PROGRESS REPORT
OF THE
UNIVERSITY OF MISSOURI - ROLLA
NUCLEAR REACTOR FACILITY

APRIL 1, 1980 to MARCH 31, 1981

Submitted to
The Nuclear Regulatory Commission
and
The University of Missouri - Rolla

By
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I. Introduction

This progress report is prepared in accordance with the requirements of the Nuclear Regulatory Commission 10 CFR 50.71 concerning the operation of the University of Missouri - Rolla Nuclear Reactor Facility (License R-79).

This reactor, a swimming pool type modified BSR, was first licensed as a 10 Kw training and research facility with initial criticality on December 9, 1961. In January 1967 an amendment was granted by the Nuclear Regulatory Commission to upgrade the facility, allowing an increase in power level to 200 Kw.

The Nuclear Reactor Facility is operated as a university facility available to the faculty and students of the various departments of the university for their educational and research programs. Several other universities has made use of this facility during this reporting period. The facility is also made available; for the purpose of training reactor personnel, to the nuclear industry and electric utilities.

The reactor staff has continued to review the operation of the reactor facility in an effort to improve the safety and efficiency of its operation and to provide conditions conductive to its utilization by students and faculty from this and other universities. The following sections of this report are intended to provide a brief outline of the various aspects of the operation of this facility including its utilization for education and research.

II. PERSONNEL AND REACTOR STAFF

A. Reactor Staff

Name	Title
Dr. D. Ray Edwards	Reactor Director
Alva E. Elliott	Reactor Manager
R.L. Jones	Reactor Maintenance Engineer
Carl Barton	Electronic Technician
Karen Lane	Secretary
Juls William	Lab Mechanic
Mike Middleton	Reactor Operator
Charles Ruggeri	Student Research Assistant
Ray Bono	Campus Health Physicist
Dan Carter	Health Physicist Tech.

B. Licensed Operators

Alva E. Elliott	Senior Operator
R.L. Jones	Senior Operator
Carl Barton	Reactor Operator
Karen Lane	Reactor Operator

C. Radiation Safety Committee

Nord L. Gale (chairman)	Life Sciences
Ray Bono (secretary) (ex officio)	Health Physicist
Ernst Bolter	Geology and Geophysics
O.K. Manuel	Chemistry
D. Ray Edwards (ex officio)	Reactor Director
Alva E. Elliott (ex officio)	Reactor Manager
N.T. Tsoulfanidis (ex officio)	Radiation Safety Officer
Ed Hale	Physics
Laird Schearer	Physics

This committee is required to meet at three month intervals. However in practice, the frequency of the meetings are usually greater.

D. Independent Audit

Dr. Franklin Pauls, former Reactor Director, acts as the independent auditor of the Reactor Facility. He reviews all records, procedures, and operating methods of the facility on a semi-annual basis. Semi-annual audits were completed on September 10, 1980 and May 2, 1980 and are included in the appendix of this report.

III. Supporting Facilities

Several supporting facilities are either operated or maintained by the reactor staff for users of the reactor. These greatly contribute to the efficiency of research and educational programs available to the faculty and students of the University of Missouri - Rolla.

<u>Analog Computer</u>: This computer is currently available to faculty and students and is used in scheduled classes for both graduate and undergraduate students. Several units of auxiliary equipment are also available to widen the scope of its operation.

<u>Slow Neutron Chopper</u>: A slow neutron chopper is available for student use at the reactor facility. This chopper, constructed as a masters research project, is mounted on the face of the thermal column door.

<u>Activation Analysis Lab</u>: The activation analysis lab has proven to be the most utilized supporting facility. The laboratory contains a 4096 channel analyzer, with NaI or GeLi Selectable Detector input. Included in the auxiliary equipment is a tape punch, multi-scaler programmer, a scope camera, and a teletype terminal. Three scalers are included in the laboratory equipment with the appropriate detectors for counting alpha, beta, and gamma radiation. A shielded detector with four ton low background lead shield housing two 3X3 sodium iodide crystals, is also available. These detectors are used in conjunction with the multi-channel analyzer. Several other units of equipment are available for the detection and evaluation of radioactive materials.

Pneumatic Tube Assembly: A dual tube pheumatic system is installed in the core of the reactor. This is a dual tube system, one tube being cadmium lined, the other bare. This system is a positive pressure type, using nitrogen as the propellant.

Dynamic Void: A method of introducing a void on the perifery of the core by use of nitrogen gas. This allows for a variation in void as a function of core height, total volume or volume change.

IV Improvements

The following items are considered improvements to the existing facilities during this reporting period.

(1) The purchase and installation of Two Counter/Single Channel Analyzers with Na-I detectors has been completed. These items will replace counter/scalers funded in 1962 and will be used primarily by students in the reactor physics courses taught at the facility.

(2) The facility has purchased an Apple-II personal computer system. This will be used for records budgets, etc.

(3) The installation of the New Radiation Area Monitoring System was completed in August 81. This system replaces the origional RAM with "State of the Art" and has improved the overall operation of the facility considerably.

(4) The intermediate and lower levels of the facility was rewired, in conduit. A new, High Radiation Area Warning System and Beam Port Control System was installed at this time. We also added a High Level Basement Sump alarm system to prevent flooding of the Lower Level. Flooding of this level has occurred in the past due to high rainfall with some damage to non-essential equipment.

V. REACTOR OPERATIONS

Facility Use

Table 1 depicts the current core loading designated as 67. The number 67 denotes the Sixty Seventh core configuration (assembly and location), that has been used at the reactor facility since the original operating license was issued in 1961. This 67 core has been in use since December 1978 and periodically checked for all parameters listed in Table 5 (core data). The core was unloaded for Control Rod Inspection during the Month of August '80. It was partially unloaded (4 or 5 assemblies) approximately 5 times for training exercises in fuel handling and 1/M core load's during this reporting period.

UMRR CORE AND RACK STORAGE FORM

TABLE 1

DATE December 19, 1978

Original Loading

LOADING NUMBER 67T

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
IP	CA													

RACK STORAGE FACILITY

R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R30
				F-13	F-20	HF-1	F-22	F-2	F-5	F-3			F-18	F-21

	1	2	3	4	5	6	7	8	9
A									
B					S				
C			HR-1	F-14	F-1	C-4			
D			D-8	C-1	F-16	F-9	F-4	F-10	
E			F-6	C-2	F-19	C-3	F-12	F-11	
F			BR	F-17	F-15	F-7	CR		

BRIDGE SIDE

UMRR CORE STATUS

KEY TO PREFIXES

- F - Standard Elements
- C - Control Elements
- HF - Half Front Element
- HR - Half Rear Element
- CA - Core Access Element
- IP - Isotope Production Eleme
- S - Source Holder
- Other ______

Elem.	Pos.	Mass	Elem.	Pos.	Mass	Elem	Pos.	Mass
HR-1	C3	84.912	F-16	D5	170.270	F-12	E7	168.774
F-8	D3	170.229	F-19	E5	170.264	F-10	D8	170.193
F-6	E3	169.160	F-15	F5	168.889	F-11	E8	168.969
F-14	C4	170.210	C-4	C6	102.112			
C-1	D4	102.112	F-9	D6	170.178			
C-2	E4	102.125	C-3	E6	101.978			
F-17	F4	169.111	F-7	F6	170.154			
F-1	C5	170.223	F-4	D7	170.206			

Bridge Position

Inches from T.C. 0.0

ΔK/K 0.905% @76°F
(measured value)

Total Mass Grams 2870.069

Core Data

During this reporting period only one core designation has been used to any extent. The "W" mode core was used for normal reactor operations since students cannot operate the reactor when the excess reactivity is above 0.7%. The "T" mode is used for extended operation (>3 hrs), beam port or thermal column experiments. The excess ρ was measured cold, clean critical. In day to day operation the excess ρ is quite often lower due to temperature increase of the pool.

Core Technical Data

Average Thermal Flux	$1.6X10^{12}$ at 200 Kw
Maximum Thermal Flux	$2.8X10^{12}$ at 200 Kw
Average Epithermal	$1.6X10^{11}$ at 200 Kw
Worth of Thermal Column	0.37% @ 76°F
Worth of Beam Port	Not detectable

Rod Worth

I. 2.64% II. 2.65% III. 3.36% Reg. 0.347% Date 10/22/80

Excess Reactivity 0.905% Shutdown Margin 4.385%

Void Coefficient -4.0X10 -7 ρ/cm^3 Date 10/3/80 Limit -2.0X10 -7 ρ/cm^3

Temperature Coefficient -9.66X10 -5 ρ/°F Date 10/29/80 Limit -4.0X10 -5 ρ/°F

Zenon Free Temp. Coeff. $-1.25X10^{-5}$ ρ/°F

Reactivity Addition Rate (max % ρ/sec)

I. 0.0608ρ/sec II. 0.0176 ρ/sec III. 0.0183 ρ/sec Reg. 0.0226 ρ/sec

Date 12/30/80

Rod Drop Time (24")

I. 390 msec II. 400 msec III. 400 msec Date 12/29/80

Magnet Separation Time

I. 35 msec II. 40 msec III. 40 msec Date 12/29/80

Table 2

Facility use of core or core grid plate locations

Number of Facility	Hours Used
B2 -	0.167
B4 -	0.47
B5 -	0.4
B6 -	1.033
B7 -	0.167
B8 -	0.5
C2 -	0.067
C3 -	0.833
C4 -	0.667
C5 -	1.783
C7 -	0.533
C8 -	1.30
D2 -	0.167
D3 -	0.25
D5 -	1.25
D6 -	2.067
D7 -	1.33
D8 -	0.917
D9 -	1.9
E5 -	1.33
E7 -	0.5
E8 -	0.75
F3 -	5.564
F5 -	1.0
	24.95 Total

Table 3

Facility use other than the grid space around the core

Facility	Hours
Neutron Chopper	1.87
Bare Rabbit	5.56
Beam Port	13.47
Reactor Console	800.0
Thermal Column	3.728
	824.62 Total

Table 4

Hours in Use	1575
Hours available but not in use	505
Hours at Power	188
Hours of Maintenance	824
KW Hours	12258
Hours for Research	7
Hours for Instruction	793
Experimenter Hours	1149
Sample Hours	213
Average Number of Experiments	1.04
Average Number of Samples	0.24
Grams U^{235} Burned	0.53392
Grams U^{235} Burned and Converted	0.63199

Hours in Use: is a total of Instruction, research and maintenance hours. With maintenance hours being only those hours when the reactor remained shutdown during the entire day.

