

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July, 1993

Prepared for

THE U.S. DEPARTMENT OF ENERGY

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DE-AC07-76ER02082

During FY 1993 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and the understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic Triga Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix Stainless Steel Clad
Number of Core Positions	91
Average Enrichment	17 percent
^{235}U per Element	32 g
Total ^{235}U	3.0 kg
Maximum Power (Steady-State)	250 Kw (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} cm^{-2} s^{-1}
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Piercing Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator

Ancillary Facilities	Four 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Ge),and magnetic-tape/disk data-transfer.

3. Personnel (30 Jun 93)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	John C. Kirkland
Radiation Safety Officer	John P. Lambert
Senior Reactor Operator	Brendan Ryan Quinton S. Lies
Reactor Safeguards Committee	Norman D. Eckhoff (ex officio) John P. Lambert (ex officio) John C. Kirkland (ex officio) J. Kenneth Shultis Richard E. Faw Clifton Meloan Patrick Richard

4. Reactor Utilization[1]

a.	Total Hours of operation[2] Mwh produced	299.1 13.4
b.	Total hours of operation at full power	56.2
c.	Operating hours in a typical week	6.0
d.	Experiment-hours of irradiation service	143.1
e.	Formal courses using reactor and number of students involved	Nuclear Engineering Laboratory (2) Nuclear Engineering Concepts (17) Reactor Operations Laboratory (15) Radiation Safety with Research Laboratory (7) Chemistry Principles (63) Advanced Chemistry (64)

[1]Utilization was less than normal because of preparation for installation of replacement reactor console and heat exchanger.

[2]Total hours of operation includes experiment-hours plus an estimated thirteen hours per month for pre-experiment operations and reactivity balances.

f.	Nuclear engineering graduate students using reactor for thesis work	Ahmed Nejmaoui Shulin He Matthew J. Burger
g.	Nuclear Engineering undergraduate honors research	John Curtis Brian Grelk
h.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Chemistry
i.	Commercial or non-academic utilization	Rare earth element assay in mineral specimens (NSF) Elemental analysis of process residues (Boeing)
j.	Anticipated changes in utilization	Work on replacement of the reactor console and enlargement of the control room began on 15 May 93 and is expected to be completed by 15 Aug 93.

5. Summary of Reactor Services

5.1 Service Irradiations

A principle use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC07-76ER02082. In FY 1993, irradiations were provided to (1) faculty, undergraduate, and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and its nearby states.

There were 148 sample insertions in FY 1993. Activation analysis required approximately 400 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in section 7.

Uranium and Thorium in Phosphate Ores: [Nuclear Engineering] This project involves study of ores from Morocco and determination of uranium by activation to ^{239}U and ^{239}Np and thorium by activation to ^{233}Th and ^{233}Pa. Principal investigator is H. J. Donnert, Professor of Nuclear Engineering.

Heavy Metals in Soils: [Nuclear Engineering] This project involves determination of heavy metals and pathfinder elements in soil samples. This is an honors research project conducted by John Curtis under direction of Richard Faw, Professor of Nuclear Engineering

Trace Elements in TLD Devices: [Nuclear Engineering] This project involves determination of trace elements in LiF thermoluminescent compounds used in radiation dosimetry. Principal investigator is Joseph F. Merklin, Professor of Nuclear Engineering.

Standards Development: [Nuclear Engineering] This project involves development of methods for using iron wires as flux monitors. This is an honors research project conducted by Brian Grelk under the direction of Richard E. Faw, Professor of Nuclear Engineering.

Analysis of Process Residues: [Nuclear Engineering] This project involved analysis of surface residues on metal parts after metallurgical treatment. It was undertaken as an exploratory project for the Boeing Co., Wichita Division, Principal Investigator: Richard E. Faw, Professor of Nuclear Engineering.

5.2 University Education

The second major use of the KSU TRIGA reactor is for graduate and undergraduate instruction.

