UNIVERSITY OF VIRGINIA

REACTOR FACILITY

1992 ANNUAL REPORT

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University of Virginia Reactor Facility

I. INTRODUCTION

A. Reactor Facility Reporting Requirements

1. Reporting Period

This report on Reactor Facility activities during 1992 covers the period January 1, 1992 through December 31, 1992.

2. Basis for Reporting

An annual report of reactor operations is required by the UVAR and CAVALIER Technical Specifications, section 6.6.2. Additionally, it is the desire of the Facility management to document and publicize the most important results derived from reactor operations.

B. Reactor Facility Description

The Reactor Facility is located on the grounds of the University of Virginia (U.Va.) at Charlottesville, Virginia and is operated by the Department of Mechanical, Aerospace and Nuclear Engineering. The Facility houses the UVAR 2 MW pool type research reactor and CAVALIER 100 watt training reactor (now shutdown, awaiting decommissioning). The Facility also has a 6,000 curie cobalt-60 gamma irradiation facility, a hot cell facility with remote manipulators, several radiochemistry laboratories with fume hoods, radiation detectors, counters and laboratory counting equipment, computerized data acquisition-analysis systems, and fully equipped machine and electronics shops.

1. 2 MW UVAR Reactor

The UVAR reactor is a light water cooled, moderated and shielded type reactor that first went into operation at a licensed power level of one megawatt in June 1960, under license No. R-66. In 1971, the authorized power level was increased to two megawatts. In September 1982 the operating license for the UVAR was extended for 20 years. Figure 1 shows a layout of the reactor and the various experimental facilities associated with it.

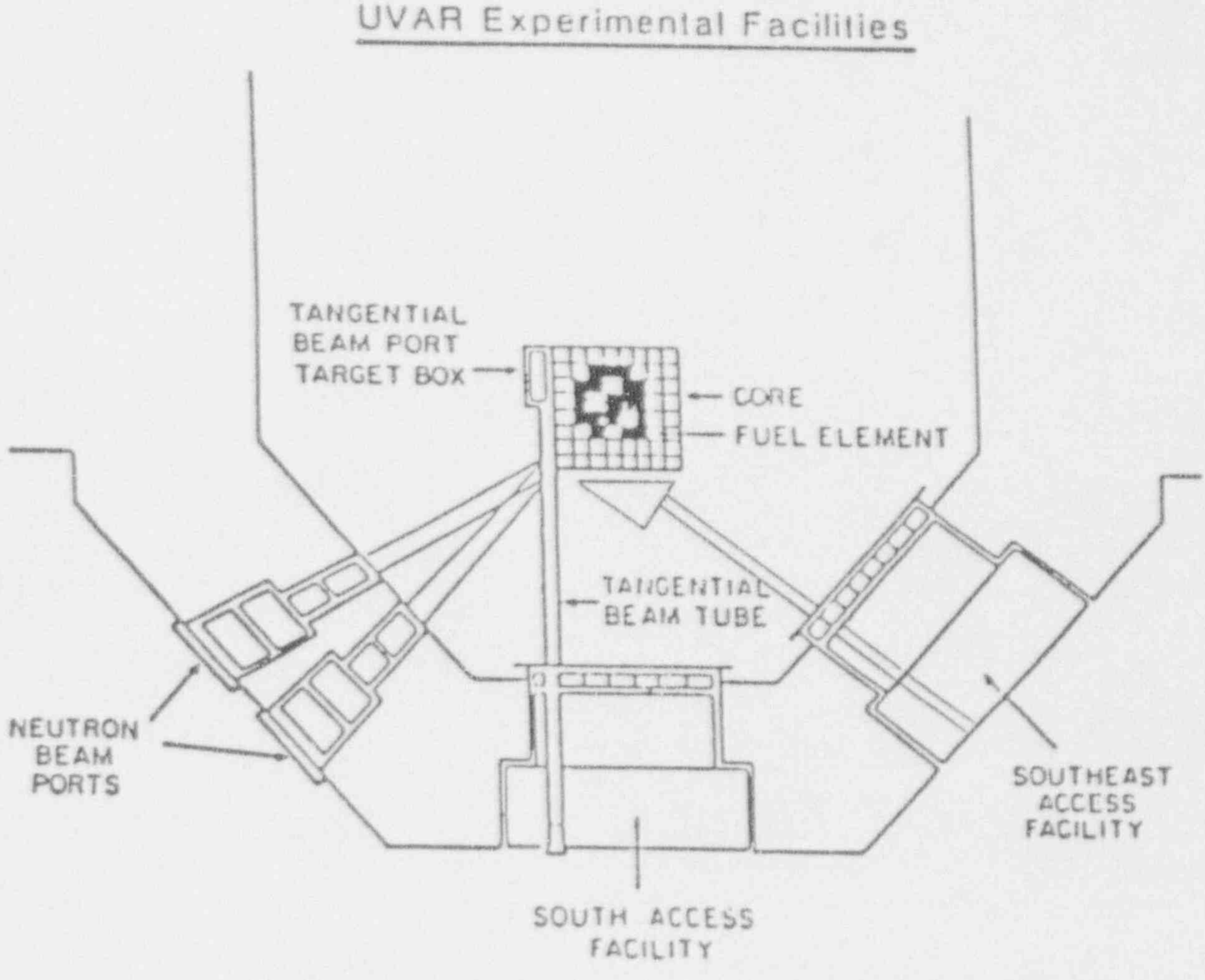

UVAR Experimental Facilities
TANGENTIAL
BEAM PORT
TARGET BOX
CORE
FUEL ELEMENT
TANGENTIAL
BEAM TUBE
NEUTRON
BEAM
PORTS
SOUTHEAST
ACCESS
FACILITY
SOUTH ACCESS
FACILITY

Figure 1

2. 100 W CAVALIER Reactor

The CAVALIER (Cooperatively Assembled Virginia Low Intensity Educational Reactor) first went into operation in October 1974, under license R-123, at a licensed maximum power of 100 watts. The reactor was built to accommodate reactor operator training and perform experiments for undergraduate laboratory courses. The operating license was renewed in May 1985, for a period of 20 years. Figure 2 shows a layout of this reactor and its control room. A dismantlement plan was submitted in November, 1987 to the NRC. The NRC requested a decommissioning plan which was submitted early in 1990. An order to decommission was issued on February 3, 1992. The reactor components, less the fuel and tank, are being donated to the University of North Texas and shipment is planned for spring 1993.

3. Past Operating History

a. UVAR Reactor

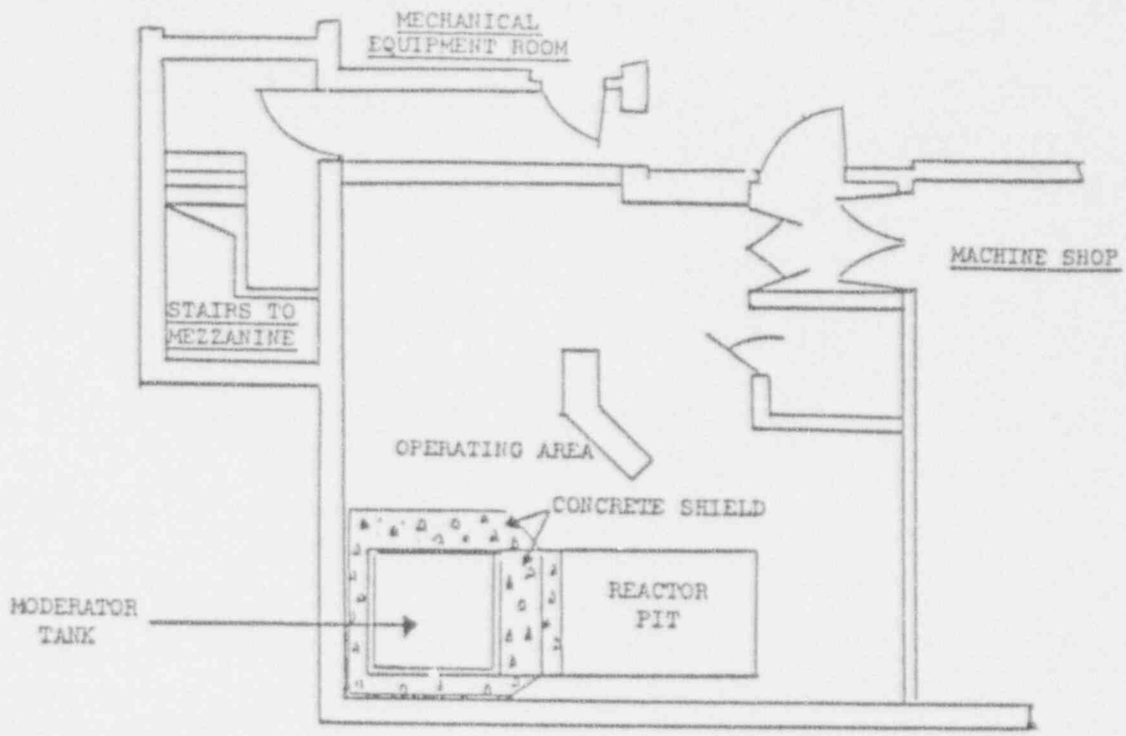
The UVAR reactor operating history is shown in Table 1.