Table 5

Unscheduled Shutdowns

4-16-80

Rundown; High Area Radiation (setpoint 10 mrem/hr) ... Rabbit tube sample became stuck in close approximately to Reactor Bridge and radiation detector. Building Evacuation Alarm activated and radiation detector. Building Evacuation Alarm activated and all personnel exited facility. Upon re-entry by Senior Licensed Operators, the gas pressure to the rabbit tube system was increased and sample dislodged. Reactor was operating at 200 Kw prior to rundown with radiation levels on contact with rabbit tube < 500 mr/hr. Maximum personnel total exposure was less than 20 mrem whole body.

7-24-80

Rundown; High Area Radiation (setpoint 10 mrem/hr) ... N-16 diffuser pump discharge nozzle mis-aligned. Re adjusted nozzle and returned reactor power to 200 Kw. Reactor at 200 Kw prior to rundown with radiation level at area monitor <12 mr/hr.

7-25-80

Dropped Shim Rod; No alarm ... Shim Rod 2 magnet current to low. Readjusted current in accordance with SOP and returned to power. Reactor operating at approximately 20 watts prior to rod drop.

9-11-80

Rundown; High Area Radiation (setpoint 10 mrem/hr) ... Operator failed to turn on N-16 diffuser pumps for reactor operation >20 Kw. Reactor was at 200 Kw with reactor bridge area radiation monitor reaching 12 mrem/hr prior to rundown.

9-15-80

Rundown; High Area Radiation (setpoint 10 mrem/hr) ... Spurious trip of newly installed system. Reactor at 200 Kw with normal radiation reading on all channels during rundown.

10-29-80

Rundown; High Area Radiation (setpoint 10 mrem/hr) Due to extended operation of reactor at 200 Kw the Intermediate level area radiation monitor (next to demineralizer) reached setpoint and caused a rundown. Portable HP instruments indicated radiation levels of <20 mr/hr. Area radiation monitors were adjusted to 20 mr/hr and reactor was returned to a power level of 200 Kw. Facility technical specifications allow radiation area monitor setpoints to be $\leq$ 30 mrem/hr.

11-5-80

Rundown; 120% demand ... student operator failed to change Linear NI selector switch while increasing reactor power from 6 watts to 20 watts. Reactor power approximately 7.2 watts.

11-5-80

Rundown; 120% demand ... student operator changed Linear NI selector switch while decreasing reactor power before system reached indicated range. Reactor power level 8 watts.

11-14-80

Rundown; 120% demand ... student operator failed to change Linear NI selector switch while increasing reactor power from 20 to 600 watts. Reactor power was 24 watts when rundown occured.

11-17-80

Rundown; 120% demand ... student operator failed to change inear NI selector switch while increasing reactor power from 20 to 600 watts. Reactor power was 24 watts when rundown occurred.

11-18-80

Rundown; Reg Rod insert limit in auto ... student operator placed rod control in auto with reg. rod on insert limit while prepairing to do rod worth measurements. Reactor was at 20 watts prior to rundown.

11-21-80

Scram; manual ... during routine shutdown of reactor shim rod 3 would not insert (or withdraw). Manual scram was innitiated by the operator. Upon investigation it was determined that the rod drive motor was inoperable (openwinding). Reactor was operating at <20 watts prior to scram (SR1 & 2 were being rundown).

12-10-80

Rundown; 120% full power ... Pool temperature was at 68°F due to maintenance on shim rod drive motor. The Nuclear Instrumentation system was alligned and calibrated with a pool temperature of 73°F. This difference in pool temp resulted in a Linear NI reading of 180 Kw and a Log N NI reading of 230 Kw. The power range NI detectors (callibrated at 73°F) were reading 85 to 90% of full power. Reactor was at approximately 180 Kw and was operated at this power level following the rundown.

01-08-81

Rundown; 120% demand ... student operator did not change selector switch on Linear NI during a power increase from 6 w to 20 w reactor power level 7.2 watts prior to rundown.

Table 6

Maintenance

04-09-80

Repair N-16 diffuser pump #2. Electrical connection broke off during operation, probably due to vibration. Replaced terminal and returned to service.

04-14-80

Replaced Shim Rod #2 rod drive brake solonid. Open coil resulted in drag (slower speed) on rod drive for both insert and withdrawl. Tested for correct rod drive speed and returned to service.

C5-27-80

Adjusted warm gear clutch on Linear recorder. Recorders were sticking on low end of scale.

06-26-80 to 07-18-80

Rewired (in conduit) Intermediate and Lower level of reactor building. Installed Ultrasonic detectors, new High Radiation warning sytem, Beam Port control, Thermal Column control and Basement Sump high level annunciator system.

07-23-80

Adjusted Linear NI recorder worm gear clutch. Recorder sticking on low end of scale.

07-29-80

Replaced Linear NI amplifier in accordance with Semi-Annual surveillance requirements. Checked for proper allignment as noted on Semi-Annual Checklist.

08-26-80

Completed Control Rod Physical Inspection as noted on Semi-Annual Checklist.

09-27-80

Completed installation of new Radiation Area Monitoring System. Checked for proper operation, calibrated with source and placed in service.

12-08-80

Replaced Shim Rod #3 rod drive motor (Model # 05088-FPE25L-107-5) with one of Similar type (Model # CDA 211454). Open winding in origional drive motor prevented either insert or withdrawl (no torque). Replacement motor has slower withdrawl and insert speed (5.8 inches/min vs. 6.0 inches/min).

12-22-80

Replaced Power Range Uncompensated Ion Chamber detector #1. Aligned system and checked for proper operation. Reactor will be power calibrated during Semi-Annual surveillance and detector will be physically adjusted with respect to core at that time.

12-23-80

Replaced suction hose for pool skimmer by draining approximately 7000 gallons of pool water. Water was sampled before during and after discharge for radioactivity. (All samples within 10CFR20 limits). Refilled pool and commenced purification of water. Completed Semi-Annual surveillance requirements as noted on Semi-Annual Checklist.

2-3-81

Replaced Shim Rod #1 Control Rod Drive Motor Model #05088-FPE25L with re-wound Shim Rod #3 motor. SR #1 motor shipped out for rewind (open winding) by O.E.M.

2-10-81

Re-wired and installed new relay control for under water pool lights.

VI Public Relations

The reactor staff has put forth considerable effort to educate the public in the field of nuclear energy. Over 2450 persons have toured the facility during this report period. This includes groups representing social, military, civic, industrial, governmental and educational fields. These groups are usually given a pre-orientation lecture by members of the reactor staff. These lectures are augmented by visual aids such as slides and displays. Many high school, junior college and college groups, (from this and other universities) have attended the various lectures and open houses. Some groups from other universities have spent an entire day at the facility becoming acquainted with the reactor and performing simple experiments. Usually these groups are from colleges which have no reactor facilities. A guided tour by the reactor staff includes a brief description of the basic nuclear reactions, components of a nuclear reactor, a few specific examples of how nuclear energy is used in industrial and educational field and how nuclear energy helps the environmental situation.

The Nuclear Engineering faculty are members of various social civic, professional, and governmental committees. The faculty and students also are involved in speaking engagements around Missou[illegible] and several other states concerning the reactor facility and in recruitin[illegible] programs at high schools and colleges.

The reactor staff is cooperating with several police departments in activation analysis of samples.

VII. Educational Utilization

Approximately 39 UMR students, graduates and undergraduates have participated in classes at the facility, utilizing 1616 student - semester hours of allocated time. Also students from several colleges, and high schools have used the facility

The following is a list of scheduled classes at the facility along with the total hours of Reactor Use for this reporting period.

NE 304 Reactor Lab	54.49 hrs.
NE 306 Reactor Operations	122.29 hrs.
NE 308 Advanced Reactor Lab	114.18 hrs.
NE 300 Special Problems	8.03 hrs.
NE 490 Research	0.0 hrs.
Reactor Operator training Program (via extension)	474.13 hrs.

The current enrollment in Nuclear Engineering is 74 students. During this reporting period the reactor was used 99.9% for instruction and 0.1% for research.

The use of the Nuclear Reactor by departments other than Nuclear Engineering on this campus has continued to decrease. This condition is a common occurance with campus reactors that have been in service for a considerable number of years. This is reflected in the amount of time the reactor was used for Research during this (and previous) reporting periods. It should be noted however, that the reactor use has remained very high in the area of training.

The Nuclear Reactor Facility was accepted, by the Union Electric Company of St. Louis, Mo., to provide serveral two week programs in operational training.

This training augments the first Phase of their Commercial Nuclear Reactor Operator Training, with actual hands on experience in Start-up, Shutdown, etc. This training was provided during July, September, January of 1980 and March of 1981.

Reactor Health Physics Activities
for the period
April 1, 1980 through March 31, 1981

Health Physics activities at the UMR Reactor Facility consist of radiation and contamination surveys, monitoring of personnel exposures, airborne activity, pool water activity and waste disposal. Releases of all by-product material to authorized, licensed recipients are surveyed and recorded. In addition, health physics activities include calibrations of portable and stationary radiation detection instruments, personnel training, special surveys and monitoring of non-routine procedures.

Routine Surveys

Monthly radiation surveys of the facility consist of direct gamma and neutron measurements with the reactor at full power. No unusual exposure rates were found. Monthly surface contamination surveys consist of 20-30 swipes counted separately for alpha and beta-gamma activity. In 12 monthly surveys, no significant contamination outside of contained work areas was found.

By-Product Material Release Surveys

During the period, 5 shipments of by-product material were surveyed and released from the reactor facility. Total activity released was 85.084 mCi. Three of the shipments were Radwaste which accounted for 85.082 mCi of the total activity. The other two shipments were utilized on the UMR Campus.

Routine Monitoring

44 reactor facility personnel and students frequently involved with operations in the reactor facility are currently assigned beta-gamma, neutron film badges which are read twice each month. There are five beta-gamma, neutron area and spare badges assigned. 24 campus personnel and students are assigned beta-gamma film badges and frequently TLD ring badges for materials

and X-ray work on campus. There are 20 beta-gamma area and spare badges assigned. In addition, 7 direct-reading dosimeters are used for visitors and high radiation area work. There have been no personnel over exposures during the period.