Standard laboratory experiments using the reactor are carried out in the course "Reactor Operations Laboratory", a laboratory course devoted exclusively to the use of the reactor and required of all undergraduate students. The graduate course "Nuclear Engineering Laboratory", also a laboratory course devoted to the use of the reactor, is required for all candidates for advance degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection", and "Nuclear Engineering Concepts". The reactor is also used in the elective course "Radiation Measurement Systems". Graduate Research Assistants in the Chemistry and Biology Departments make use of the reactor in the course "Radiation Safety in the Research Laboratory".

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1993, lectures, tours, and demonstrations have been provided for (1) high school and college students, both local and regional, (2) public officials, (3) scouting and 4-H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for FY 1993 was 1359. This includes 129 elementary and junior high school students, 38 high school and junior college students, 189 Kansas State University students, 46 in general interest campus tours, and professional and civic clubs, 47 members of scouting and 4-H groups, 52 individuals on walk-in tours, and 56 maintenance workers and inspectors. In addition, there were 452 during Open House, and 350 during Scholarship Days. The university students include 127 persons enrolled in Chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	19.6	3.3	0
Operator Training and Requalification	13.7	1.3	0
Undergraduate Class Use	41.3	3.5	10
Graduate Class Use	7.0	0.7	0
Neutron Activation Analysis			
a. Uranium in phosphate minerals	0.8	0.4	3
b. Trace elements in TLD devices	1.2	1.2	7
c. Heavy elements in soils	12.5	12.0	21
d. Standards development	9.6	8.6	18
e. Elements in process residues	3.3	2.2	3
Subtotal Nuclear Engineering Department	109.0	33.2	62
Other University Departments			
Isotope Production & Irradiation Service			
a. Chemistry Department	2.1	0.0	30
Subtotal Other University Departments	2.1	0.0	30
Outside Users			
Neutron Activation Analysis			
a. Geology Department [administered by KSU]	32.0	32.0	56
Total Reactor Utilization	143.1	65.2	148

*Includes full-power hours

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

This project involves determination of the composition of the lower abundant arkoses with minor basalt flows and the upper abundant basalt flows with minor arkoses. Principal investigators for this project are Professors Peter Berendsen of the University of Kansas and Robert L. Cullers of Kansas State University. During the year, the project required four hours of reactor operations.

7.2 Wichita State University

Igneous rocks formed in different geological environments have different compositions. Correspondingly, sediments formed by weathering of these igneous rocks should have diagnostic compositions. This hypothesis is to be tested in order to determine tectonic environments in ancient rocks. Principal investigators for this project are John Gries and Sam Sangmor, Wichita State University, and Robert L. Cullers of the Geology Department of Kansas State University. Twelve hours of reactor operation were required this year for the research in this project.

7.3 Kansas Geological Survey

This project involves studies of the petrology and Chemical composition of Keweenawan-rift sediments from Kansas to Wisconsin. Principal investigators are Pieter Berendsen of the Kansas Geological Survey and Robert L. Cullers of the Geology Department at Kansas State University. During the year, this project required sixteen hours of reactor operations.

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REACTOR SHARING IN GEOLOGY RESEARCH

AT

KANSAS STATE UNIVERSITY

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1993 - June 30, 1994

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July, 1994

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NOS. DE-FG07-80ER10723
DE-AC07-76ER02082

During FY 1994 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and the understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix Stainless Steel Clad
Number of Core Positions	91
Average Enrichment	17 percent
^{235}U per Element	32 g
Total ^{235}U	3.0 kg
Maximum Power (Steady-State)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} cm^{-2} s^{-1}
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Piercing Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator

Ancillary Facilities	Four 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Ge).

3. Personnel (30 Jun 93)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Brendan C. Ryan
Radiation Safety Officer	John P. Lambert
Senior Reactor Operator	Quinton S. Lies
Reactor Operator	Barton Schawe
Reactor Safeguards Committee	Norman D. Eckhoff (ex officio) John P. Lambert (ex officio) Brendan C. Ryan (ex officio) J. Kenneth Shultis Richard E. Faw Clifton Meloan Patrick Richard