TABLE 1

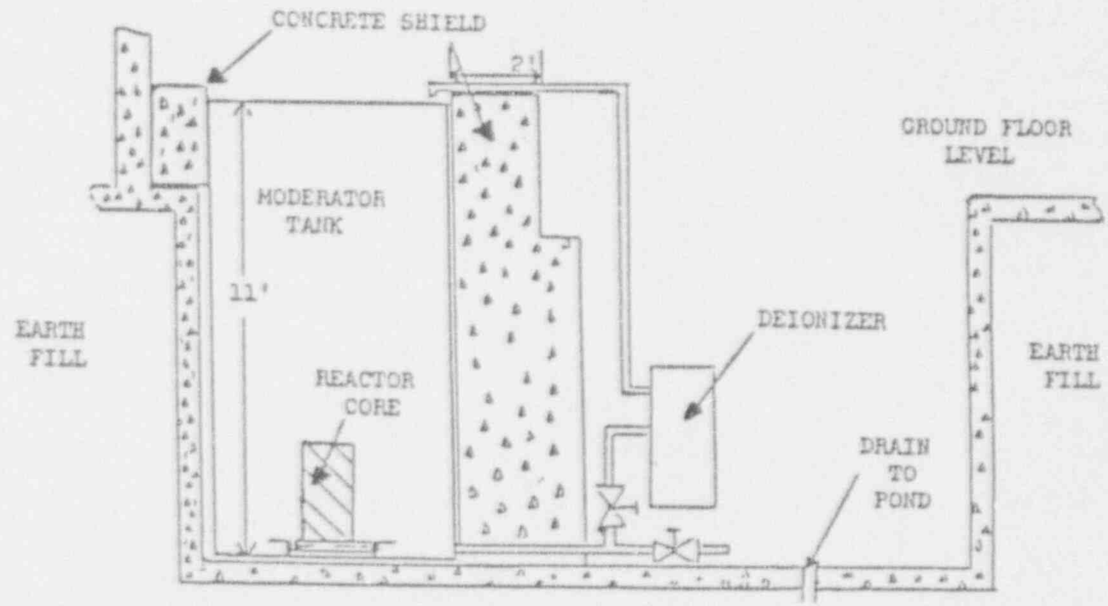
Operating History of University of Virginia Reactor

Years(s)	Megawatt-hours	Hours Operated
1960-1965	1218	1500
1966-1970	2742	3000
1971-1975	1654	1800
1976-1978	1769	1480
1979	4426	2764
1980	4610	2863
1981	4988	3568
1982	5507	3024
1983	6079	3556
1984	5687	3166
1985	927	718
1986	1330	891
1987	1220	801
1988	910	621
1989	1378	869
1990	1837	1087
1991	2360	1365
1992	2428	1450

During the years 1979 through 1984, the UVAR reactor was operated approximately 110 hours per week to irradiate metal specimens for radiation damage studies on pressure vessel steels. Since that time, the reactor has operated on a variable schedule up to 40 hours per week. The intent of the reactor management is to perform various on-going small and diverse irradiation projects, rather than a single large irradiation project.



Plan View of CAVALIER Operating Area



Vertical Section Through Reactor Pit

Figure 2

b. CAVALIER Reactor

The CAVALIER reactor operating history is shown in Table 2.

TABLE 2

Operating History of CAVALIER reactor

Years(s)	Watt-hours	Hours Operated
1974-1980	2128	758
1981-1985	1278	388
1986	147	37
1987	28	29
1988-1992	shutdown	shutdown

The CAVALIER reactor has been used primarily for reactor operator training and undergraduate lab experiments, although it has not been operated over the past three years. A dismantlement plan was submitted to the NRC in November, 1987 but the NRC decided the Facility should submit a decommissioning plan. A complete decommissioning plan was submitted in January, 1990. The CAVALIER fuel and start-up source were unloaded on March 3, 1988 and decommissioning should be completed in 1993.

4. Summary of 1992 Reactor Utilization

a. UVAR Reactor

During 1992, the UVAR was operated for 1450 hours and a total integrated power of 2428 Megawatt-hours. The following experiments were performed utilizing the UVAR reactor:

- 199 neutron activation analysis (NAA) samples were run in the pneumatic rabbit system
- No NAA samples were run in the hydraulic rabbit system
- Twelve sets of samples were run in the mineral irradiation facility (MIF)
- Two separate runs were made in the rotating irradiation facility (RIF)
- 144 hours of reactor operations were dedicated to neutron radiography

b. CAVALIER Reactor

The CAVALIER reactor was permanently shut down in 1988 and will no longer be operated.

5. Special Facilities

The following facilities are operated in connection with UVAR:

- Two neutron beam ports, of eight inch diameter entrance, stepped to 10 inches at the exit, are available. One beam port is currently dedicated to neutron radiography.
- Two access ports (6 ft x 4 ft). One port is currently configured for a high energy photon beam, and the other port for a neutron beam.
- Hydraulic rabbit, for activation analysis, permitting samples with less than 0.69 inch diameter and 6 inch length.
- Pneumatic rabbit, for activation analysis, permitting sample diameters of 1 inch and length not exceeding 2.3 inches, accessing either a thermal or an epithermal irradiation facility.
- Solid gel irradiator for electrophoresis.
- Epithermal neutron mineral irradiation facility.
- A rotating irradiation facility used to equalize the neutron levels seen by a large number of specimens.
- Epithermal neutron irradiation facilities with heaters for sample temperature control.
- Cobalt-60 gamma irradiation facility with 6,000 Ci, permitting exposures at rates up to 170,000 R/hr.
- Depleted uranium subcritical facility (due to be transfered to another university in 1993).
- Small hot cell, with remote manipulators.
- Machine and electronic shops.
- Several radiochemistry labs with fume hoods, counters and standard lab equipment.
- Low-background counting room with shielded, solid state germanium and silicon detectors and computerized data acquisition/analysis system.

C. Reactor Staff Organization

1. Operations Staff

A Reactor Facility organization chart is shown in Figure 3. Personnel on the reactor staff as of the end of 1992 were:

R.U. Mulder . . . Reactor Director
J.P. Farrar . . . . . Reactor Administrator
P.E. Benneche . . Services Supervisor
B. Hosticka . . . . Research Scientist
D.R. Krause . . . Senior Reactor Operator
L.L. Scheid . . . . Senior Reactor Operator
T.E. Doyle . . . . Operator Trainee
W.N. Wilson . . . Operator Trainee
V.G. Hampton . Electronics Shop Supervisor
J.S. Baber . . . . . Machine Shop Supervisor
V.S. Thomas . . . Reactor Facility Secretary
M.J. Combs . . . . Research Associate (1/2 time)

2. Health Physics Staff at the Facility

D. Steva . . . . . . Reactor Health Physicist
E. Easter . . . . . . Radiation Safety Technician
S. Garver . . . . . Radiation Safety Technician

The Health Physicist is assisted by a Reactor staff member paid from reactor services income. Other health physicists and technicians employed by the University are on call with the Office of Environmental Health and Safety.

3. Reactor Safety Committee

The Reactor Safety Committee is composed of the following individuals:

A.B. Reynolds . . Professor, Nuclear Engineering - Chairman
W.R. Johnson . . Professor Emeritus, Nuclear Engineering
R.A. Rydin . . . . Associate Professor, Nuclear Engineering
J.S. Brenizer . . . Associate Professor, Nuclear Engineering
J.R. Gilchrist . . . Assistant Director, Environmental Health & Safety
R.U. Mulder . . . Reactor Director & Asst. Professor, Nuclear Engineering
R.G. Piccolo . . . University Radiation Safety Officer

As of July 1, 1992, the Nuclear Engineering Department merged with the Mechanical and Aerospace Engineering Department. Dr. Reynolds again became chair of the Committee.