Airborne activity in the reactor facility is constantly monitored by a fixed-filter, particulate air monitor (CAM) located in the reactor bay. Rb-88 and Cs-138 are the particulate daughters of Kr-88 and Xe-138 which are monitored particulate activity above the natural background of Radon daughter products.

Argon-41, Krypton-88 and Xenon 138 are the gaseous activity routinely detected during operations.

Pool water activity is monitored monthly to insure no gross pool contamination nor fuel cladding rupture has occurred. Gross counts and spectra of long-lived gamma activity are compared to previous monthly counts. From April through March sample concentrations averaged 4.6×10^{-6} µci/ml.

Waste Disposal

Release of gaseous and particulate activity through the building exhausts is determined by relating the operating times of the exhaust fans and reactor power during fan operation to previously measured air activity at maximum reactor power. During this period 14.43 millicuries were released into the air. Released isotopes were identified as Kr-88, Rb-88, Xe-138, Cs-138 and Ar-41.

Solid waste, including used water filters, used resins and contaminated paper is stored and/or transferred to the campus waste storage area for later shipment to a commercial burial site. Radioactive waste released to the sanitary sewer is primarily from regeneration of the resin exchange column. During this period 8 releases to the sanitary sewer totaling approximately

9,255 gallons of concentrated resin regeneration solution and pool water were discharged with a total activity of 0.846 millicuries. Isotopes released were: Hydrogen-3, Sodium-24, Cr-51, Mn-54, Fe-59, Co-58, Co-60, La-140, and Ba-140. All isotopes released were below 10 CFR 20. Appendix B, Table I, Column 2 limits.

Instrument Calibrations

During this period, portable instruments were calibrated 4 times. Remote area monitors were checked for calibration 4 times.

IX Plans

The appendix of this report contains the final report of the UMR-Chancellor-Nuclear Facility Study Committee. Several members of the faculty undertook this 7 month study to determine the long range plans of the facility and the cost/benefit of continuing to operate this facility. The contents of the report is favorable to continuing to operate the reactor primarily as an educational (training) facility.

During the future reporting period the reactor staff will complete replacement of all origionally installed, control room instrumentation. The final items to be purchased consist of two compensated ion chamber power supplies for the Linear and Log-N Intermediate Range Nuclear Instruments. The Source Rnage, Magnet Power Supply and Power Range equipment has been previously purchased and needs only to be installed.

There will be two-ten day Reactor Operator Training programs in August or September of 1981 for Union Electric Company of St. Louis, Missouri. With the completion of these two programs our service to U.E. will be completed for their initial operator licensing effort. Continued programs (One-Ten day class per year) will be for only replacement operators and new professional employees. There are plans to obtain another steady customer from the utility industry, whose initial licensing effort is underway or just beginning.

The facility is still involved in a re-licensing effort that began in November of 1979. We have been informed by the NRC that their review of the initial facility documents will be completed and the resulting questions/answer series will begin during the future reporting period.

It is anticipated that the reactor staff will be expanded to include Three Senior Licensed Operators. Operator Licensing exams for One SRO and TWO Ro's will be given in June of 1981. The current plans call for an increase in licensed operators without acquiring any new personnel. These individuals scheduled for licensing have been members of the staff for some time and will therefore, require only a change in Job Title/Duties. This should allow the facility to expand it's operation without (or only minor) increase in operating cost to the University.

$\overline{X}$ Summary

The University of Missouri - Rolla Nuclear Reactor was in use approximately 136% of the time class was in session at the university (40 wks) or 82% of the total available time based on a 2080 hour work year. These previous precentages utilize the old established method for use rate and are some what misleading. A more reasonable percentage of use would be 50%(1) and 39 %(2) respectively. The total maintenance time of the facility was 824 hours (39%) which provided a total availability (reactor operational) of 1280 hours (61%).

It should be noted that during this reporting period approximately 350-hours of maintenance time was used for new equipment installation and that the facility was operating with only two licensed Senior Reactor Operators (normal compliment of three).

A total of 12.26 megawatt hours of energy was produced using 0.6312 grams of U-235. The ratio of usage was 99.9% for instruction and 0.1% for research.

A total of 216 samples was irradiated during this reporting with most samples being used on a intra-campus basis.

The reactor was visited by 2450 people during the past year. At the same time there were 36 UMR students enrolled for courses at the Reactor Facility. The Facility was thus comitted to over 1836 student-hours of classes involving about 27 hours per week during the Fall and Spring Semester. There were no classes at the reactor during the Summer of 1980 to allow for an extended maintenance period.

The facility continues to be utilized by electrical utilities for operator training. Four-ten day and three-five day non-credit university extension

(1) $\frac{\text{Hours of Instruction \& Hours of Research}}{\text{1600 hours}}$

(2) $\frac{\text{Hours of Instruction \& Hours of Research}}{\text{2080 hours}}$

programs were completed with approximately 440 hours of facility time being used for these programs. These programs provided $72,474 to the University with net revenue of $25,640 to the facility. These funds are and will be used to purchase new or replace out dated equipment.

APPENDICES

APPENDICES A

Semi Annual Check List

Date Commenced DEC 22 1980

Date Completed DEC : : 1980

Total Hours on Hour Meter 07286.1

1. Vacuum Tube Test and Clean Chassis — Initial

a. Log N Power Supply — 12-23-80

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
V4	5651

(3) Additional Comments

~~None~~ CMB None

b. Linear Power Supply — 12-23-80

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type

(3) Additional Comments

None

12-23-80
CMB
CMB

c. Linear Pulse Amplifier

(1) Cleaned chassis

(2) Tested all vacuum tubes

Replaced:

tube #	tube type
V-4	6AC7
V-2	6AC7

(3) Additional Comments

~~None~~ CMB None

12-23-80
CMB
CMB

d. Scaler Timer

(1) Cleaned chassis

(2) Tested all vacuum tubes

Replaced:

tube #	tube type

(3) Additional Comments

CMB None

12-23-80
CMB
CMB

e. Safety Amplifier

(1) Cleaned chassis

(2) Tested all vacuum tubes

Replaced:

tube #	tube type

(3) Additional Comments

f. Area Radiation Monitor 12-23-80

(1) Cleaned chassis CMB

(2) Tested all vacuum tubes CMB

Replaced: tube # tube type

tube #	tube type

(3) Additional Comments

SYSTEM IS NOW SOLID STATE

g. Micro-Micro Ammeter 12-23-80

(1) Cleaned chassis CMB

(2) Tested all vacuum tubes CMB

Replaced: tube # tube type

tube #	tube type

(3) Additional Comments

MICRO-MICRO AMMETER SN 19683 REMOVED AND MICRO-MICRO AMMETER SN. 19650 INSTALLED.

h. Fission Preamp 12-24-80

(1) Cleaned chassis and inspected CMB

(2) Additional Comments CMB

None

12-24-80

i. Public Address System

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
V-1	6AX5

(3) Additional Comments

None

12-24-80

j. Log Count Rate Recorder

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type

(3) Additional Comments

None

12-24-80

k. Linear Recorder

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type

(3) Additional Comments

None

l. Period Recorder 12-24-80

(1) Cleaned chassis CWB

(2) Tested all vacuum tubes CWB

Replaced: tube # tube type

tube #	tube type

(3) Additional Comments

None

m. Log N Recorder 12-24-80

(1) Cleaned chassis CWB

(2) Tested all vacuum tubes CWB

Replaced: tube # tube type

tube #	tube type

(3) Additional Comments

None

n. PAT 60 12-24-80

(1) Cleaned chassis CWB

(2) Tested all vacuum tubes CWB

Replaced: tube # tube type

tube #	tube type

(3) Additional Comments

None

12-24-80

o. Regulated Power Supply

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — [illegible]

Replaced:

tube #	tube type

(3) Additional Comments

Regulated Power Supply is now Solid State, contains no tubes.

12-24-80

p. Conductivity Brigge

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — [illegible]

Replaced:

tube #	tube type

Additional Comments:
Conductivity Brigge is solid State

12-24-80

q. Safety Amp Preamp

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type

(3) Additional Comments

None

2. Relay Test 12-23-80

a. Console relays tested and replaced as per SOP 815 [initials]

b. Additional Comments None

3. Detector Resistance

Safety #1

	Value	
(1) Signal to ground	3×10^{11}	[initials]
(2) Positive to ground	2×10^{12}	[initials]
(3) Additional Comments		

b. Safety #2

	Value	Initial
(1) Signal to ground	9×10^{11}	[initials]
(2) Positive to ground	8×10^{10}	[initials]
(3) Additional Comments		

c. Log N

(1) Signal to ground	6×10^{10}	[initials]
(2) Positive to ground	3×10^{9}	[initials]
(3) Negative to ground	5×10^{10}	[initials]
(4) Additional Comments		

d. Linear

(1) Signal to ground	6×10^{9}	[initials]
(2) Positive to ground	3×10^{9}	[initials]
(3) Negative to ground	8×10^{8}	[initials]
(4) Additional Comments		

4. Calibration Checks

Note: Any instrument found to be out of calibration should be realigned in accordance with its technical manual.

A. Temperature Recorder

1. Reading #

Reading #	Thermometer	Recorder
1	32 ~~80°F~~	32
2	32 ~~80°F~~	33
3	32 ~~80°F~~	32
1	140°F	140
2	140°F	141
3	140°F	140

Note: All readings should be ± 4°F

2. 135°F Interlock   Trip Point 135°   Initial [initials]

B. Log Count Rate Channel

1.

Pulse Generator*	Meter	Recorder	Initial
10	~~1100~~ 11	10	CMB
100	110	80	CMB
1000	1100	1000	CMB
10,000	10000	9990	CMB

Note: All readings should give .7 to 1.4 ratio of true-to observed readings.

2. Additional Comments

None

C. Linear

1.

Keithley	Meter	Recorder	Initial
$6.66X10^{-5}$	6.66	100%	CMB
$2.0X10^{-5}$	2.0	100%	CMB
$6.66X10^{-6}$	6.7	100%	CMB
$2.0X10^{-6}$	2.0	99%	CMB
$6.66X10^{-7}$	6.8	101%	CMB
$2.0X10^{-7}$	2.0	100%	CMB
$6.66X10^{-8}$	6.66	98%	CMB
$2.0X10^{-8}$	2.0	98%	CMB
$6.66X10^{-9}$	6.60	98%	CMB
$2.0X10^{-9}$	2.0	99%	CMB
$6.66X10^{-10}$	6.60	99%	CMB
$2.0X10^{-10}$	1.95	97%	CMB

Note: From 10^{-3} to 10^{-8} the overall accuracy should be better than 2% of full scale.