4. Reactor Utilization

a.	Total Hours of operation[1] Mwh produced	363.0 22.3
b.	Total hours of operation at full power	86.8
c.	Operating hours in a typical week	7.3
d.	Experiment-hours of irradiation service	207.0
e.	Formal courses using reactor and number of students involved	Nuclear Engineering Thermal Hydraulics (7) Nuclear Engineering Concepts (10) Reactor Operations Laboratory (7) Principles of Radiation Detection (14) Chemistry Principles (477) Advanced Chemistry (216)

f.	Nuclear engineering graduate students using reactor for thesis work	Shulin He Brendan Ryan Barton Schawe
g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Veterinary Medicine Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Nuclear Engineering Chemistry
h.	Commercial or non-academic utilization	Rare earth element assay in mineral specimens (NSF) Reactor Operator Training (Wolf Creek Nuclear Power Plant Neutron Activation Analysis for the Armed Forces Radiobiology Research Institute.
i.	Anticipated changes in utilization	None

5. Summary of Reactor Services

5.1 Service Irradiations

A principle use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC07-76ER02082. In FY 1994, irradiations were provided to (1) faculty, undergraduate, and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and its nearby states.

There were 79 sample insertions in FY 1994. Activation analysis required approximately 210 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in section 7.

Project Lead Coffins: [Nuclear Engineering] This project involved determination of trace elements in the human remains found in lead coffins buried during the 17th century in St. Mary's City, early capital of Maryland. Principal investigator at Kansas State University is Brendan Ryan, Reactor Supervisor. Work was performed under the auspices of Mark Moore of the Armed Forces Radiobiological Research Institute, who serves as Technical Director of the Technical Team for Project Lead Coffins.

Trace Elements in TLD Devices [Nuclear Engineering] This project involved determination of trace elements in LiF

thermoluminescent compounds used in radiation dosimetry. Principal investigator was Joseph F. Merklin, Professor of Nuclear Engineering.

Iodine Determination in Feline Blood: [Veterinary Medicine] This project involved deterimination of combined organic and inorganic iodine in feline blood, to assist in diagnosis and treatment of feline thyroid disorders. Principal investigator was Dr. Tom Smith of the College of Veterinary Medicine.

5.2 University Education

The second major use of the KSU TRIGA reactor is for graduate and undergraduate instruction. Standard laboratory experiments using the reactor are carried out in the course "Reactor Operations Laboratory," and in the course "Nuclear Reactor Thermal Hydraulics," The former is a laboratory courses devoted exclusively to the use of the reactor and required of all undergraduate students. The graduate course "Nuclear Engineering Laboratory", also a laboratory course devoted to the use of the reactor, is required for all candidates for advance degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection", and "Nuclear Engineering Concepts". The reactor is also used in the elective course "Radiation Measurement Systems". Graduate Research Assistants in the Chemistry and Biology Departments make use of the reactor in the course "Radiation Safety in the Research Laboratory".

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1994, lectures, tours, and demonstrations have been provided for (1) high school and college students, both local and regional, (2) public officials, (3) scouting and 4-H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for FY 1994 was 2177. This includes 201 elementary and junior high school students, 334 high school and junior college students, 837 Kansas State University students, 44 in general interest campus tours, and professional and civic clubs, 145 members of scouting and 4-H groups, 9 individuals on walk-in tours, and 2 maintenance workers. In addition, there were 500 during Open House, and 105 during Scholarship Days. The university students include 693 persons enrolled in Chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	38.8	5.9	1
Operator Training and Requalification	43.9	1.8	0
Undergraduate Class Use	28.7	6.8	6
High-School Workshops	5.4	3.2	4
Neutron Activation Analysis			
a. Project Lead Coffin	11.3	4.3	15
b. Trace elements in TLD devices	0.3	0.3	2
Subtotal Nuclear Engineering Department	128.3	22.3	28
Other University Departments			
Neutron Activation Analysis			
a. College of Veterinary Medicine	2.8	2.4	10
Isotope Production & Irradiation Service			
a. Chemistry Department	2.6	0.1	24
Subtotal Other University Departments	5.4	2.5	34
Outside Users			
Wolf Creek Nuclear Power Plant	5.3	0	0
Neutron Activation Analysis			
a. Geology Department [administered by KSU]	68.0	62.0	17
Total Reactor Utilization	207.0	86.8	79

*Includes full-power hours

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 Kansas Geological Survey and University of Kansas

Formation of Keweenawan Sediments: This project involves studies of the petrology and Chemical composition of Keweenawan-rift sediments from Kansas to Wisconsin. Principal investigators are Pieter Berendsen of the Kansas Geological Survey and Robert L. Cullers of the Geology Department at Kansas State University. During the year, this project required twenty-eight hours of reactor operations.