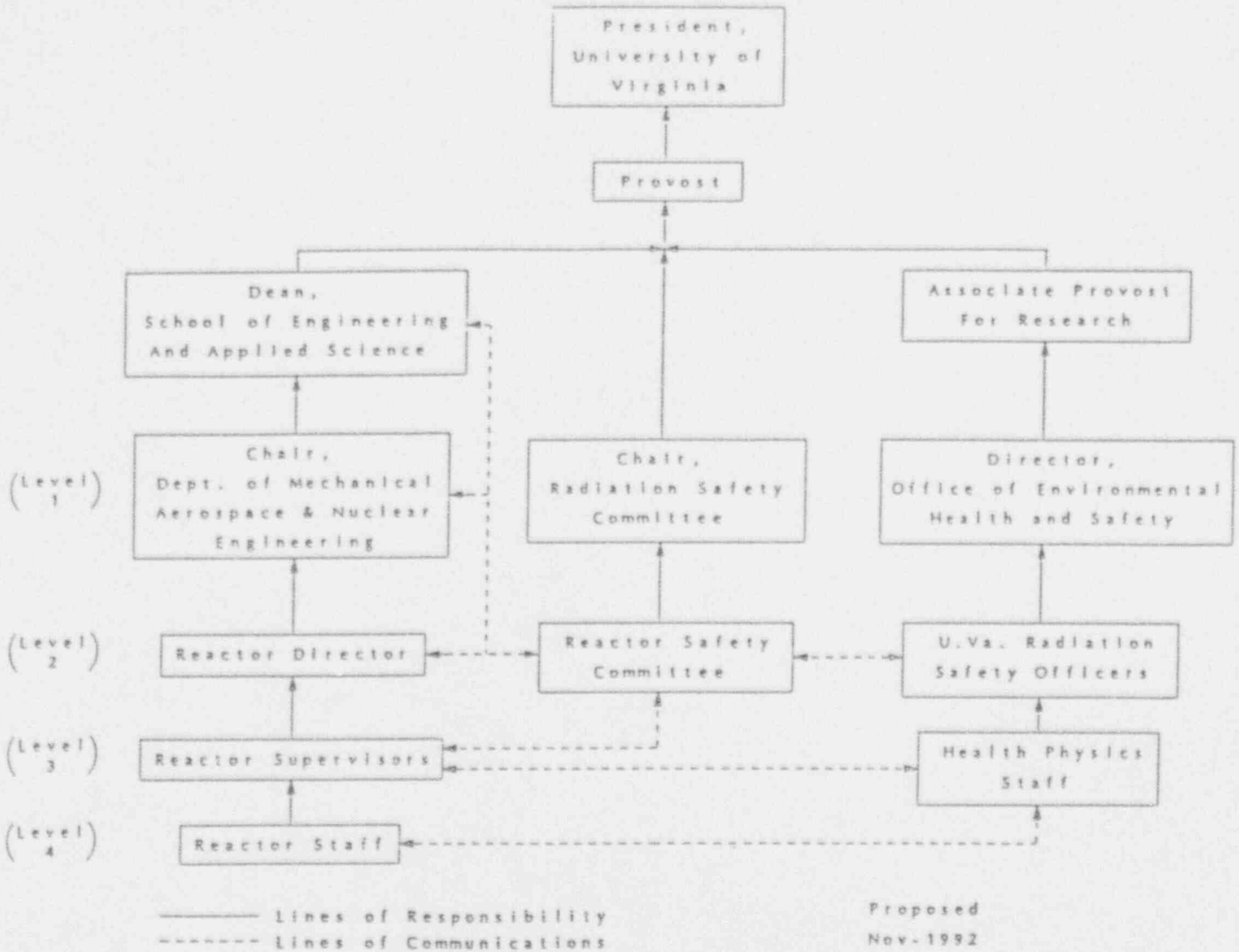


Figure 3 Organizational Structure of the U.Va. Research Reactor Facility

II. REACTOR OPERATIONS

A. UVAR Reactor

1. Core Configurations

A typical UVAR core configuration is shown in Figure 4. The reactor employs three boron-stainless steel safety rods and one stainless steel regulating rod for fine power control. The fuel elements are of the Materials Test Reactor (MTR) curved plate-type elements, utilizing a U-AL alloy. The fuel is approximately 93% enriched in the U-235 isotope. The elements have 18 fuel plates per element, with a loading of approximately 195 grams of U-235 per element. The control rod elements have 9 fuel plates with a loading of approximately 97.5 grams U-235/element. A plan view of these elements is shown in Figure 5.

2. Standard Operating Procedures

Three sections of the UVAR standard operating procedures were changed during the year in the areas of: liquid waste release, the daily checklist, and irradiation request forms. The Reactor Safety Committee reviewed and approved these changes.

3. Surveillance Requirements

The following surveillance items were completed during the year as required by Section 4.0 of the Technical Specifications:

a. Rod Drop Tests and Visual Inspection

Rod drop times are measured at least semi-annually, or whenever rods are moved or maintenance is performed.

Magnet release time should be less than 50 milliseconds and free drop time less than 700 milliseconds.

Rods are visually inspected at least annually.

Rod drop times were measured on the UVAR reactor and are shown in Table 3.

UNIVERSITY OF VIRGINIA REACTOR CORE LOADING DIAGRAM

CORE LOADING 33-A — SHUTDOWN MARGIN 0.9 % delta k/k

Date 11-24-92 — EXCESS REACTIVITY 3.55 % delta k/k

U-235 3785 GRAMS — EXPERIMENT WORTH 0.82 % delta k/k

F - Normal Fuel Element
PF - Partial Fuel Element
CR - Control Rod Fuel Element
G - Graphite Element
S - Graphite Source Element
REG - Control Rod Fuel Element with Regulating Rod
P - Grid Plate Plug
HYD RAB - Hydraulic Rabbit
THER RAB - Thermal Pneumatic Rabbit
EPI RAB - Epithermal Pneumatic Rabbit
H.T. - Hot Thimble

Rod Worths #1 -1.84 % #2 -3.0 % #3 -2.61 % Reg -0.26 %

MINERAL IRRADIATION FACILITY

G 11	F V-05 12	F V-04 13	F-REG VC-26 14	F V-02 15	F V-01 16	P 17	P 18
G 21	F V-06 22	F V-14 23	V-27 24	F-CR1 VC-21 25	F T-07 26	P 27	P 28
G 31	F V-08 32	F-CR2 VC-25 33	F V-03 34	F T-10 35	F T-24 36	P 37	P 38
G 41	F V-09 42	F V-11 43	F-CR3 VC-20 44	F V-10 45	F T-30 46	P 47	P 48
G 51	F T-18 52	F T-13 53	F T-09 54	F T-14 55	F T-8 56	P 57	P 58
G 61	G 62	H.T. #3 63	G 64	H.T. #1 65	S 66	P 67	P 68
G 71	THER RAB 72	G 73	EPI RAB 74	G 75	G 76	HYD RAB 77	P 78
G 81	G 82	G 83	G 84	G 85	G 86	G 87	G 88

Figure 4

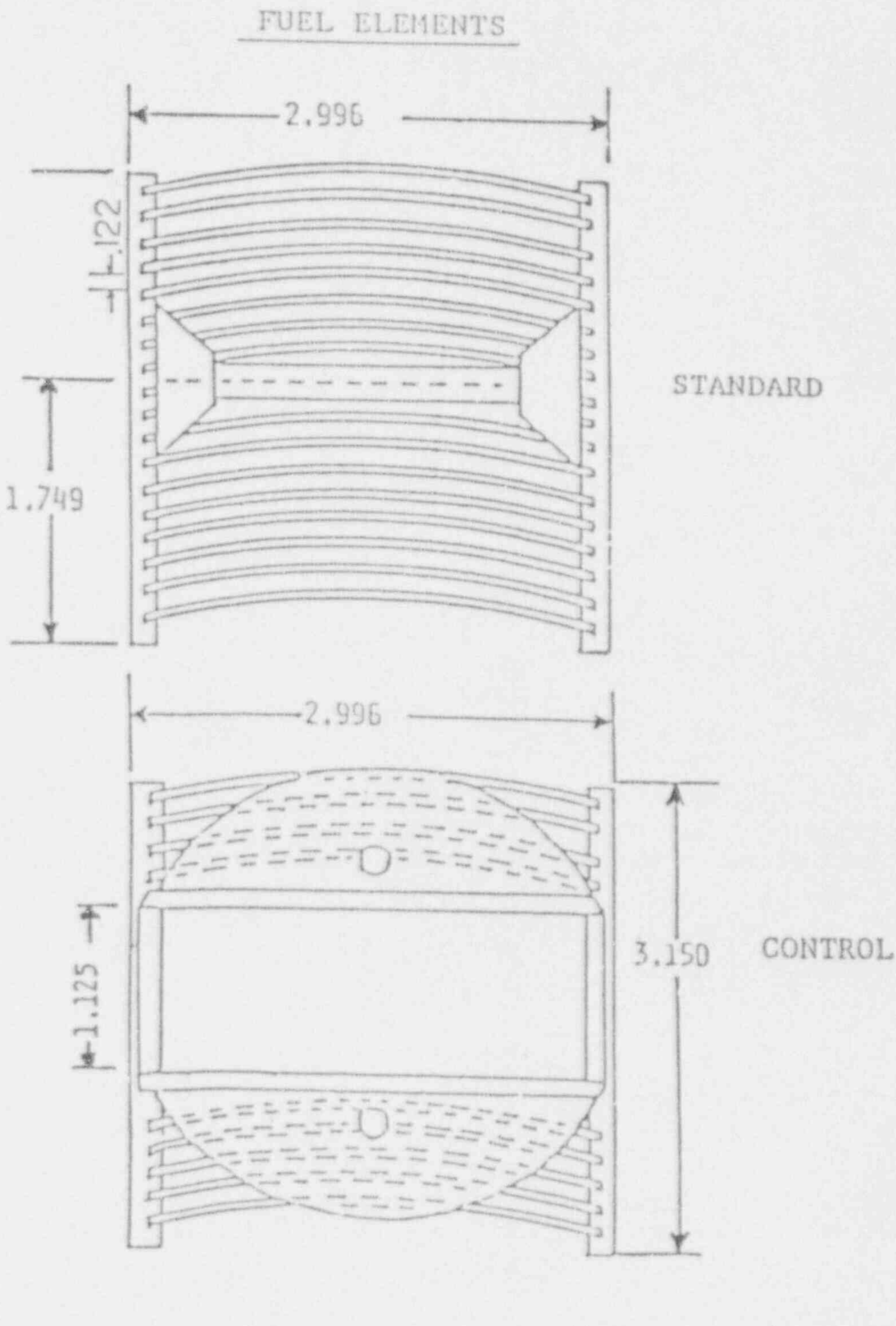

FUEL ELEMENTS
2.996
.122
1.749
STANDARD
2.996
1.125
3.150
CONTROL

Figure 5

TABLE 3					
Measured Control Rod Drop Times on UVAR Reactor					
Rod Number	Magnet Current (m-amps)	Rod Position (inches)	Magnet Release Time (msec)	Free Drop Time (msec)	Total Drop Time (msec)
4-22-92	Removed rod 1 drive and cleaned magnet face				
1	160	26	23	480	503
6-15-92	After visual inspection of rods on 6-12-92				
1	165	26	17	492	509
2	165	26	20	492	532
3	80	26	48	464	512
7-01-92	Changed fuel element on rod 2				
2	165	26	29	456	485
9-30-92	After testing dummy LEU fuel element on rod 1				
1	165	26	23	491	514
10-22-92	After unloading the reactor grid plate completely				
1	165	26	17	495	512
2	165	26	42	466	508
3	75	26	41	465	506

The rod drop times continue to be within the limits required by the Technical Specifications (700 msec free drop and 50 msec magnet release).

The UVAR control rods were visually inspected on 6-12-92. The following is abstracted from the reactor log book and the surveillance files:

Rod #1 - Inspected rod under ~4 feet of water. Dose rate at surface of water was ~23 mr/hr. No sign of cracking or rub marks. Rod passed 0.95 inch gauge easily.

Rod #2 - Inspected rod under ~4 feet of water. Dose rate at surface of water was ~36 mr/hr. No evidence of cracking or rubbing. Rod passed 0.95 inch gauge easily.

Rod #3 - Inspected rod under ~4 feet of water. Dose rate at surface of water was ~35 mr/hr. No evidence of cracking or rub marks. Passes 0.95 inch gauge easily.

b. Tests and Calibrations

Data on these tests and calibrations are on file at the Facility.

1) Monthly

Operational checks of the ventilation duct, personnel door, truck door and emergency exit cover were performed as required.

2) Semi-Annually

Visual inspection of gaskets on personnel door, ventilation duct and truck door was completed.