From $3X10^{-9}$ to $3X10^{-13}$ the overall accuracy should be better than 4%.

2. Additional Comments

None

D. Log N

1.

	Meter	Recorder	Keithley	Initial
5×10^{-5}	100	92	92	CMB
	10	10	14	CMB
	1	1	1.4	CMB
	0.1	0.1	0.1	CMB
	.01	0.008	0.011	CMB
	.001	0.0013	0.0008	CMB
	.0001	0.00014	0.00008	CMB

Note: The ratio of true-to-observed readings should be between 0.7 and 1.4.

2. Additional Comments

None

5. Verification of Rod Drop Times

a.

Rod #	Rod Height (inch)	Separation Time* (< 50 msec)	Rod Drop Time (< 600 msec at 24'
1	6	~~230~~ 35	230
1	12	↓	290
1	18	↓	360
1	24	↓	390
2	6	40	230
2	12	↓	290
2	18	↓	350
2	24	↓	400
3	6	40	230
3	12	↓	290
3	18	↓	360
3	24	↓	400

b. Date performed DEC 29 1980 Preformed by [signature]

Director or Supervisor [signature]

* by SOP 305

6. Void Coefficient Determination

a. Value of void coefficient -4.0×10^{-7} % ΔK/K/cm³

b. Calculation performed by [signature]

c. Date performed 10/3/80

d. Director or Supervisor [signature]

7. Temperature Coefficient Determination

a. Value of temperature coefficient -9.66×10^{-5} (-1.25×10^{-5})* % ΔK/K/°F

b. Calculations performed by [signature] *Xenon free

c. Date performed 10/29/80

d. Director or Supervisor [signature]

8. Rod Speeds

Time (Sec)	I.	II.	III.	Reg.
0-24"	239.7	240.6	247.5	62.7

(3) Additional Comment

Date DEC 29 1980 Performed By [signature]

9. Rod Indicator Calibration

Actual Height	Indicator Reading * I.	II.	III.	Reg.
1"	1	1	1	1
6"	6	6	6	6
12"	12	12	12	12
18"	18	18	18	18
24"	24	24	24	24

* values ± 0.1 inch

10. Results of Annual Control Rod Inspection

Not Done on this Semi Annual [signature]

A. Control Rod Number 1

11.b Control Rod Number 2

11.c Control Rod Number 3

d. Date Performed ______________________

e. Director or Supervisor ________________

Date 12-29 19 80

I have reviewed the results of this Semi-Annual Check on this date and discussed any problems and/or errors with the operating staff.

Director or Reactor Manager

_______________ [signature]

DEC 29 1980

Fire Alarm System Checked (all Smoke, Heat and Manual Pull Stations) for Building and Remote (Campus Police) indication. Pull Station checked on Battery Back up also.

[initials]

DEC 29 1980

Security System tested for all Signals which cause Remote indication (Door, Ultrasonic, Dead Bolt

7-28-80

Semi Annual Check List

Date Commenced JUL 28 1980

Date Completed AUG 29 1980

Total Hours on Hour Meter 07062.7

1. Vacuum Tube Test and Clean Chassis

Initial

a. Log N Power Supply

(1) Cleaned chassis CMB

(2) Tested all vacuum tubes CMB

Replaced:

tube #	tube type
V4	5651
V7	5651

(3) Additional Comments

None

b. Linear Power Supply

(1) Cleaned chassis CMB

(2) Tested all vacuum tubes CMB

Replaced:

tube #	tube type
V3	5651
V4	5651
V7	5651

(3) Additional Comments

None

7-28-80

c. Linear Pulse Amplifier

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
None	

(3) Additional Comments

None

d. Scaler Timer

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
V2	6201/12AT7
DCU1 V1	5963
DCU1 V4	5963
DCU3 V1	5963

(3) Additional Comments

DCU1 V1 + 4 weak (5963)

DCU 3 V1 weak

e. Safety Amplifier

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
None	

7-28-80

(3) Additional Comments

f. Area Radiation Monitor
(1) Cleaned chassis CMB
(2) Tested all vacuum tubes CMB
Replaced:

tube #	tube type
V1	6DQ6

(3) Additional Comments

g. Micro-Micro Ammeter
(1) Cleaned chassis CMB
(2) Tested all vacuum tubes CMB
Replaced:

tube #	tube type
NONE	

(3) Additional Comments

h. Fission Preamp
(1) Cleaned chassis and inspected CMB
(2) Additional Comments CMB

7-28-80

i. Public Address System

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
None	

(3) Additional Comments

j. Log Count Rate Recorder

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
V1	12AX7
V2	12AX7

(3) Additional Comments

k. Linear Recorder

(1) Cleaned chassis — CMB

(2) Tested all vacuum tubes — CMB

Replaced:

tube #	tube type
None	

(3) Additional Comments

7-28-80

l. Period Recorder CMB

(1) Cleaned chassis CMB

(2) Tested all vacuum tubes

Replaced:

tube #	tube type
None	

(3) Additional Comments

m. Log N Recorder CMB

(1) Cleaned chassis CMB

(2) Tested all vacuum tubes

Replaced:

tube #	tube type
None	

(3) Additional Comments

n. PAT 60 CMB

(1) Cleaned chassis CMB

(2) Tested all vacuum tubes

Replaced:

tube #	tube type
None	

(3) Additional Comments

o. Regulated Power Supply
   (1) Cleaned chassis
   (2) Additional Comments

p. Conductivity Bridge
   (1) Cleaned chassis
   (2) Tested all vacuum tubes N/A SOLID STATE
   Replaced:

tube #	tube type
NONE	

q. Safety Amp Preamp 7-28-80
   (1) Cleaned chassis
   (2) Tested all vacuum tubes
   Replaced:

tube #	tube type
NONE	

(3) Additional Comments

2. Relay Test
   a. Console relays tested and replaced as per SOP 815
   b. Relays Replaced

K-6	K-18	K-30
K-4	K-21	K-36
K-1	K-22	Shin 1-B
K-11	K-29	

(c) Additional Comments

3. Detector Resistance

a. Safety #1

	Value	
(147) Signal to ground	1.8x10^11	[initials]
(149) Positive to ground	2.0x10^12	[initials]
Open Circuit Resistance	1x10^14	[initials]

b. Safety #2

(143) Signal to ground	7.2x10^11	[initials]
(145) Positive to ground	8.5x10^10	[initials]
Open Circuit Resistance	1x10^14	[initials]

c. Log N

(125) Signal to ground	5.3^9	[initials]
(123) Positive to ground	3.2x10^9	[initials]
(121) Negative to ground	5.5x10^11	[initials]
Open Circuit Resistance	1x10^14	[initials]

d. Linear

(114) Signal to ground	5.5x10^9	[initials]
(112) Positive to ground	2.9x10^9	[initials]
(110) Negative to ground	7.2x10^8	[initials]
Open Circuit Resistance	1x10^14	[initials]

4. Fire Alarm System Tested as Per SOP 817 [initials]

5. Calibration Checks

Note: Any instrument found to be out of calibration should be realigned in accordance with its technical manuel.

A. Temperature Recorder

1.

Reading #	Thermometer	Recorder
1	32°F	32
2	32°F	33
3	32°F	33
1	160°F	161
2	160°F	161
3	160°F	162

Note: All readings should be ± 4°F

2. 135°F Interlock Trip Point

135 [initials]

B. Log Count Rate Channel

1. Pulse Generator*

Pulse Generator*	Meter	Recorder	Initial
10	12	10	[illegible]
100	130	120	[illegible]
1000	1200	1200	[illegible]
10,000	8500	9000	[illegible]

Note: All readings should give .7 to 1.4 ratio of true-to observed readings.

2. Additional Comments

C. Linear

1. Keithley 7-19-82

Keithley	Meter	Recorder (%)	Initial
$6.66X10^{-5}$	6.66	99%	CMB
$2.0X10^{-5}$	1.97	99%	CMB
$6.66X10^{-6}$	6.67	100%	CMB
$2.0X10^{-6}$	2.05	102%	CMB
$6.66X10^{-7}$	6.66	99%	CMB
$2.0X10^{-7}$	2.0	100%	CMB
$6.66X10^{-8}$	6.67	101%	CMB
$2.0X10^{-8}$	2.0	101%	CMB
$6.66X10^{-9}$	6.67	100%	CMB
$2.0X10^{-9}$	1.98	98%	CMB
$6.66X10^{-10}$	6.66	98%	CMB
$2.0X10^{-10}$	1.95	100%	CMB

Note: From 10^{-3} to 10^{-8} the overall accuracy should be better than 2% of full scale.
From $3X10^{-9}$ to $3X10^{-13}$ the overall accuracy should be better than 4%.

2. Additional Comments

D. Log N

1. Meter

	Meter	Recorder	Keithley	Initial
$5X10^{-5}$	100	103	110	ne
$5X10^{-6}$	10	11.0	14.0	ne
$5X10^{-7}$	1	1.20	1.30	ne
$5X10^{-8}$	0.1	.120	.100	ne
$5X10^{-9}$	.01	.013	.009	ne
$5X10^{-10}$	.001	.0014	.0008	ne
$5X10^{-11}$	.0001	.000135	.0001	ne

Note: The ratio of true-to-observed readings should be between 0.7 and 1.4.