7.2 Kansas Geological Survey and Geoforschungs Zentrum Potsdam

Shales and Granitic Rocks from Kansas Shales: This project involves analysis of the shales to determined the source rocks that weathered to produce the shales, and to determine any unusual concentrations. Some of the black shales, for instance, are greatly enriched in uranium, thorium, and chromium. The goal is to determine the environments of deposition, e.g., how reducing or other specialized conditions produced the enrichments. Principal investigators are Pieter Berendsen of the Kansas Geological Survey, Robert L. Cullers of the Geology Department at Kansas State University, and Peer Hoth of the Geoforschungs Zentrum Potsdam. During the year, this project required twenty hours of reactor operations.

7.3 University degli Studi della Basilicata

Composition of Pelitic Rocks in the Southern Appenines: This project involves determination of the compositions of whole pelitic rocks (mudrocks) and mixed separates in order to determine what kinds of rocks weathered to produce theses mudrocks. The goal is to determine how the elements are distributed among the minerals. Principal investigators are Robert L. Cullers of the Geology Department at Kansas State University, and Giovanni Mongelli of the University degli Studi della Basilicata, Potenza, Italy. During the year, this project required twenty hours of reactor operations.

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AT

KANSAS STATE UNIVERSITY

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KANSAS STATE UNIVERSITY

TRIGA Mk II

NUCLEAR REACTOR FACILITY

Progress Report

for Period July 1, 1994 - June 30, 1995

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July, 1995

Prepared for

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACTS

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DE-AC07-76ER02082

During FY 1995 the KSU TRIGA Mk II Nuclear Reactor Facility continued to serve the following major functions:

1. A research and educational tool for undergraduate and graduate nuclear engineering education at Kansas State University.
2. A "Reactor-Sharing" Facility for graduate and undergraduate research and education at user educational institutions in Kansas and neighboring states.
3. A specialized facility for research in neutron activation analysis.
4. A demonstration facility to promote public awareness of nuclear energy and the understanding of nuclear reactor systems.

2. Facility Description

Reactor Type	General Atomic TRIGA Mk II
Facility Operating License	R-88
Initial Criticality	October, 1962
Type of Fuel Elements	Enriched Uranium in ZrH Matrix Stainless Steel Clad
Number of Core Positions	91
Average Enrichment	17 percent
^{235}U per Element	32 g
Total ^{235}U	3.0 kg
Maximum Power (Steady-State)	250 kW (thermal)
Maximum Thermal Neutron Flux (Steady-State)	10^{13} cm^{-2} s^{-1}
Special Facilities	Rotary Specimen Rack Pneumatic Transfer System Thermal Column Thermalizing Column Two Radial Beam Ports One Tangential Beam Port One Fast-Piercing Beam Port Bulk-Shielding Tank In-Core LiDO Fast-Neutron Generator
Ancillary Facilities	Two 4096-channel multi-parameter pulse height analyzers with solid state detectors (Ge-Li and Ge).

3. Personnel (30 Jun 95)

Facility Director and SRO	Richard E. Faw
Reactor Supervisor and SRO	Brendan C. Ryan
Radiation Safety Officer	John P. Lambert
Reactor Operator	Barton Schawe Heather Vieth Mutty Sharfi
Reactor Safeguards Committee	Norman D. Eckhoff (ex officio) John P. Lambert (ex officio) Brendan C. Ryan (ex officio) J. Kenneth Shultis Richard E. Faw Clifton Meloan Patrick Richard

4. Reactor Utilization

a.	Total Hours of operation[1] Mwh produced	394 26.8
b.	Total hours of operation at full power	107.3
c.	Operating hours in a typical week	7.9
d.	Experiment-hours of irradiation service	238.0
e.	Formal courses using reactor and number of students involved	Nuclear Reactor Operations I (14) Nuclear Reactor Operations II (14) Nuclear Engineering Concepts (13) Principles of Radiation Detection (14) Nuclear Engineering Colloquium (7) Chemistry Principles (477) Advanced Chemistry (216) Radiation Safety in the Research Laboratory (7)
f.	Nuclear engineering graduate students using reactor for thesis work	Barton Schawe Brendan Ryan