Calibration checks of source range channel, linear power channel, core gamma monitor, bridge radiation monitor, reactor face monitor, duct argon monitor, constant air monitor, pool level monitors, pool temperature monitor, core differential temperature monitor, and primary flow instrument were done.

3) Annually

The emergency cooling system was tested during the month of September, 1992. The results are as follows:

	S.E. Tank (gal/min)	S.W. Tank (gal/min)
minimum required flow	11.0	11.5
9-14-92 actual flow	12.2	12.5
last five year range	11.3-12.2	12.2-12.9

No pattern was observed in the variation of the test results for the last five years.

4) Daily Checklist

The daily checklist, which is completed when the reactor is to be operated, provides for checks on all the significant automatic shutdown systems associated with the reactor.

5) Reactor Pool Water Quality

The Technical Specifications require that the pH and conductivity of the pool water be measured at least once every two weeks. These measurements were actually made on a daily basis when the reactor was operating and at least once each week. These measurements have indicated that the water quality was maintained well within the Technical Specification limits of pH between 5.0 and 7.5 with conductivity < 5 micromhos/cm.

6) Core Configuration Changes

a) In March, 1992, the epithermal rabbit developed a leak and had to be removed from the reactor. Although no fuel was changed, the rods were recalibrated and the worth of all experimental facilities was remeasured.

b) In June 1992, the epithermal rabbit was reinstalled in the reactor and the fuel elements for rods 1, 2, and 3 were replaced. The rods were recalibrated and the worth of all experimental facilities was measured.

c) In July, 1992, low levels of fission product activity were detected in the pool water. Investigation revealed a leak in the fuel element attached to rod 2. This element was removed from the reactor and stored in the north end of the pool. This element was replaced and the rods calibrated and the worth of experimental facilities measured.

d) In November, 1992, two Hot Thimble facilities were added to the reactor. The rods were again recalibrated and the worth of all experimental facilities was measured.

7) Communication Checks

The security system and emergency communications with the University Police were checked on a weekly basis throughout the year.

8) Alarm System Checks

The fire alarm system was checked during the month of December for proper alarm functions, both in the Facility and at the University Police Department.

Data on all of these tests and calibrations are on file at the Facility.

4. Maintenance

The maintenance performed on the UVAR reactor systems during the calendar year 1992 is shown in Table 4.

TABLE 4			
Reactor System Maintenance Performed in 1992			
Date	System	Problem	Corrective Action
1-06-92	Power range system	Power range #1 reading low and erratic at power	Replaced detector and leads. Functions normally.
1-30-92	Fire alarm system	Intermittent power trouble on alarm indicator.	Found and replaced battery with bad connectors and checked out system.
1-31-92	Criticality monitoring system	Found no reading on detector #1 when checking with field calibrator.	Replaced detector and calibrated.
4-06-92	Deta T system	Alarm system malfunctioning	Found and cleaned corroded contacts. Adjusted alarm set-points. Functions properly.
4-22-92	Control rod #1	Rod keeps falling away from magnet while attempting to withdraw rod.	Removed drive system, cleaned magnet face and rod extension. Reassembled and tested, works fine. Performed rod drop test.
5-11-92	Servo control system	Wide meter swings-dead spots while turning potentiometer.	Replaced potentiometer and checked with current generator.
5-11-92	Cooling tower		Drained and cleaned cooling tower as part of yearly preventative maintenance.
5-27-92	Constant air monitor	Air flow below 20 LPM. Could not be adjusted.	Found considerable vane dust on outlet filter. Replaced pump and cleaned inlet and outlet filters.
6-01-92	Power range system	Power Range #2 follows power up to ~ 85% and then slowly increases to full power in 10-15 minutes.	Replaced detector and checked out at next startup.
6-03-92	Power range system	Power Range #1 signal erratic.	Replaced detector and checked out at next startup.
7-28-92	Intermediate channel	Detector not responsive, signal pegged low.	Replaced detector, all connectors, and bottom five feet of cable run. Responded properly during reactor start-up.
8-02-92	Demineralizer system	Small leak from pump packing glands and pipe threads.	Adjusted packing glands and applied epoxy to pipe threads.
9-16-92	Waste tanks	Could not start circulating pump. Found corroded contacts on 2 switches and relay.	Replaced switches and relay, replaced wiring, cleaned all contacts and re-soldered all connections.
10-9-92	Power range #1 bistable trip	Adjustment of trip point erratic between 123% - 127%.	Replaced potentiometer and re-calibrated entire drawer.
11-4-92	Intermediate channel	Erratic signal, very noisy.	Replaced detector, functions properly.

No significant trends were noted in the maintenance.

During the first week of August, 1992, the site pond was drained to a level of approximately two feet above the spillway inlet grate. Pond releases during the spring and early summer of 1992 showed a decrease in discharge flow to about 200 gpm (about 600 gpm being normal). An inability to discharge adequate flow through the spillway indicated that the outlet grating in the pond was becoming clogged. During the winter and early spring several trees had fallen over into the pond near the spillway and it was believed their branches and leaves were restricting flow into the spillway. The trees were removed in early July without giving a significant increase in flow. It was decided that some other obstruction was covering the inlet grate. Flows were not sufficient to allow mixed pond and waste tank discharges. The need to release the waste tank was becoming necessary and therefore it was decided that draining the pond to a level where the staff could work on the grate was required. The pond was sampled and analyzed as with any pond release and an extended pond drain was started on August 4, 1992. A total of seven pond release samples were taken over the next two and one-half days with analyzed levels well below the release limits. The release was terminated on August 7, 1992. Two staff members entered the pond and proceeded to remove about 12 inches of organic matter from the outlet grating. The material removed from the grate was placed on the sides of the pond below normal water level. The organic matter was mostly leaves from around the pond. The fallen trees acted as a filter and caused the buildup of material rather than allowing the debris to flow through the outlet grating. Pond bottom samples were taken at various points around the pond and analyzed. All samples contained only trace amounts (just above minimum detectable levels) of cobalt-60 and cesium-137. The pond returned to its normal level after about three weeks. No disturbance of any fish or animal life was detected. The pond release rate increased to normal levels (about 650 gpm). A total of 700,000 gallons was drained from the pond during this evolution and it is estimated that the pond (when completely full) contains 900,000 usable gallons.

5. <u>Unplanned Shutdowns</u>

The 56 unplanned shutdowns which occurred on the UVAR reactor during the calendar year 1992 are shown in Table 5.

6. <u>Unplanned Reactor Downtime</u>

On September 22, 1992 one of two aluminum cans of ceramic beads containing trace amounts of iridium had its top come off while being irradiated in the UVAR reactor. The reactor was shut down and remained shutdown for five weeks (until October 28) until the cans and the material they contained were permanently encapsulated. Recovery procedures for both cans were written and approved by the Reactor Safety Committee. During the recovery process both cans of beads were inadvertently spilled within the confines of the pool and reactor cooling system. Additional procedures to recover the beads were written and approved and these were successfully carried out. A complete report on this incident was sent to the NRC and is in the RSC records.

TABLE 5

Unplanned Reactor Shutdowns in 1992

Date	#	Shutdown Mechanism
01-07-92	2	electronic noise spike on intermediate range period
01-08-92	1	electronic noise in console, no annunciator indication
01-31-92	1	building electrical power fluctuation
02-05-92	1	power range #2, while adjusting control rods to compensate for xenon burnup, no indication of power increase
02-05-92	1	air compressor to MIF experiment became unplugged
02-17-92	1	electronic noise while moving rods, reactor was sub-critical
02-18-92	1	electronic noise on intermediate range period, reactor was sub-critical
02-19-92	1	loss of building electrical power
03-10-92	1	electronic noise on intermediate range period
	1	electronic noise in power range #2 when removing sample from rabbit
03-25-92	1	pump off indication although no loss of flow
03-26-92	3	Rod #1 dropped 3 times while withdrawing rod. Realigned drive mechanism
04-22-92	1	loss of building electrical power
04-23-92	1	electronic noise in console
04-28-92	1	electronic noise in console
05-01-92	1	loss of building electrical power
05-08-92	1	electronic noise when moving rods
	2	electronic noise in intermediate range period
05-12-92	1	electronic noise in intermediate range period
05-13-92	2	electronic noise in console
05-14-92	1	from MIF experiment while checking lead temperature leads at reactor bridge
05-27-92	1	caused by accidently kicking wire cover behind reactor bridge
06-03-92	1	power range #1 while adjusting detector position
06-10-92	1	electronic noise on intermediate range period
06-15-92	2	intermediate range period while moving fuel, reactor was sub-critical
	1	loss of building electrical power
06-19-92	1	loss of power to scram logic drawer
06-22-92	1	electronic noise in relay for header down/pump on circuit
06-24-92	1	loss of building electrical power
07-17-92	1	loss of building electrical power during thunder storm
07-24-92	1	high radiation alarm when removing sample from rabbit (60 mr/hr at reactor bridge monitor). Ran sample back down and alarm cleared.
08-18-92	2	loss of building electrical power
09-18-92	1	electronic noise in power range #1 when moving rods
09-21-92	1	loss of building electrical power
11-04-92	2	electronic noise on intermediate range period
11-05-92	1	electronic noise in console
11-06-92	1	when rods taken out of automatic control, apparent electronic noise from auto switch
11-16-92	2	electronic noise in console
11-18-92	3	electronic noise in console
12-18-92	1	loss of electrical power to secondary console
	2	electronic noise on intermediate range period
12-21-92	2	electronic noise on intermediate range period
12-22-92	1	blew fuse in secondary console while working on argon monitor

7. Pool Water Make-up

During the calendar year 1992, make-up water to the UVAR pool averaged approximately 27 gallons per day. Over the past 15 years, the pool water make-up has varied from a minimum of 16 gallons per day to a maximum of 85 gallons per day, depending on reactor operation. The loss of water is mostly due to evaporation from the pool while operating at full power.