2. Additional Comments

E. Automatic Control System for Regulating Rod

Final Settings*

Reset 6

Rate time .04

Proportional Band 70

Setpoint 39

*Adjust as per SOP 814

F. Radiation Area Monitor

1. SOP 806 completed for RAM [initials]

2. SOP 807 completed for RAM (Neutron) [initials]

6. Verification of Rod Drop Times

Rod #	Rod Height 6"	12"	18"	24"	Separation Time* 6"
1	250 ms	275 ms	345 ms	380 MS	15 ms
2	260 ms	275 ms	330 ms	380 MS	20 MS
3	270 ms	260 ms	325 MS	380 MS	15 MS

* Time calculated by (Time at normal current + 10 mamps) - (Time at minimum current + 5 mamps) = separation time.

b. Date performed AUG 28 1980 Preformed by [signature]

7. Void Coefficient Determination

a. Value of void coefficient -7.8 x 10^{-5} $\%\Delta K/K/cm^3$

b. Calculation performed by [signature]

c. Date performed Nov 15, 1979

8. Temperature Coefficient Determination

a. Value of temperature coefficient -6.6 X 10^{-3} $\%\Delta K/K/°F$

b. Calculations performed by [signature]

c. Date performed Nov 7, 1979

9. Power Calibration as per SOP 816 [signature]

a. Additional Comments 8/29/80

10. Rod Speeds (Sec.)

Time	I.	II.	III.	Reg.
0-24"	240.3	238.8	239.4	62.2

(3) Additional Comment

Date AUG 28 1980 Performed By [signature]

11. Rod Indicator Calibration

Actual Height	Indicator Reading I.*	II.*	III.*	Reg.*
1"	1	1	1	1
6"	6	6	6	6
12"	12	12	12	12
18"	18	18	18	18
24"	24	24	24	24

* values ± 1/16 inch [signature]

12. Results of Annual Control Rod Inspection.

A.1 Control Rod Number 1

2 mr top
1.25 R at bottom

Top cleaner than usual. No unusual signs of pitting and cracking.

A.2 Control Rod Drive Mechanism Brake and Solonid Sat RB

B.1 Control Rod Number 2

5 mr top
4 R at bottom
Top cleaner than usual. No unusual signs of pitting and cracking.

B.2 Control Rod Drive Mechanism Brake and Solonid Sat RB

C.1 Control Rod Number 3

5 mr top
6 R at bottom
Bow 10" from bottom of 0.0050 in. Noted during inspection, will continue observance.

C.2 Control Rod Drive Mechanism Brake and Solonid Sat RB

d. Date Performed AUG 26 1980

e. Director or Supervisor [signature]

Date Aug. 26 19 81

I have reviewed the results of this Semi-Annual Check on this date and discussed any problems and/or errors with the operating staff.

Director or Reactor Manager

______________________ [signature]

UNIVERSITY OF MISSOURI-ROLLA - NUCLEAR REACTOR

STANDARD OPERATING PROCEDURES

S.O.P.: 817	REVISED: 7-24-75	PAGE 1 OF 1

TITLE: Fire Alarm System

The UMR Nuclear Reactor building, fire alarm system consists of two type of detectors; four heat sensing units and two smoke detectors, plus two manual alarm station.
The system has a built in circuit failure warning system with an audible and visible alarm at the control box.
The alarm system is normally powered from building power, with batteries for a backup.
When a actual alarm is initiated an internal and an external building fire alarm is sounded and when the building security system is in operation a remote alarm is sounded at the campus police headquarters.

PROCEDURE:

1. Replace the emergency power supply batteries in the battery box.

2. Test emergency power by securing power to the alarm system (switch 32 in the power panel) and test system operational.

3. Check the four heat detectors by applying a heat blower on them and acknowledging alarm actuation, audible and visible and their resetting after the heat is removed.

4. Check the two smoke detectors by placing a burning cigarette on a long pole momentarily removing all power to the alarm control box.

5. Check the two manual alarm stations and acknowledge alarm actuation, audible and visible and reset.

6. Check all indication lights operational.

JUL 29 1980

WRITTEN BY: R.M. Luckett

APPROVED BY: D.R. Edwards

APPENDICES B

November 10, 1980

I am retiring after this year. After the Spring 1981 inspection some other arrangement will need to be made.

F. B. Pauls

REACTOR FACILITY INSPECTION -- Date(s) Nov 6 & 7, 1980
(Phone: 341-4236)
Econo " : 4240

Date(s) of last NRC inspection Sept 9 & 10, 1980

Date(s) of last "inhouse" inspection May 1 & 2, 1980 Comments see p 5

Log Book Inspection:

	Log Book Number	Page	Date
From entry:	4	404	May 1, 1980
Through entry:	4	468	Nov 7, 1980

Follow up items from previous inspection (item; follow-up):

1) Hot water in emergency shower — warm
2) Check whether emergency exit is clear — OK clear
3) Records — duplication — } have duplicate set
— health physics records at reactor — }
4) Pool paint — as before
5) Licensed operators — 3 at present

No follow up items from NRC inspection that needs attention.

	OK	Comments
A. Technical specifications ------------ Appendix A -- Jan. 6, 1967 Status of ? Still in the works. As per last inspection.	✓	Changes ~~, if so, list
1. (2.1) Ventilating fans ------------	✓	
Automatic closure ----------------	✓	
2. (3.1) Pool water depth (16 ft. min above core) ----------------	✓	Check: July 24, 1980 (OK) p 413 (Check 3/... p 4..) Reload core to 67 approach to critical training program for U.E.
3. (3.1) Inlet water temperature 60°F < t < 135°F ---------------	✓	
4. (3.2) Radiation one meter above pool < 5 mr/hr ------------------	✓	
5. (3.2) Resistivity > 0.5 megohm-cm-	✓	
6. Fuel ------------------------------	✓	Type of elements: MTR - pool storage Other Triga (dry storage)
Still part of Japan { (4.1.3) $\rho_{ex} < 1.5\%$ ------------------	✓	Present loading(s): 67W as of Dec 1978 Sr. Oper.
1.5% < ρ_{ex} < 3.5% five consecutive days twice a year ----------------	—	Dates: (1) X (2)
7. Control rod: (9.5) condition -----	✓	Date inspected: Last inspection Dec 6, 1979 Aug 26, 1980
(4.2.3) Reactivity shutdown margin at least 8% ---------------	✓	
(4.2.4) Drop time < 600 msec ------	✓	(9.3) Dates: (1) ~~on~~ annual (2) ~~semi~~ check
(4.3.2) Limit lights, shim range lights; magnet contact lights ----	✓	
8. Neutron source (min. 10^6 n/sec) ---	✓	

Page 417
Follow up on bowing of control rod #3 in next rod inspection

	OK	Comments
9. Safety systems (annunciator) ------	✓	
(5.4) Start-up channel ------------	✓	
(5.4) Linear channel -------------	✓	
(5.4) Log N - Peroid channel ------	✓	
(5.4) Safety channel #1 -----------	✓	
(5.4) Safety channel #2 -----------	✓	
10. (5.5) Magnet release time < 50 msec	✓	
11. (5.7) Radiation levels < 0.1 mr/hr-	✓	Location / Reading: Pool surface above core ------------ 2×10^{-3}; Near demineralizer - 2×10^{-3}; Beam room ---------- 1×10^{-3}; ~~X~~
Ram calibration (Quarterly (2nd Tue))	✓	
12. (5.8) Portable survey instruments -	✓	

List:

Neutron — Alpha

Gamma — See attached sheet — Beta

Other Instr calibration Quarterly - 3rd Thursday

	OK	Comments
13. Experimental facilities -------------	✓	Give example as to how used.
Hung samples ----------------------	✓	
(6.1.1) Core access element --------	✓	
(6.1.1) Isotope prod. element ------	✓	
(6.1.2) Rabbit tube ---------------	✓	
(6.1.2) Thermal column ------------	✓	
(6.1.2) Beam port -----------------	✓	
(6.2.2) Documentation of exps. ----	✓	
(6.2.3) Single independent experiment: $\rho_{ex} < 0.7\%$ --------------	✓	
(6.2.4) Single movable experiment: $\rho_{ex} < 0.4\%$ --------------	✓	
0.6% all movable exp. ------	✓	
(6.2.5) Experiments having moving parts: $\rho_{ex} < 0.05\%$ ---------------	✓	
(6.2.6) Position of any/all exp. --	✓	
14. General Operating Limitations		
(7.1) Startup: Sr.Oper. plus one (in the control room)	✓	
(7.1) Operation: S.O. plus one -- (in building)	✓	
(7.4) No fuel position vacancies in core; loading (wall chart) ----	✓	

Item	Ok	Comments
15. Fuel Storage & Transfer		
wall chart	✓	
(8.3) Fuel handling tools locked	✓	
(8.4) Fuel transfer--three men (Sr. Oper.; Lic. Oper.; plus one	✓	
16. (10.1) New loading: approach to critical exp. (reason & date)	✓	Loading 67 W as of Dec 1978 Checks with loading chart on wall
(10.2) Core configuration change: one grid position. (Reason & date)	✓	
(10.3) Loading change of more than one grid position-unload 50%	✓	
17. Instruments functioning (Table I)	✓	(On weekly check list - *)
Scram: Manual	✓	startup
Period < 5 sec.	✓	*
150% full power	✓	startup
Bridge motion	✓	*
Log N - Period non-op	✓	*startup
Rundown: 120% power (linear)	✓	*
Period < 15 sec	✓	*
Reg Rod (insert limit-auto rundown)	✓	*
120% full power (log N)	✓	*
Low CIC voltage	✓	startup
High radiation	✓	startup
Rod prohibit: Period < 30 sec.	✓	*
Any recorder off	✓	*
Low count rate	✓	*
Reg Rod prohibit (rods below shim range)	✓	
Inlet temp. > 135°F	✓	*
Servo-prohibit on reg. rod	✓	
18. Check Lists and records		
Log book checked	✓	
(9.1) Daily facility check list	✓	
(9.3) Instrument channels & area monitors-calibrated at 90 day intervals	✓	Dates: (1) (2) (3) (4) Intend to check in details during the spring audit.
UKRR startup check list	✓	
Hourly records-note variations	✓	
Shut-down check list	✓	
Weekly check list	✓	
~~Work load log~~	✓	
Six month systems check	✓	Dates: (1) July 28 — Aug 29, 1980 (2)

Observed start-up Nov 6, 1980

Previous Check Jan, 1980

	OK	Comments
B. Records		
1. Log books	✓	Current book number 4 Other ____ Stored ____
2. Recorder charts	✓	Stored: where and for how long
Log N (permanent)	✓	Located: In Reactor Bldg.
3. Evacuation alarms: number and cause	✓	1. None. Should have an 2. evacuation drill this semester.
4. Evacuation procedures, drills	✓	
5. Use of by-pass keys	✓	1.
6. Key security	✓	
General security	✓	
Night use of building	✓	
7. SOP'S - Note any revisions	✓	
8. Film badge, dosimeter	✓	
9. Night watchman record	✓	
C. Reactor Bay		
1. General condition of pool	✓	
2. General condition of storage	✓	
3. Use of cable trench	✓	
4. Nitrogen diffuser	✓	
5. Miscellaneous (List)	✓	
D. Control Room	✓	
List of current operators	✓	Senior operators: Alva E. Elliott – Aug 3, 1980 Ron L Jones – Apr 18, 1979 Operators: Carl M. Barton – June 11, 1980
E. Office (film badge rack, etc.)	✓	
F. Counting Room	✓	
G. Rooms & Storage upstairs	✓	