[1]Includes 13 hours per month for general maintenance and surveillance activities required by Technical Specifications and carried out by facility staff.

g.	Academic departments (KSU) using reactor	Research Nuclear Engineering Geology Formal Courses Nuclear Engineering Chemistry Irradiation Services Nuclear Engineering Chemistry
h.	Commercial or non-academic utilization	Rare earth element assay in mineral specimens by neutron activation analysis Neutron activation analysis in human remains, for the Armed Forces Radiobiology Research Institute Analysis of trace elements in tall fescue grass, for the SE Kansas Agricultural Experiment Station
i.	Anticipated changes in utilization	None

5. Summary of Reactor Services

5.1 Service Irradiations

A principle use of the KSU TRIGA reactor is to provide neutron irradiation for neutron activation analysis (NAA). This activity is supported in part by the U.S. Department of Energy under contract DE-AC07-76ER02082. In FY 1995, irradiations were provided to (1) faculty, undergraduate, and graduate students in the Nuclear Engineering Department of KSU, (2) faculty and students in other departments of KSU, and (3) users from other institutions in Kansas and elsewhere. Much of the work supported by the Department of Energy under the Reactor Sharing Program has been devoted to geology research at many institutions, where researchers work in collaboration with Professor Robert L. Cullers of the Geology Department at Kansas State University. A bibliography of geology publications covering work supported by the Reactor Sharing Program is appended to this report.

There were 70 sample insertions in FY 1995. Activation analysis required approximately 186 laboratory hours. Listed below are brief descriptions of selected projects carried out for KSU researchers. Projects of outside users are described in section 7.

Project Lead Coffins: [Nuclear Engineering] This project involved determination of trace elements in the human remains found in lead coffins buried during the 17th century in St. Mary's City, early capital of Maryland. Principal investigator at Kansas State University is Brendan Ryan, Reactor Supervisor. Work was performed under the auspices of Mark Moore of the Armed Forces Radiobiological Research Institute, who serves as Technical Director of the Technical Team for Project Lead Coffins.

5.2 University Education

The second major use of the KSU TRIGA reactor is for graduate and undergraduate instruction. Standard laboratory experiments using the reactor are carried out in the courses "Reactor Operations Laboratory I and II." These courses are laboratory courses devoted primarily to the use of the reactor, and are required of all undergraduate students. The graduate course "Nuclear Engineering Laboratory", also a laboratory course devoted to the use of the reactor, is required for all candidates for advance degrees. The following required undergraduate courses also make use of the nuclear reactor as part of laboratory requirements: "Principles of Radiation Detection", and "Nuclear Engineering Concepts". The reactor is also used in the elective course "Radiation Measurement Systems". Graduate Research Assistants in the Chemistry and Biology Departments make use of the reactor in the course "Radiation Safety in the Research Laboratory." Both "Basic Chemistry" and "Advanced Chemistry" courses offered by the Chemistry Department make use of the reactor, not only in tours and demonstrations, but also for preparation of radionuclides used in laboratory exercise.

5.3 Public Education

The KSU TRIGA reactor is unique in this region, and is used extensively to improve public knowledge of nuclear engineering and nuclear energy. During FY 1995, lectures, tours, and demonstrations have been provided for (1) high school and college students, both local and regional, (2) public officials, (3) scouting and 4-H groups, (4) symposia attendees at conferences and workshops, (5) the general public at Open House sessions, and (6) general interest groups. The total number of persons touring the reactor for FY 1995 was 2285. This includes 55 high school and junior college students, 660 Kansas State University students, 35 in general interest campus tours, and 308 members of scouting and 4-H groups. In addition, there were 548 during Open House, and 567 during Scholarship Days. Conference and workshop participants numbered 112, including 15 professionals from the Riley County Emergency Medical Service, who took part in training programs. The university students include 593 persons enrolled in Chemistry classes. These classes used the reactor to prepare radioisotopes for use in laboratory exercises.