8. Fuel Shipments

a. Fresh Fuel

Two control rod fuel elements were received in July 1992 from the Babcock & Wilcox Company. These were spare elements that had been in storage in Lynchburg, Virginia.

b. Spent Fuel

No spent fuel was shipped from the Facility during 1992.

9. Personnel Training and Instruction

a. Reactor Facility Staff

At the end of 1992 the staff had five senior reactor operators. Two new staff members participated in a reactor operator training program sponsored by the U.S. Department of Energy, however, one of the trainees dropped out of the program at the end of June. Another individual, a student in the department who had recently received his PhD, joined the staff in March and began training for an operator license. Both trainees took the NRC operator exam in July, 1992, and passed the operating exam but failed to pass the written exam. The exams are being rescheduled for early 1993. Three senior operators took the NRC requalification exam in July and successfully passed. One operator was upgraded to senior operator. All licensed operators participated in the Facility's operator requalification program, which was carried out during the year. The program consisted of periodic lectures, participation in the daily operation of the Facility, performing checklists and start-ups of the reactor.

In 1992, an additional individual joined the staff on a half-time basis. A recent PhD graduate of the department began working primarily at the UVA Hospital but with some research activities being conducted at the Reactor Facility. This person will not be pursuing a reactor operator's license.

b. Summer Course for High School Teachers

During the month of June, 1992, 49 High School teachers from within the state of Virginia attended a one week special course at the Reactor Facility entitled: "Science of Nuclear Energy: Environmental Issues and Safety". The course consisted of formal lectures, laboratory experiments with the UVAR reactor in the areas of sub-critical multiplication, rod calibration, measurement of temperature coefficient and power calibration. During the week the teachers also visited the North Anna Nuclear Power Station.

c. Disadvantaged American Reactor Operator Training

U.Va. has, since 1984, administered a reactor operator training program for minority and disadvantaged americans sponsored by the U.S. Department of Energy. The program involved four other universities, but at the beginning of 1990 only U.Va. remained active in the program. The program was scheduled to terminate at the end of 1990 but sufficient funds remained in the program to justify its continuation. U.Va. requested and was granted a no-cost extension of the program. The female trainee hired in 1990 applied for admission to the U.Va. medical school and was accepted. She left the training program in July, 1991. Two trainees were hired in December, 1991. The DOE grant was terminated at the end of November, 1992.

10. Reactor Tours

During the calendar year 1992, the staff guided 52 groups on tours of the Facility, for a total of 926 visitors.

B. CAVALIER Reactor

1. Core Configuration

The reactor was completely and permanently unloaded during the first week of March, 1988. A decommissioning order was issued by the NRC on February 3, 1992. The decommissioning should be completed in 1993.

III. REGULATORY COMPLIANCE

A. Reactor Safety Committee

1. Meetings

During 1992, the Reactor Safety Committee met eleven times, on the following dates:

March 24, 1992	October 8, 1992 (2 meetings)
May 26, 1992	October 26, 1992
September 22, 1992	November 19, 1992
September 29, 1992	November 24, 1992
October 7, 1992	December 10, 1992

2. Audits

During the year sub-committees of the Reactor Safety Committee performed two audits of the Facility in the areas of: reactor operations records, the emergency plan and implementing procedures, and the security plan.

3. Approvals

The Reactor Safety Committee approved three changes to the UVAR Standard Operating Procedures during the year concerning liquid waste releases, the daily checklist, addition of a new checklist following reactor core changes, and the irradiation request forms.

4. 10 CFR 50.59 Reviews

The following 10 CFR 50.59 analyses were performed during the year and were reviewed by the Reactor Safety Committee:

a. Reintroduction of hot thimble irradiation facilities into regular use

b. Remodeling of storage/student section of mezzanine

B. Changes to the Reactor Facility

1. Low Enriched Uranium Conversion Plans

The NRC mandated in 1986 a change from high enriched uranium (HEU) fuel to low enriched uranium (LEU) fuel, with the date of conversion to depend on several factors. The U.Va. Facility will be among the initial group of research reactor facilities to convert to LEU fuel. A study funded by DOE was begun in the spring of 1986 to accomplish this. A management decision has been made to shut down the CAVALIER reactor and a dismantlement plan was submitted to the NRC, however, the NRC has requested that a complete decommissioning plan be submitted. This was accomplished in early 1990 and a decommissioning order was issued by the NRC in February, 1992. The CAVALIER will be decommissioned in 1993. The present plans call for the conversion of the UVAR reactor in the spring of 1993. A Safety Analysis Report on the LEU fuel and revised Technical Specifications were submitted to the NRC and the Facility is awaiting approval of these submittals.

C. Inspections

During 1992 the Facility underwent three NRC compliance inspections, at the following times and in the areas of:

7-22-92	Health Physics
9-21-92	Reactor Operations
11-17-92	Emergency Preparedness

D. Licensing Action

The NRC was notified that as of July 1, 1992, the Department of Nuclear Engineering merged with the Department of Mechanical and Aerospace Engineering to form the Department of Mechanical, Aerospace and Nuclear Engineering. Dr. P.E. Allaire is the chairman of this combined department.

E. Emergency Preparedness

1. On January 31, 1992, a practice evacuation of the Facility was initiated by actuating the criticality alarm system located at the fuel storage room. The UVAR reactor was operating at the time and the operator manually scrammed the reactor and isolated the reactor room before evacuating. There were fourteen individuals in the Facility at the time of the drill and all personnel evacuated the Facility in a timely manner. Verification was made of alarms sounding in the CAVALIER room, first floor hallway and mezzanine hallway.

2. During the months of September and October 4 different training sessions were held with the reactor staff to review the Emergency Plan and Implementing Procedures and to discuss the appropriate response to several different emergency scenarios.

3. On November 17, 1992, a full-scale emergency drill involving several outside agencies was held at the Facility. Two NRC personnel (one from Region II and one from Washington) and nine personnel from the Virginia Office of Emergency Services and Department of Health were present as observers. The scenario involved a graduate student boiling down an acid solution containing ten microcuries of cesium-137 in a fume hood adjacent to the boiler room, which also contains the main electrical panel for the building. A loose hose clamp on a secondary chemistry valve develops a leak, spraying a solution onto the electrical panel. This results in a circuit breaker shorting out, causing a major arc explosion. The force of the explosion causes the cover of the breaker to rupture, sending pieces of the breaker through the side of the fume hood, rupturing the glass beaker being used by the student. The student is severely injured with second degree burns and several pieces of contaminated glass are embedded in his face and chest. Pieces of the breaker are also thrown across the boiler room causing a rupture of a fuel line with the possibility of a fire.

   The drill coordinator initiated the drill by pulling a circuit breaker at the main panel at 1002, cutting power to part of the building. This cut power to the reactor console, automatically shuting down the reactor. The reactor operator secured the reactor and summoned other staff members to investigate. The staff discovered the injured student and began first aid treatment. The senior staff member present assumed the role of emergency director and set up an emergency control center in the front office. One of the staff members, when informed of the arcing electrical panel and fuel leak, secured power to the entire building and shut off the fuel lines, however the emergency coordinator informed the staff that a fire had commenced. The injured student was moved to the far end of the building to await medical assistance. The emergency director called 911 and asked for assistance from the fire department and rescue squad. The University police were called and asked to send a squad car to the Facility to control traffic. An unusual event emergency was declared at 1016 and calls were made to the NRC both in Washington and Atlanta. The Office of Emergency Services in Richmond was notified. The drill was terminated at 1155 and a critique was held in the afternoon.

IV. HEALTH PHYSICS

A. Personnel Dosimetry

1. Visitor Exposure Data For 1992

Visitors to the UVAR primarily consist of students, tour groups, maintenance personnel and vendors. Visitor exposure at the UVAR is monitored through the use of gamma and X-ray sensitive direct reading pocket dosimeters. In 1992, the Reactor Facility purchased six additional new electronic pocket dosimeters to be utilized by visitors and staff. During 1992, there were 2,618 visitor entries into the Reactor Facility. Of these entries, 1692 were individual visitor entries and 926 were visitors as part of 52 groups. No visitor received an exposure greater than five milli-roentgens in any one visit.

2. Reactor Facility Personnel Dosimetry Data For 1992

a. Monthly Whole Body Badge Data

Radiation doses received by Reactor Facility personnel were measured using Landauer film badges. The film badge dosimeters measured exposure from beta, X-ray, gamma and thermal neutron radiation. In 1992, all personnel working with the neutron beamports at the Facility were issued neutron dosimeters in addition to their whole body film badges. The neutron dosimeters used were Landauer Neutrak ER badges which allowed detection of an extended range of neutron energies. All dosimeters were changed out on a monthly basis.

The dose distribution for personnel badged at the Reactor Facility during the period January 1 through December 31, 1992 is shown in Table 6.

TABLE 6	
Personnel Radiation Does Received at Reactor Facility	
Measured Cumulative Total Dose* (mrem)	Number of Occurrences in 1992
Less than 10	64
10 - 20	70
21 - 30	4
31 - 40	1
41 - 50	1
51 - 60	1
61 - 70	1
71 - 80	0
81 - 90	0
Greater than 90	3

Number of badged personnel: 145 persons

Total population dose for this group: 1.86 person-rem

* whole body deep dose only as measured by film badge dosimeters

NOTE: The dosimeters used by the Reactor Facility had a detection minimum of 10 mrem for gamma, X-rays and thermal neutrons and 40 mrem for energetic beta particles.

The individual who received the highest dose (280 mrem), was a Reactor Facility staff member routinely involved in unloading the mineral irradiation facility and handling radioactive materials for neutron activation analysis.

b. Neutron Exposures

Nine Facility personnel were issued Neutrak ER neutron badges in 1992. The neutron dose distribution for this group is shown in Table 7.