	OK	Comments
H. Stairwell & pump area	✓	
1. Demineralizer system	✓	
2. Outside air filters	✓	
I. Stairs and beam room	✓	
1. Thermal column	✓	
2. Beam tube	✓	
3. Fuel storage	✓	
4. Liquid & solid waste storage	✓	
J. Health Physics		
1. Sample removal	✓	
2. SOP'S (list)	✓	
3. Excursion or incident monitor	✓	
a. Film badge placement	✓	
b. Other	✓	
4. Film badge, dosimeter records	✓	
a. Staff	✓	
b. Students	✓	
c. Guests	✓	
d. Night watchman	✓	
5. Possible detection of fuel element rupture	✓	
6. Radiation survey	✓	Dates:
a. Periodic swipe tests	✓	2nd [illegible]
b. Pool water	✓	1st & 4th [illegible]
c. Inside air	✓	3rd [illegible]
d. Outside air		
e. Neutron level (sub-critical	✓	
f. Misc. items (list)	✓	
7. Emergency box (Physics Bldg.)	✓	

General comments:

1. I did not detect any items of great concern. I'm always pleased to see the excellent general housekeeping.
2. A building evacuation drill is needed for this semester.
3. I understand the avalability of "hot" water in the emergency shower room is under advisement. At present there is a temperature difference. At least the "hot water" is some warmer, but only slightly. The hot water to the sink is turned off. I think this ought to be turned back on.
4. I had a lengthy discussion with the health physicist as to the relationship between him and the reactor facility. During the spring inspection I intend to go into detail, records etc.

Signed: Franklin B. Pauls

Copies to: Dr. N. L. Gale, Chairman, Radiation Safety Committee
Dr. D. R. Edwards, Director of Nuclear Reactor
Mr. A. E. Elliott, Manager of Nuclear Reactor

UMR Reactor

Health Physicists Survey Instruments

Calibrated & In-use

Date: October 18, 1977

Instrument/Model	Manufacturer	Serial Number
Cutie Pie Survey Meter/CP-3	Technical Associates	602
Cutie Pie Survey Meter/CP-3A	Technical Associates	477
Cutie Pie Survey Meter/CP-3A	Technical Associates	478
Cutie Pie Survey Meter/CP-3A	Technical Associates	479
G.M. Survey Meter/E-120	Eberline	3194
Radiation Monitor/RM-14	Eberline	2247
High Range Survey Meter/RadectorIII	Victoreen	897
High Range Survey Meter	Eberline PIC-6A	1405
GM Survey Meter/Thyac 3850	Victoreen	1202
Neutron Survey Meter/488A	Victoreen	243
Neutron Dosimeter/D-300C	Kaman	163
High Range Survey Meter	Eberline PIC-6A	1799
High Range Survey Meter	Eberline PIC-6A	1851

[illegible]/80 OK

Operator Requalification During License Period

A. Examination Review Sheet (Annual exam -- usually in summer)

Name of Operator	License number and date	Exam dates	Comments	5-year record
1. C M Barton	OP 5236 June 16, 1980	11/3/80	Start-up and shut down	
2. R. L. Jones	OP 2964-1 Apr 18, 1979	July 16, 1980 11/3/80	Start-up and shut down	
3. A. E. Elliott	OP 434-8 Aug 3, 1980	~~July 1976~~ June 8, 1979	July 16, 1980	
4.				

B. Performance Evaluation (Semi-annual)

Name of Operator	Evaluation Date	Comments
1.		
2. R. L. Jones	11/3/80 completed 11/5/80	Good
3.		
4.		

C. On the Job Training: Progress Report (Annual Summary)
(Notebook kept by the operator.)

Name of Operator	Annual Summary Date	Comments
1.		
2.		
3.		
4.		

Special Nuclear Materials (SNM)

Position	Name
Reactor Director --------------	A. E. Elliott
Reactor ~~Supervisor~~ Manager -------------	
SNM Custodian -----------------	

1. (See p. 2) Procedures reviewed annually by the Reactor Supervisor:
   Date Name

2. SNM Records: Where kept? On file in main office

   (1) Position and/or change of position of non-irradiated fuel: None

   (2) Position and/or change of position of irradiated fuel: none

   (3) SNM receipts: None

   (4) SNM shipments: None

   (5) Semi-annual Material Status Report:
   Most recent previous report: Date 4/1/79 - 9/30/79 (Period)
   Current report:
   Date 3/31/80 10/1/79 - 3/31/80 | Could be one more
   3/20/80 | Sept 4/1/80 - 9/30/80

   (6) Annual Physical Inventory (SNM status log):
   Date
   Previous report: ―
   Current report: 3/31/80

   (7) SNM loss, theft or sabotage reported: None
   Date To whom reported (Director Region III NRC)

   (8) (See p. 5) Violations of Written Procedures: None

   (9) SNM Internal Control Areas:

   Dry storage area (basement): ✓

   Reactor: None

   Containment building: None

APPENDICES C

REPORT

SUBMITTED TO THE UMR CHANCELLOR

BY

THE NUCLEAR FACILITIES STUDY COMMITTEE

29 APRIL 1981

CONTENTS

NUCLEAR FACILITIES STUDY COMMITTEE

Chairman, Nicholas Tsoulfanidis, Nuc. Eng.

Bassem F. Armaly, Mech. Eng.

Albert E. Bolon, Nuc. Eng.

Kenneth H. Carpenter, Elec. Eng.

Thomas J. Dolan, Nuc. Eng.

Edward B. Hale, Phys.

Arvind Kumar, Nuc. Eng.

Leonard L. Levenson, Phys.

ABSTRACT

The Nuclear Facilities Study Committee has been charged with the task of recommending to the Chancellor of the University of Missouri-Rolla (UMR) the facilities that will be required to satisfy the nuclear needs of the University for the next 20 years. The committee has considered four types of facilities: 1) Nuclear Reactor, 2) Thermal-Hydraulics Laboratory, 3) Radiation Damage and Effects Research Center, and 4) Fusion Research Center.

The committee believes that to maintain a strong Nuclear Engineering program UMR must continue to have an operating Nuclear Reactor. Therefore, the refueling of the reactor is an item of highest priority.

A Thermal-Hydraulics Laboratory should be established for instructional purposes within the Nuclear Engineering program. The development of research in the area of thermal-hydraulics can be accomplished only by hiring additional faculty who have experience in this field.

Both fission and fusion reactors require extensive and continuous study of materials properties and of the change of these properties under adverse physicochemical and radiation environments associated with these types of reactors. UMR, which already has considerable research capability in this area, should expand its research efforts by buying additional equipment needed for the study of irradiated materials.

The present fusion research effort at UMR should be expanded to increase the laboratory experience of students and the research opportunities for interested faculty. UMR should play a leadership role in developing fusion technology.

INTRODUCTION

The Nuclear Facilities Study Committee was appointed by Chancellor Marchello in the fall of 1980 and was charged with the responsibility of recommending to him the nuclear facilities that will be required to satisfy the nuclear instructional and research needs of the University for the next 20 years. The committee was assigned an account fund and was encouraged to invite persons from industry, academia, and national laboratories to UMR for discussions.

The committee held several meetings, some of which involved only the committee members, and others included guests. The minutes of these meetings are included as Appendix A.

Additional information that has helped the committee formulate its recommendations was obtained in two ways. First, questionnaires were prepared and mailed to the chairmen of several Nuclear Engineering departments and to alumni of UMR's Nuclear Engineering program. Factual information and opinions concerning nuclear engineering education for now and the future were requested. A copy of the questionnaire and the tabulated responses are included as Appendices D and E. The responses were very well thought out and very useful for the committee's work. Second, several persons knowledgeable in the nuclear field were invited to discuss with the committee the subject of nuclear experimental facilities. The persons who met with the committee were:

- Mr. Paul Appleby, Superintendent of Training, Union Electric Company
- Dr. Howard Arnold, General Manager of Advanced Reactors Division, Westinghouse Power Company
- Dr. David Bartine, Head of Reactor Analysis and Shielding Section, Oak Ridge National Laboratory
- Dr. D. Ray Edwards, Director of the UMR Reactor
- Mr. Alva Elliott, Manager of the UMR Reactor
- Dr. D. Eppelsheimer, Professor Emeritus of Metallurgical and Nuclear Engineering, UMR
- Dr. Nord Gale, Head of Life Sciences, UMR
- Mr. Ron Jones, Senior Reactor Operator, UMR Reactor
- Dr. George Russell, Chancellor, UMKC.

From the affiliations and titles of these persons, it can be seen that the committee attempted to obtain opinions, ideas, and information from people whose backgrounds encompass a variety of fields related to nuclear education, research, and technology.

In following the Chancellor's guidelines, the committee has formulated its recommendations in answer to the following question: "What will be the facilities that UMR should develop and acquire to satisfy the needs for nuclear education and research for the next two decades?"

The committee has interpreted its task to be not "how to obtain the..." but rather "what is needed for..." Therefore, the committee's recommendations are based on the firm belief that UMR is a prominent technological institution which should remain in the forefront of educational and research activities that support energy technologies. Recommendations are made for four areas. These are: 1) Nuclear Reactor, 2) Thermal-Hydraulics, 3) Materials and Radiation Damage, and 4) Fusion.

NUCLEAR FACILITIES

UMR Nuclear Reactor

General Comments

The UMR reactor went into operation in December 1961. Since that time, it has not only been used for education, research, and training, but has been and remains a prime attraction for visitors who come to UMR for such events as University Day, Parents Day, and Merit Badge Day. The reactor was built as a campus facility, and the committee believes it should continue to serve as such.

At the present time, the reactor's primary function is to serve as an educational laboratory for undergraduate and graduate students in nuclear engineering courses. It is used by faculty from departments other than nuclear engineering primarily to irradiate samples for activation analyses or radiation damage studies.