6. Summary of Reactor Utilization

Nuclear Engineering Department	Experiment* Hours	Full-Power Hours	Sample Insertions
Maintenance and Surveillance	19.9	2.2	0
Operator Training and Requalification	29.2	2.9	0
Undergraduate Class Use	68.4	12.0	10
High-School Workshops	6.2	3.7	1
Neutron Activation Analysis			
a. Project Lead Coffin	10.1	7.6	8
b. Reactor Console Display Design			
Subtotal Nuclear Engineering Department	133.8	28.4	19
Other University Departments			
Isotope Production & Irradiation Service			
a. Chemistry Department	7.7	0.1	15
Outside Users			
Neutron Activation Analysis			
a. Geology Department [administered by KSU]	56.0	52.4	14
b. Fission Track Analysis in Dolomite [University of Kansas]	19.2	20.8	10
c. Fescue Grass Analysis [SE Kansas Ag. Exp. Station]	11.3	7.5	12
Subtotal Outside Users	96.5	78.7	36
Total Reactor Utilization	238.0	107.3	70

*Includes full-power hours

7. Summary of Guest Institution Participation Under the Reactor Sharing Program

7.1 University of Kansas

Fission Track Analysis of Krider Dolomite: This project deals with Permian age carbonate rocks of the natural-gas rich Chase Group, which have unusually high amounts of uranium - 10-15 ppm compared to 3 ppm in more typical limestone. Neutron irradiation in these rocks leads to fission tracks which can be determined microscopically. Understanding of the process of uranium emplacement and how it relates to the diagenesis of the gas-producing rock is the overall goal of the research. The more specific goal of this work is to determine relative abundances of uranium in different mineral phases, thus determining the petrographic location of the uranium. The work is being carried out by graduate student John Luczaj, under the direction of Professor Robert Goldstein of the University of Kansas. 13.2 hours of irradiation and six sample insertions were required during the course of the work.

7.2 Kansas Southeast Agricultural Experiment Station

Analysis of Tall Fescue Grass: This work involves determination of trace elements in fescue grass, as related to beef cattle nutrition. Special interest is in the determination of calcium, magnesium, iron, copper, cobalt, molybdenum, and selenium. During the year, this work required 11.3 hours of reactor operation and 12 sample insertions. Work is being performed for Professor Ken Coffee of the Experiment Station.

7.3 Kansas Geological Survey and Geoforschungs Zentrum Potsdam

Shales and Granitic Rocks from Kansas Shales: This project involves analysis of the shales to determined the source rocks that weathered to produce the shales, and to determine any unusual concentrations. Some of the black shales, for instance, are greatly enriched in uranium, thorium, and chromium. The goal is to determine the environments of deposition, e.g., how reducing or other specialized conditions produced the enrichments. Principal investigators are Pieter Berendsen of the Kansas Geological Survey, Robert L. Cullers of the Geology Department at Kansas State University, and Peer Hoth of the Geoforschungs Zentrum Potsdam. During the year, this project required four hours of reactor operations.

7.4 University degli Studi della Basilicata

Composition of Pelitic Rocks in the Southern Appenines: This project involves determination of the compositions of whole pelitic rocks (mudrocks) and mixed separates in order to determine what kinds of rocks weathered to produce theses mudrocks. The goal is to determine how the elements are distributed among the minerals. Principal

investigators are Robert L. Cullers of the Geology Department at Kansas State University, and Giovanni Mongelli of the University degli Studi della Basilicata, Potenza, Italy. During the year, this project required thirty-two hours of reactor operations.

7.5 University of Maine and State University of New York

Rare Earths in the Perry Mountain Formation: This work involves determination of the reasons for unusual rare-earth element distributions in the Perry Mountain Formation in northwestern Maine relative to the adjacent Rangeley Formation. The goal is to determime the source rocks from which these formations were derived. Principal investigators are Charles Guidotti of the University of Maine, Barbara Bock of the State University of New York at Stony Brook, and Robert L. Cullers of the Geology Department at Kansas State University. During the year, this project required twenty hours of reactor operations.

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