TABLE 7	
Personnel Neutron Doses at the Reactor Facility	
Measured Cumulative Neutron Dose (mrem)	Number of Occurrences in 1992
Less than 20	9
20 - 30	0
Greater than 30	0
NOTE: These dosimeters have a minimum reporting dose of 20 mrem.	

c. Extremity Exposures

During 1992, 35 Facility personnel wore TLD ring badges in addition to their whole body badges. Table 8 is a summary of the extremity doses received by Reactor Facility personnel who wore ring badges during the period January 1, 1992 through December 31, 1992.

TABLE 8	
Personnel Extremity Doses at the Reactor Facility	
Measured Extremity Dose (mrem)	Number of Occurrences in 1992
Less than 100	30
101 - 500	2
501 - 1000	0
Greater than 1000	3

The individual who received the highest extremity dose (1590 mrem), was a Reactor Facility staff member routinely involved in unloading the mineral irradiation facility and handling radioactive materials for neutron activation analysis.

d. Direct-reading Dosimeter Exposures

Direct-reading dosimeters (in addition to whole body film badges) are worn by UVAR personnel when they are handling irradiated material which has a calculated or measured exposure rate of greater than 100 mR per hour, measured at one foot from the source. If the exposure totals more than 5 mR in one day, the exposure is logged into an exposure log kept in the control room. This information is helpful in assessing the amount of exposure received during specific operations. The total of all exposures recorded in the log book during 1992 was 270.7 mR. The highest individual exposure was 20.5 mR. This exposure was received by an individual working with the mineral irradiation facility (MIF). It should be noted that the MIF is currently being redesigned to be unloaded underwater. This should reduce personnel doses.

B. Effluents Released During 1992

1. Airborne Effluents

Argon-41 gaseous release concentrations are calculated using a methodology described in a June, 1977 memorandum entitled: "Memo to Senior Operators - argon-41 production in UVAR." The methodology described in this memorandum assumes:

a. a maximum production rate for Ar-41 (with present UVAR core loading)

b. immediate evolution of Ar-41 from the pool water into the UVAR confinement atmosphere

c. no decay

d. air saturating the UVAR pool water at 68°F.

Based on this method, and using the known amount of time the reactor was at power during 1992 (2 MW for 1214 hours), the calculated total activity of Ar-41 released was 3.5 Curies.

2. Liquid Effluents

Liquid radioactive waste generated at the UVAR is disposed of by one of two means. Liquid waste generated in the laboratories is poured into approved containers which are collected and disposed of by the Environmental Health and Safety Office. Other liquid wastes generated by the UVAR operation are released off-site in accordance with 10 CFR 20 release limits. The majority of liquid released off-site is from an on-site pond. This pond receives surface runoff and water from a creek which flows into it. In unusual situations, it may receive a direct discharge from the Facility (e.g. draining of the reactor pool). Regeneration of the UVAR demineralizer system is the major source of radioactivity in the liquid effluent released from the Facility.

Prior to release, the regeneration liquid is stored in two 5,000 gallon underground tanks where it is circulated through Cuno filters. The liquid in these tanks is analyzed for radioactivity content and then released through the pond spillway where it is diluted with pond water. Prior to, and during all liquid releases, water samples are collected and analyzed for radioactivity content. During 1992 there were 36 releases of liquid effluent to the environment (see Figure 6).

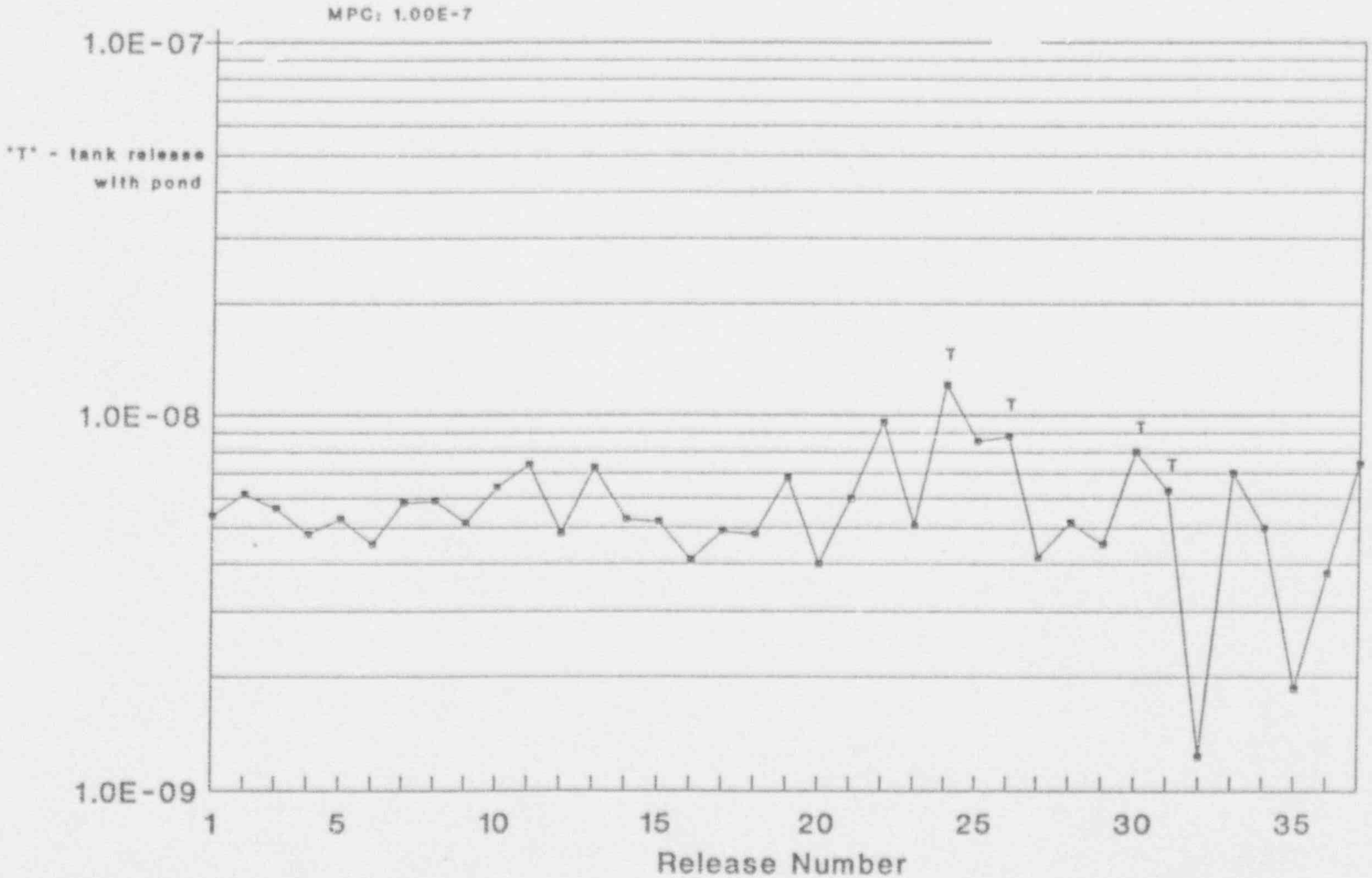
In 1991 it was verified that leakage was occurring through the pond spillway to the release standpipe at an average rate of three gallons per minute. As this is considered release of pond water, it is sampled on a monthly basis and analyzed for gross beta particle activity. Consequently, the volume and activity released via this pathway is included in the 1992 liquid release totals. The total volume of liquid released offsite in 1992 was 31,700,000 liters (8,400,000 gallons).

Figure 6

Liquid Effluent Releases

Gross Beta Analysis Results (uCi/ml)

January-December 1992



Apriori LLD: 3.0 E-9 uCi/ml

The average concentration of radioactive material (as measured by gross beta particle activity analysis) released in effluent from the UVAR site was 5.77×10^{-9} μCi/ml. This concentration was 6% of the applicable MPC. The average concentration of radioactive material in the water leaking through the spillway was 5.71×10^{-9} μCi/ml. The total activity (excluding tritium activity) released in effluent was 184 μCi. This activity includes naturally occurring radionuclides contributed to the pond from sources described above.

The aver. e tritium concentration in effluent from the site was 5.7×10^{-8} μCi/ml. This concentration was 0.002% of the applicable MPC. The total tritium activity released during 1992 was 1459 μCi.

3. Solid Waste Shipments

During 1992 there were four transfers of small amounts of radioactive waste from the reactor to EHS. No shipments of radioactive waste were made to an offsite waste disposal facility in 1992.

C. Environmental Surveillance

1. Water Sampling

Environmental water samples are collected on a monthly basis from the locations indicated in Table 9. During 1992, environmental water samples inadvertently were not analyzed during the months of July and November. Gross beta particle activity analysis was performed on all water samples collected. The results of the analyses are provided in Table 10. The average gross beta concentration measured at each location was less than the applicable MPC.