The reactor is the major experimental facility for UMR's nuclear engineering program. As the comments of the Director of the Reactor (App.B), the nuclear engineering faculty (App.C), other nuclear reactor departmental chairmen (App.D), and nuclear engineering alumni (App.E) show, the reactor is considered to be an important asset for nuclear engineering education. No university can conduct a strong nuclear engineering program, either graduate or undergraduate, without a nuclear reactor. If UMR did not have a reactor, it would be very unlikely that it would build one now. Since the reactor exists and is operating, shutting it down would constitute a decided loss for UMR.

It is difficult to estimate the replacement cost of the reactor. In 1961, when the facility was constructed and licensed, it cost about $140,000. The cost of the fuel is not included in this amount, because the Federal Government provided the fuel. The Government still provides fuel for research reactors at no cost to the academic institutions. The construction cost of the reactor today would be about $420,000, which is the original cost adjusted to 1980 dollars in accordance with the Consumer Price Index. The task of licensing a new reactor is presently of such magnitude that it is unlikely that any academic institution in the U.S. would undertake such an endeavor.

The reactor is still operating with its initial fuel, which had a warranted life of nine years. Because this fuel has been in the reactor for 20 years, it would not be surprising if one or more of the fuel elements developed a leak which would increase the radioactivity of the pool water. In such a case, if new fuel is not obtained, the reactor might have to be shut down.

The annual operating cost of the reactor is about $126,000, the major portion of which is used for the salaries and wages of the present staff of 5.5 FTE's:

0.5 FTE Director
1.0 FTE Manager (Sr. Operator)
1.0 FTE Reactor Maintenance Engr. (Sr. Operator)
1.0 FTE Electronics Technician
1.0 FTE Secretary-Receptionist
1.0 FTE Custodian and Lab Mechanic

Recommendations

The committee believes that the reactor will continue to be one of the major facilities if not the major experimental facility for the nuclear engineering program at UMR. Most of the nuclear engineering baccalaureate graduates will continue to be employed by utilities operating nuclear power plants. For this reason, the experience the students gain by performing experiments with the reactor is and will be invaluable as has been proven to be in the past.

The use of the reactor for research is at the present time extremely low. This is due to a variety of factors such as lack of adequate staff and limited operation at maximum power because of insufficient cooling. These factors have contributed to the lack of interest on the part of the UMR faculty.

The committee recommends, in order of funding priority, the following:

Reactor Refueling: The present fuel, which is of the MTR (Materials Testing Reactor) type is not routinely manufactured because of limited current use. Nearly all the research reactors in the world use TRIGA (Testing Reactor Isotopes - General Atomic) type fuel.

The new fuel should be of the TRIGA type, not only because this fuel is better and more easily obtained than the MTR type fuel, it is (more importantly) enriched to less than 20% in ^{235}U. This lower enrichment means that it is much easier to satisfy the ever increasing Federal security requirements.

Most of the cost of refueling the reactor would be for transporting the used fuel to the Savannah River Laboratory*. This cost is estimated to be between $25,000 and $50,000 (1980 dollars). The cost of the new fuel would be borne by the Federal Government, but the expense of shipping and installing it, which would be in the range of $2,000 to $5,000 would have to be borne by UMR.

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* UMR has already obtained four control TRIGA elements and one instrumented element, which are stored at the reactor as well as the necessary console instrument for steady-state, [illegible] of 200 kW

Staffing: The committee recommends that the Director of the Nuclear Reactor should not hold another major administrative post. He should be given the responsibility and the resources to increase the number of on and off-campus users to achieve maximum utilization of the reactor.

Before the rest of the staffing recommendations are put forward, it is necessary to explain the special nuclear reactor requirements posed by Federal regulations implemented through the Nuclear Regulatory Commission (NRC).

A nuclear reactor, according to NRC regulations, should have a director and operators who are licensed by the NRC. There are two types of operators. One is a Reactor Operator (RO) and the other is a Senior Reactor Operator (SRO). A person who wants to become either a RO or a SRO has to study and obtain certain experience in operating a reactor before he can take the NRC administered test. To become a RO, a person has to have worked in a reactor facility for at least six months. To become a SRO, the requirement is at least one year as a licensed RO.

Operator's licenses are issued for a specific facility, not for all reactors. To keep a valid license a SRO or a RO has to take a requalification examination once a year and has to show to the NRC that he has completed at least one startup and one reactivity change, e.g., change of power or shut down, every calendar quarter. The requalification exam is not necessarily administered by the NRC.

For the operation of the reactor, the NRC requires the following:

(a) A SRO should be in the control room during startup and also during any change in power.

(b) A RO is not allowed to start up the reactor without a SRO being in the control room.

(c) A SRO is not allowed to start up the reactor unless another person is in the control room with him (not necessarily an operator, a secretary, for example, could be the other person).

(d) After the reactor reaches the desired power level, the SRO may leave the control room, but he must stay in the building.

In addition to operating the reactor, the members of the staff perform the following tasks:

(a) Routine maintenance.

(b) Calibration of instruments at regular intervals as required by the NRC.

(c) Preparation of periodic reports required by the NRC.

(d) Preparation of reports requested by the NRC from time to time.

(e) Services provided for courses involving the reactor (mainly NE 304, NE 306, and NE 308).

(f) Services provided to any faculty member who wants to use the reactor.

The NRC regulations relative to reactor operators mean that an operating nuclear reactor should have at least two operators, at least one of whom should be a senior operator. With only two operators, however, meaningful operation of a facility is questionable because leaves, sickness, and absences, for a variety of reasons pose operational problems. For full utilization of the UMR reactor, the committee recommends three SRO's*, one of whom might be the director, and two RO's.

In order to have a sufficient number of RO's, the present reactor management has encouraged the electronics technician and the secretary to study and take the RO examination. The committee recommends that the campus administration support this policy by rewarding the staff members who obtain a RO license.

The positions of the secretary-receptionist, electronics technician, and custodian are not required by the NRC. Experience has shown, however, that these positions are necessary for proper operation of the facility.

Cooling Capability for Continuous Operation at Maximum Power: When the reactor operates at its maximum power of 200 kW, the water temperature in the pool increases at the rate of about

* Until 1979 the reactor had three SRO's. In 1979, one SRO resigned, and in 1980 one FTE was abolished from the reactor staff.

3°F/h. After an eight-hour operation, this temperature reaches about 100°F, depending, of course, on the ambient temperature. At about 140°F, the resins of the demineralizer, through which the water continuously circulates, begin to melt. The resins lose their ion-exchange effectiveness at even lower temperatures. It is standard practice to keep the temperature as low as possible, because high temperatures decrease the life of the resins. If the melting temperature is reached, the resins have to be replaced.

Because the temperature of the pool decreases by only about 3°F overnight, it is impossible to operate the reactor at full power the next day. For this reason, the staff tries to limit long runs to Fridays so that the pool may have adequate time to cool during the weekend.

It is obvious that continuous operation at 200 kW, needed for any experiments requiring large neutron fluence, is not possible. For this reason, the committee recommends that a cooling capability for continuous operation at maximum power should be added. The cost of providing this cooling capability at 200 kW is estimated to be about $30,000 ($20,000 for equipment and $10,000 for installation).

Increase of Power to 1 MW: No extra fuel is needed to increase the power from 200 kW to 1 MW. It is necessary, however, to purchase one new meter (recorder) which costs between $17,000 and $20,000.

If the power is increased to 1 MW and adequate cooling is provided, many new experiments and new research projects could be performed. Experiments could be designed to show the connection between core physics and coolant parameters, such as coolant flow rate, coolant temperature, and coolant temperature coefficient of reactivity.

At the present time, the flux is of the order of $10^{12}n/cm^2\cdot s$, and the reactor can only operate at a maximum power for about eight hours before an extended cooling down period is required. Thus, the maximum continuous fluence to which a sample can be exposed is about $3x10^{16}n/cm^2$. Unlimited operation at 1 MW will make a flux of about $5x10^{12}n/cm^2\cdot s$ available for as long a time as needed to reach the desired fluence.

Accessory Equipment: Accessory equipment, which would improve the research capabilities of the facility, includes a fume hood or glove box for sample preparation, a Thermo-Luminescent Dosimeter (TLD) reader, and an improved pneumatic tube sample insertion system. The total cost estimated would be $15,000.

Table 1 summarizes these recommendations.

TABLE 1

RECOMMENDATIONS FOR THE UMR REACTOR

Funding Priority	Operation	Cost ($10^3$$)
1	Refueling	50
2	Senior Reactor Operator	20 (annual cost)
3	Research Technician	20 (annual cost)
4	Cooling Capability	30
5	Increase of Power to 1 MW	20
6	Accessory Equipment	15

Thermal-Hydraulics Laboratory

General Comments

Heat transfer and fluid mechanics are two technical areas that are of major importance to all fields of engineering. At UMR, the research and instruction in these areas are performed mainly by the faculty of the departments of Chemical and Mechanical Engineering. The nuclear related thermal-hydraulics problems have not received the needed attention or the interest they deserve during a time of nuclear energy development.

At present, the nuclear engineering program at UMR has no experimental facilities for either instruction or research in these areas, although most of the problems of commercial nuclear power plants come from the thermal-hydraulics part of the plant and not from the nuclear part (reactor core). Because about 80% of the nuclear engineering graduates are hired by utilities that operate LWR plants, it is essential for nuclear engineering students to be exposed, through laboratory courses, to measuring instruments, equipment, and systems that are associated with the heat transfer and fluid mechanics areas. For example, the measurements of temperature and heat flux in boiling and forced convection systems, measurements of velocity and flow rates, measurements of pump, compressor and turbine performances are only a few of the experiments that should be a part of the nuclear engineering curriculum. At present, such experiments are not available to the nuclear engineering students at UMR.

Recommendations

To cover the area of thermal-hydraulics, it is recommended that UMR establish an instructional laboratory to satisfy the needs of nuclear engineering students. The laboratory will need approximately 1000 ft^2 of space and an initial investment of about $80,000 for equipment, instruments, and supplies. A list of suggested equipment is given in Table 2 in the order of importance. The pieces of equipment listed in Table 2 are self-contained experimental modules which are available in the marketplace and easily assembled.

To initiate nuclear-related, thermal-hydraulic research, at least two new faculty members should be hired: one with interest in convective and boiling heat transfer and the other with interest in fluid mechanics and two-phase flow. These faculty members should have demonstrated through published research strong interests in nuclear-related thermal-hydraulics problems. It would also be very desirable for these faculty members to have interests in both the experimental and the analytical phases of these topics. Suitable laboratory space of about 500 ft^2/person and an initial investment of $100,000 per person for establishing and developing experimental research facilities appropriate to their work should also be provided. It should be expected that the two new faculty members would acquire annual external funding at least equal to their salaries.