TABLE 9 ENVIRONMENTAL WATER SAMPLE LOCATIONS		
Location	Description	Distance/Direction from UVAR
W-1	Creek upstream of on-site pond	on-site
W-2	Water filtration plant	0.26 mi. southeast
W-3	Meadow Creek near Barracks Road, downstream of main University water discharge point (2 samples taken short distance apart on creek, results are averaged)	1.8 mi. northeast

TABLE 10 ENVIRONMENTAL WATER SAMPLING RESULTS			
Gross Beta Particle Activity Analyses Results μCi/ml (% 1 sigma error)			
	Upstream of Reactor Facility Pond W-1	At Water Filtration Plant W-2	Meadow Creek W-3
JAN	4.7×10^{-9} (2)	1.7×10^{-9} (580)	2.3×10^{-9} (36)
FEB	7.1×10^{-9} (16)	9.8×10^{-10} (82)	6.8×10^{-9} (11)
MAR	2.9×10^{-9} (26)	5.7×10^{-10}(152)	2.9×10^{-9} (26)
APR	1.8×10^{-9} (62)	-3.7×10^{-10} (-262.5)	2.4×10^{-9} (36)
MAY	7.4×10^{-9} (16)	-4.2×10^{-10} (-190)	3.6×10^{-9} (21)
JUN	6.9×10^{-9} (21)	1.3×10^{-9} (80)	5.5×10^{-9} (17)
JUL	No Data	No Data	No Data
AUG	7.4×10^{-9} (14)	7.7×10^{-9} (14)	3.5×10^{-9} (16)
SEP	7.8×10^{-9} (15)	7.4×10^{-9} (15)	5.2×10^{-9} (13)
OCT	8.5×10^{-9} (15)	1.9×10^{-9} (46)	4.2×10^{-9} (16)
NOV	No Data	No Data	No Data
DEC	6.7×10^{-9} (14)	2.9×10^{-9} (26)	5.9×10^{-9} (13)
Average	6.2×10^{-9}	2.4×10^{-9}	4.2×10^{-9}
Apriori LLD: 3.0×10^{-9} μCi/ml			

2. Air Sampling

Environmental air samples are collected on a monthly basis at the following locations:

A-1 Roof of reactor building
A-2 Indicator - approximately 0.13 mi. E of UVAR
A-3 Control - approximately 3.1 mi. NW of UVAR

Fixed sampling locations are utilized to collect air samples at locations A-2 and A-3. Sampling time for these offsite samples is approximately 96 hours. Air samples are collected at location A-1 using a portable air sampler which is run for approximately 2 hours. All air samples collected at these locations were particulate air samples and were analyzed for gross beta particle activity. Results are provided in Table 11.

TABLE 11
ENVIRONMENTAL AIR SAMPLING RESULTS

Gross Beta Particle Activity Analyses Results (10^{-13} μCi/ml ± 2 sigma error)

	Roof of UVAR Facility	0.13 miles east of UVAR Facility	3.1 miles northwest of UVAR Facility
JAN	0.5 ± 2.2*	1.8 ± 0.09	1.6 ± 0.08
FEB	1.8 ± 1.4	0.9 ± 0.08	1.3 ± 0.09
MAR	6.0 ± 2.9	0.8 ± 0.07	0.7 ± 0.07
APR	1.4 ± 2.7	2.0 ± 0.12	1.9 ± 0.11
MAY	3.0 ± 2.3	1.6 ± 0.08	1.9 ± 0.09
JUN	6.3 ± 2.5	5.6 ± 0.19**	14.0 ± 0.3**
JUL	No Data	1.4 ± 0.06	1.5 ± 0.06
AUG	5.0 ± 1.2	1.2 ± 0.04	0.9 ± 0.05
SEP	1.9 ± 0.95	0.6 ± 0.04	0.5 ± 0.03
OCT	8.5 ± 2.5***	2.8 ± 0.10	2.5 ± 0.09
NOV	1.6 ± 0.98	0.5 ± 0.03	0.4 ± 0.02
DEC	1.1 ± 0.98	1.0 ± 0.07	0.9 ± 0.07
Average	3.4 ± 0.6	1.3 ± 0.03	1.3 ± 0.02

* Unusually low concentration resulting from abnormally high background.

** Filter paper counted before 24 hour waiting period (counter power failure) These numbers were not included in the computation of the averages.

*** Data on sampler flow rates and running times missing. Default values used may be inaccurate, resulting in higher apparent concentration.

Roof Sampler LLD = 2.8 E-13 μCi/ml
Environmental Samplers LLD = 0.062 E-13 μCi/ml

D. UVAR Facility Health Physics Surveys

1. Radiation and Contamination Surveys

Daily, weekly and monthly surveys are performed throughout the Facility to monitor radiation and contamination levels. All required area radiation and contamination surveys were performed during 1992.

The levels of contamination detected in the Facility during 1992 were generally very low (typically less than 100 dpm/100 cm^2). Although the procedural definition of "contamination" is an activity of 2200 dpm per 100 cm^2 or greater, most areas are decontaminated if found to have greater than 50 dpm/100 cm^2. This is in keeping with the philosophy of ALARA.

In July of 1992 an unidentified high-radiation area was created on the reactor bridge following a UVAR core configuration change. The high radiation area was a result of radiation streaming from an unbowed epithermal rabbit tube. Discovery of the radiation beam was made shortly after its creation. Exposure rate measurements were made to assess possible personnel exposure and appropriate corrective actions were taken to eliminate the radiation beam. Doses to personnel from the beam were calculated to be negligible. The NRC was notified and has, as of this time, taken no regulatory action related to this event. Routine area radiation level surveys revealed no overall background or systems-related radiation levels.

2. Airborne Radioactivity

A particulate air sample is collected in the reactor room as part of the weekly survey of the Reactor Facility. The average concentration of radioactive material detected in the air in the reactor room (as measured by gross beta analysis of the particulate samples) was 4.93×10^{-12} μCi/ml. The airborne radioactivity detected was primarily due to radon and thoron daughters. None of the measured concentrations exceeded the applicable MPC (see Figure 7).

E. Quality Assurance

The UVAR Facility participates in the U.S. Environmental Protection Agency (EPA) Laboratory Intercomparison Studies Program as part of its quality control program for radiation measurement of air and water samples. The UVAR Facility participates in the following studies:

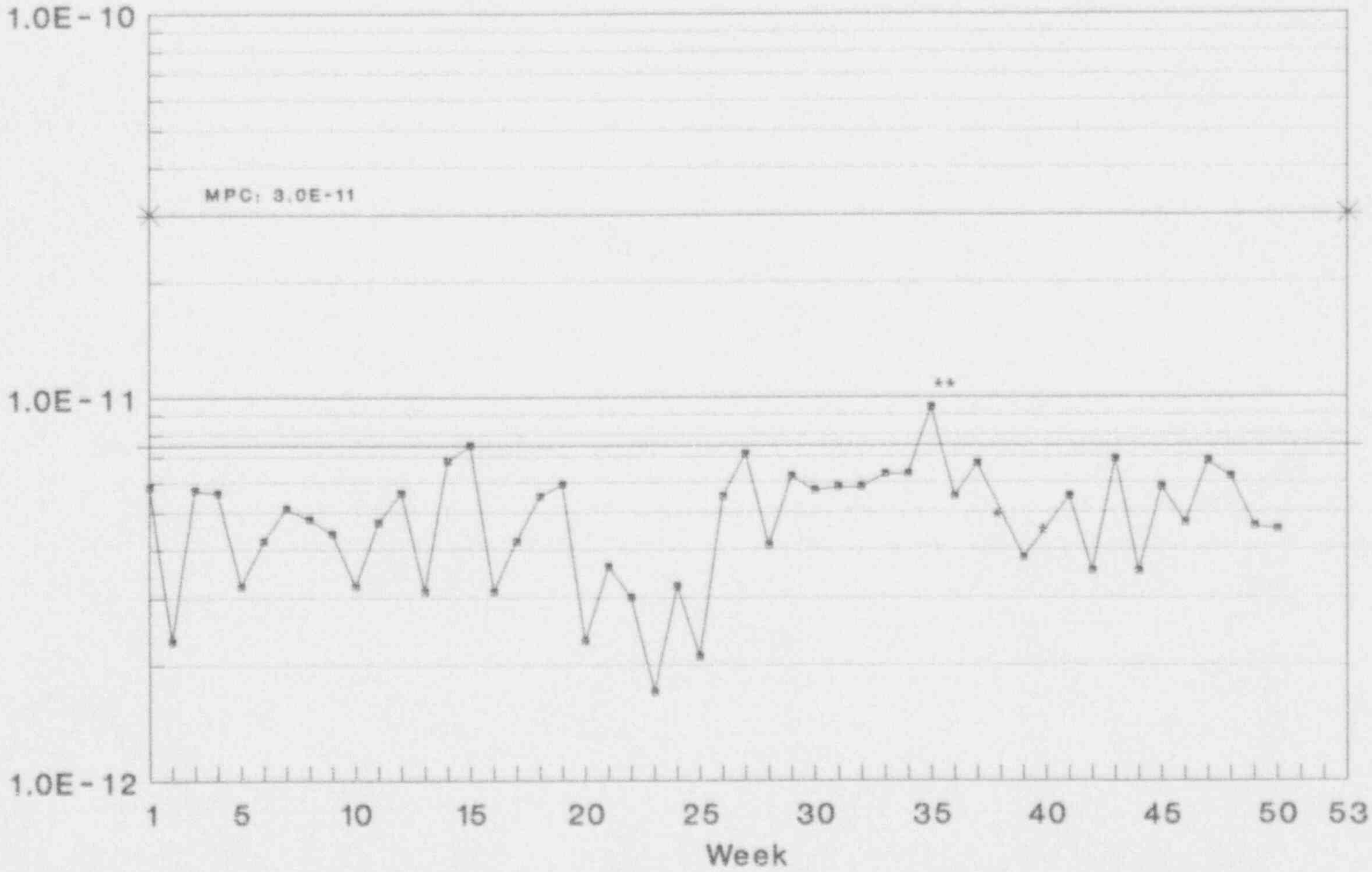
Gamma in water on a triannual basis
Gross alpha, gross beta in water on a triannual basis
Tritium in water on a semiannual basis
Gross beta on air filter on a semiannual basis

Three independent determinations for each radionuclide included in a study are made and analysis results are reported to the EPA. A tabulation of all results reported by all participating laboratories is generated by the EPA. This tabulation report contains analytical precision values which are used as a basis for judging a laboratory's performance. Table 12 shows the results of the UVAR's performance in the above mentioned studies.