TABLE 2

EQUIPMENT NEEDED FOR THE INSTRUCTIONAL THERMAL-HYDRAULICS LABORATORY

Funding Priority	Equipment		Cost (10^3 $)
1	Nucleate and Film Boiling System	10	
	Free and Forced Convection System	6	
	Thermal Conduction System	11	
	Miscellaneous	3	30
2	Multipump, Multifluid System		35
3	Cooling Tower System		17
		TOTAL	82

Radiation Damage and Effects Research Center

General Comments

The committee's basic premise is that nuclear fission power plants will continue to be used and that nuclear fusion power plants will continue to be developed. Both types of power plants must use materials that are subjected to diverse and hostile environments. The "hostile" environment may be physicochemical (pressure-temperature-contaminants) and/or induced by irradiation. In either case, performance of materials under such adverse conditions over long periods of time (~30 years) would be of great concern to materials scientists and nuclear engineers well into the next century.

Radiation damage of materials is a critical problem faced by both fission and fusion reactor technologists. It is imperative, therefore, to seek an in-depth knowledge of the physical, chemical, and mechanical properties of materials as a function of radiation exposure. Unfortunately, the radiation damage conditions expected in a particular power plant usually cannot be duplicated in time periods that are practical. There are no neutron sources with which test materials can be subjected to a fluence of 10^{23} n/cm^2 with neutron energy greater than 0.1 MeV in a period of less than several months. That is the fluence which the stainless steel cladding in a liquid-metal-cooled fast breeder reactor would be required to withstand. Means of simulating the equivalent radiation damage within time periods of days or weeks are required. The practical aspects of producing radiation damage in short periods to simulate damage taking place over long periods (~years) are very challenging. Research in this area is considered to be of great importance to both fission and fusion power reactor technologies.

In addition to the study of existing materials, there is going to be, in the years ahead, a tremendous need for the development of materials to be used in adverse environments. Examples are: first wall materials for fusion reactors and low-swelling cladding and structural materials for fast breeder reactors.

UMR already has conducted a considerable amount of research in the area of materials studies. The recommended facilities would complement the existing ones by including the field of radiation damage.

Recommendations

A list of equipment conside ed necessary for a radiation damage facility is given in Table 3. The prices of some of the listed equipment reflect only partial cost. Details for all the prices of the proposed equipment are given in Appendix F. The total space required for these facilities is estimated to be 2500 ft^2.

TABLE 3

EQUIPMENT NEEDED FOR THE RADIATION DAMAGE AND EFFECTS RESEARCH CENTER

Funding Priority	Equipment	Cost (10^3\$)	Remarks
-	High Resolution Scanning Electron Microscope with X-Ray Attachment		Has been acquired
-	200 keV Light Ion Accelerator		In operation
1	200 keV Light Ion Accelerator with Ultra-High Vacuum Hot Stage	60	Cost reflects only needed parts & final
	Accessory Capital Items	100	assembly.
2	A 200 keV Transmission Electron Microscope (TEM)	10	This is not t cost of a new TEM (see App.
3	2 MeV Van de Graaf Accelerator (RBS)	150	See App.F.
4	High Resolution Auger Electron Microprobe	350	
	TOTAL	670	

Five faculty members could conduct full-time research with these facilities. If this number of persons who would be committed to this research area could not be found at UMR, it might be necessary to hire new faculty. At UMR, persons who are interested in the area of radiation damage and effects are:

A. E. Bolon, Nuc. Eng.
E. B. Hale, Phys.
A. Kumar, Nuc. Eng.
H. P. Leighly, Jr., Met. Eng.
L. L. Levenson, Phys.

In addition to faculty members, a facility such as the one proposed here, would require the staff and operating expenses shown in Table 4.

TABLE 4

STAFFING AND OPERATING EXPENSES
FOR THE RADIATION DAMAGE AND EFFECTS CENTER

	Cost (10 $) Per Year
3 Technicians	60
1/2 Secretary	5
E&E	15
Computer	5
Utilities (electricity)	10
Other (contingency)	25
TOTAL	120

Fusion Research Center

General Comments

Nuclear fusion is one of the three ultimate energy sources for the future (along with solar and breeder reactors). If UMR wishes to take a leadership role in developing fusion technology, a first-class Fusion Research Center should be established on the campus.

Magnetic plasma confinement would be the central theme of the research. The future direction is difficult to predict for such a new area of endeavor, but the Center should be designed to be sufficiently flexible to follow technological advances as they occur. The equipment in the Fusion Research Center should be sufficiently complete so that innovative research concepts could be pursued, and the facilities should be appropriate for interdisciplinary research, i.e., nuclear engineering, electrical engineering, physics, and mechanical engineering.

Recommendations

A list of equipment, which is considered to be desirable for the proposed Fusion Research Center is given in Table 5. Funding priorities are not indicated, because deletion of any major item would make meaningful research impossible. Staffing requirements are essentially the same as shown in Table 4 for the Radiation Damage and Effects Research Center.

The total cost, which obviously contains a great deal of uncertainty, is approximately one million dollars. The space requirements are projected to be about 5000 square feet.

A team of persons experienced and interested in this research area should be assembled and given the task of developing more detailed plans and proposals. Persons on the UMR campus who have experience or interest in fusion are:

A. E. Bolon, Nuc. Eng.	T. J. Dolan, Nuc. Eng.
J. L. Boone, Elec. Eng.	R. H. McFarland, Phys.
K. H. Carpenter, Elec. Eng.	H. F. Nelson, Mech. Eng.
A. W. Culp, Mech. Eng.	K. J. Nygaard, Phys.

The instructional program in fusion should be strengthened. A 300-level laboratory course, which would be co-listed under several departments, is needed to provide students with experience in the instrumentation and techniques of fusion experiments. Equipment would be required for this laboratory in addition to the equipment dedicated to research, but research should have a higher priority than establishing the laboratory course. The existing fusion courses should be co-listed by other departments where appropriate in order to raise the level of awareness and participation of students in many disciplines.

TABLE 5

EQUIPMENT NEEDED FOR THE

FUSION RESEARCH CENTER

				Cost (10^3 $)
Magnet Coil Systems.................................				300-500
<u>Superconducting Coils</u>		or	<u>Water-Cooled Copper Coils</u>	
liquid helium closed-loop system	100-200		2 MW electric power installation	50-100
coils, dewars, supports	200 - ∞		2 MW heat exchanger installation	20-50
power supplies	20-40		high-current power supplies (2 MW @ 40 $/kW)	80
			copper coils (5000 kg @ 20 $/kg)	100
Vacuum System..				150
Large chamber (5000 kg @ 14 $/kg)	70			
pumps, valves, gauges	80			
Plasma Heating Equipment..................................				200-300
(200 kW @ 0.5 - 1.5 $/W)	--			
Plasma Diagnostic Equipment..............................				400
microwave instrumentation laboratory equipment	180			
Computerized data acquisition analysis, & control systems	60			
spectroscopic equipment	100			
particle analyzer equipment	60			
			TOTAL	1050-1350

SUMMARY OF RECOMMENDATIONS

In order that the University of Missouri-Rolla may maintain a position of excellence in all areas of engineering during the next two decades, the campus facilities for teaching, research, and service in the nuclear energy fields should be strengthened. Four types of facilities should be considered.

1. Nuclear Reactor
2. Thermal-Hydraulics Laboratory
3. Radiation Damage and Effects Research Center
4. Fusion Research Center

The Nuclear Facilities Study Committee has discussed the nature of the priorities that should be used in establishing nuclear experimental facilities at UMR. It has agreed that for the purpose of this study a distinction should be made between instructional laboratories and research facilities. The distinction is necessary, because the need for modern laboratory equipment is acute and very important for the education of the students.

To maintain the vitality of the nuclear engineering program, it is necessary to continue to have an operating nuclear reactor. This has led the committee to recommend that refueling the UMR reactor be the item with the highest priority and that adequate staffing be the priority next in succession. A third SRO should be hired. If a vigorous effort is undertaken to seek external funding for research involving the reactor, the facility could be upgraded so that it could operate continuously at maximum power either at the present 200 kW level or increased to 1 MW. A research technician should be hired, and certain accessory equipment provided.

The director of the facility should devote his efforts to the development of the research capability and the pursuit of external financial support.

It is anticipated that the area of thermal-hydraulics (as well as the two areas discussed next) will be of great importance in the years ahead for light water reactors (LWR's), breeders, and fusion reactors. About 80% of the nuclear engineering graduates are hired by utilities that operate LWR plants where most of the malfunctions come from the thermal-hydraulics part of the plant. For these reasons, the nuclear engineering program would be benefited by having a Thermal-Hydraulics Laboratory available for instruction. The development of research in the area of thermal-hydraulics can be accomplished only by hiring additional experienced faculty, who would initiate research and succeed in obtaining external funding.

The suggestions that follow regarding the establishment of a Radiation Damage and Effects Research Center and a Fusion Research Center are of a much larger scale of commitment than the two areas mentioned above. For this reason, these recommendations should be considered to be preliminary planning studies.

Materials studies for nuclear systems (both fission and fusion) constitute research areas that seem likely to grow. The Materials Research Center, Metallurgical Engineering, Ceramic Engineering and Physics are capable of performing research on many areas of materials studies, but lack some facilities for doing radiation damage and effects studies. Acquisition of such facilities is desirable, especially because UMR already has expertise in this area. Since many items of equipment needed could be used for research other than for irradiated materials, it seems logical to make the new facilities a part of the MRC.

Fusion, the ultimate energy source, is a developing technology. UMR has no significant facilities for fusion research at present but UMR could play a leadership role in this area. To achieve this, a Fusion Research Center should be established which should concentrate on plasma confinement problems and plasma diagnostics development. A senior-graduate interdisciplinary laboratory should also be established.

Since it may not be possible for UMR to achieve national recognition in all the above areas, it would be wise to pursue such recognition in at least one of them while staying competent in all.

With regard to management of the nuclear facilities, the committee recommends that the nuclear facilities discussed in this report be designated as campus-wide research centers with the exception of the thermal-hydraulics instructional laboratory which should be associated with the nuclear engineering program. The director of a nuclear facility should not hold another major administrative post, in order to devote his efforts to the full utilization of that facility.