Reactor Room Particulate Air Samples

Gross Beta Analysis Results *(uCi/ml)*

January-December 1992



Apriori LLD: 2.8 E-13 uCi/ml

* NO DATA, 24-hr count not obtained

** UVAR shutdown, early morning sample

Table 12
Results of EPA Radioactivity Measurement Laboratory Inter-Comparison Program

Date	Study	Known Value	UVAR reported average value	Normalized Deviation*
3-27-92 8-28-92	Air filter (Beta)	41 pCi/F 69 pCi/F	50.7 NRP	3.35
1-31-92 5-15-92 9-18-92	Gross α/β in H_2O	30 pCi/l 44 pCi/l 50 pCi/l	31.7 50.3 NRP	0.58 2.19
2-21-92 6-19-92	H_3 in water	7,904 pCi/l 2,125 pCi/l	5,626.7 1,587	-4.99 -2.69
2-14-92	Gamma in water	Co-60 40 pCi/l Zn-65 148 pCi/l Ru-106 203 pCi/l Cs-134 31 pCi/l Cs-137 49 pCi/l Ba-133 76 pCi/l	40.0 139.3 177.7 26.3 46.7 71.3	0.06 -1.00 -2.19 -1.62 -0.81 -1.01
6-05-92	Gamma in water	Co-60 10 pCi/l Zn-65 108 pCi/l Ru-106 149 pCi/l Cs-134 15 pCi/l Cs-137 14 pCi/l Ba-133 62 pCi/l	NRP 124.3 129.3 14.0 16.7 63.3	 2.57 -2.27 -0.35 0.92 0.38
10-04-92	Gamma in water		NRP	

NRP - No results reported by UVAR Facility

* If this value is between 2.00 and 3.00 the analytical process precision is in the warning zone; if it exceeds 3.00 it is outside of control limits specified by EPA

F. Spills

In September, 1992, an in pool failure of two canisters used for neutron activation of ceramic beads, resulted in the dispersion of activated Ir-192 ceramic beads to the research reactor pool floor and primary coolant system. Due to the location and nature of the spill no contamination of accessible areas or significant exposure of personnel resulted from the spill or recovery operations. No reportable spills occurred at the UVAR Facility during 1992.

G. Summmary

During 1992, no State or Federal limit for exposure to personnel or the general public was exceeded.

V. RESEARCH, EDUCATION AND SERVICE ACTIVITIES

A. Irradiation and Other Research Facilities Available

An overall description of the experimental facilities available at the UVAR Facility is listed in section I.B.5. During 1992, no substantial changes were made to any existing experimental facilities nor were any new facilities added.

B. Research Activities

1. A continuing program of research was pursued on behalf of the Philip Morris Company. This work was supervised by Dr. Jack Brenizer and conducted primarily by graduate students with Reactor Facility staff assistance. The major projects were neutron radiographic examinations of burning cigarettes, neutron activation analysis of various tobacco products and other substances used in the tobacco industry and the analysis of the distribution of smoke from a smoked cigarette through spiking of tobacco with radioactive isotopes.

2. Staff assistance was provided for one major project and several minor projects utilizing the cobalt-60 irradiation facility. The major project is on behalf of sponsors related to the nuclear power industry. It involves the gamma irradiation of radiation sensitive components from nuclear power plants. Dr. Albert Reynolds is the principal investigator for this project which could last several more years.

   One of the other projects was sponsored by the Continuous Electron Beam Accelerator Facility (CEBAF) in Newport News, Virginia. The researchers there are investigating the possible radiation degradation of fiber-optic type radiation scintillation detectors that are scheduled for use with the accelerator. Work on this project is continuing in 1993.

   Several researchers at both U.Va., other universities and some high schools provided a number of different kinds of samples to be sterilized in the cobalt facility.

3. A Nuclear Engineering faculty member, Dr. W.R. Johnson, and several students used reactor produced radioisotopes to perform sponsored research investigating methods of measuring corrosion inside steel pipes.

4. Neutron activation analysis services to measure trace amounts of osmium in aqueous DNA solutions were provided by the Reactor Staff to U.Va. chemistry professor M.G. Finn and his graduate students.

5. The Ciba-Geigy pharmaceutical company continued sponsoring work involving neutron activation analysis and production of samarium and erbium radioactive tracers. The interest is to develop methods to measure and control drug delivery and release mechanisms which employ hydrogel bead technology.

6. Neutron activation analysis services to measure trace amounts of ioidine in NaI(Tl) crystal material were provided by the Reactor Staff to John Shepard, a U.Va. Materials Science graduate student.

7. Reactor staff assistance in the form of computer modeling and other technical assistance was provided to Boehling Technologies, a small company which was investigating the characteristics of a novel heat engine design.

8. Initial irradiations of Charpy type steel enbrittlement test specimens in heated epithermal neutron irradiation facilities were accomplished on behalf of Professor Arvind Kumar of the University of Missouri - Rolla. This research is sponsored by both the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.

C. Service Projects

1. Iodine determination by epithermal neutron activation analysis (ENAA) was performed on behalf of several sponsors, including Ross Laboratories, Purina and Woodson-Tenent Laboratories. The substances analyzed were infant formula, liquid diet supplements, surgical diets, pet foods and various chemical compounds.

2. The project involving the color enhancement of various gemstone grade minerals by fast neutron irradiation was pursued by the reactor staff on behalf on several sponsors involved in the commercial gem trade.

3. The Protechnics International Company, which supplies various radioactive sources to industry, had the Reactor Facility irradiate and ship several sources for use by companies performing oil well drilling.

4. A number of small radioactive sources were produced for use in graduate and undergraduate nuclear engineering laboratories.

5. The National Institutes of Standards and Technology (NIST) utilized the services of the Reactor Facility to irradiate and return ship to NIST a small number of samples to be analyzed at NIST for nickel and other elements.

D. Reactor Sharing Program

The Department of Energy has for the past thirteen years funded a program at the University entitled Reactor Sharing. The purpose of this program is to make available the UVAR facilities to faculty and students at universities and other educational institutions which do not have nuclear science facilities. Over the years, hundreds of students and dozens of professors have used this arrangement to enhance both their educational and research opportunities. This past year a number of tours, laboratories and research projects were conducted under this program.

The following is a list of both the directly and indirectly funded activities completed in 1992.

School tours:

Ten tours from seven high schools, middle schools and elementary schools involving 355 students and teachers.

Five tours by special groups of junior high school and elementary school aged students involving 83 students.

College tours:

Seven tours from two colleges involving 99 students and professors.

Special tours in conjunction with U.Va. programs:

Eight tours involving 260 individuals.

College labs:

Two of the college student tours involved laboratories which were participated in by 19 individuals.

Research projects:

Several research projects utilizing neutron activation analysis or cobalt-60 gamma ray irradiation were conducted by students and faculty from other schools during the year.

E. Reactor Facility Supported Courses and Laboratories

1. Academic Courses and Laboratories

The following courses and laboratories were taught by professors of Nuclear Engineering during 1992 utilizing in part services provided by the Reactor Facility.

NE 488 - Nuclear Power Plant Operations
NE 382 - Nuclear Engineering Laboratory

During June 1992, 49 high school teachers from the state of Virginia attended a one week special course at the Reactor Facility. The title of the course was "Science of Nuclear Energy and Radiation: Environmental Issues and Safety." It consisted of lectures by University of Virginia nuclear engineering faculty, laboratory experiments using the reactor and a tour of the North Anna Nuclear Power Station.

F. Degrees Granted by U.Va. in Nuclear Engineering or Engineering Physics

The following number of degrees were awarded during 1992 by the University of Virginia in the disciplines of Nuclear Engineering and Engineering Physics (formally a part of the department which includes the Reactor Facility):

Bachelors of Science, Nuclear Engineering	3
Masters, Nuclear Engineering	5
Masters, Engineering Physics	3
Doctor of Philosophy, Engineering Physics	3
Doctor of Philosophy, Nuclear Engineering	2
TOTAL	16

The following theses by students majoring Nuclear Engineering or Engineering Physics were completed during 1992 in part using services or facilities provided at the U.Va. Reactor Facility.

Determination of Nb^{93m} Content in Pressure Vessel Steel by Liquid Scintillation Counting, MS thesis in Nuclear Engineering by William R. Kohlroser.

Aging Assessment in Nuclear Reactors: Oxidation Induction Time for Polymer Cables, MS thesis in Nuclear Engineering by L. Roger Mason.

Sequential and Simultaneous Aging Effects on Polymer Degradation, MS thesis in Nuclear Engineering by Michael B. Hall.

Real Time Detection of Corrosion in Piping Systems, MS thesis in Nuclear Engineering by Susanna E. Johnson.

F. Degrees Granted in Nuclear Engineering or Engineering Physics (continued)

Real-Time Neutron Coded Aperture Imaging: A Technique for Nondestructive Pseudoholographic Imaging, PhD thesis in Nuclear Engineering by Kenneth M. Gibbs.

A Scattering Effect Correction Technique for Neutron Tomography Image Enhancement Using the Maximum-Entropy Formalism, PhD thesis in Nuclear Engineering by Carlos A. Mora.

Gastrointestinal Scintigraphy of Radiolabeled Hydrogel Beads, PhD thesis in Engineering Physics by Matthew J. Combs.

Sequential and Synergistic Effects During Accelerated Aging of Polymers and the Utility of Oxidation-Induction-Time Measurements in Life-Assessment Methodology, PhD thesis in Engineering Physics by Thomas E. Doyle.

The research work for several other theses is in progress utilizing Reactor Facility support.

VI. FINANCES

A. Expenditures

Expenditures for 1992 were as follows:

	State Support	Locally Generated Monies
Salaries + Fringes:	$289,100	$120,590
Operations:	41,750	61,560
Subtotals:	$330,850	182,150
TOTAL:	$513,000	

B. State Support / Research and Service Income

The University of Virginia is supported by allocations from the State of Virginia. Of these monies, a portion is allocated for the operation of the Nuclear Reactor Facility. These funds cover many of the expenses directly related to the operation of the reactor but additional monies are necessary to provide for remaining services provided to the university community by the Facility. Additional income is in the form of fees received for research and service work support. This amount billed for these services totaled about $209,000 in 1992. The income is "not business related income" because it is primarily used to pay the salaries of extra professional staff members at the Facility who are not state supported. Currently, there are four staff members receiving the majority of their salaries from local funds and one other individual receives 50% support.

Many staff members take courses and receive degrees at the University while their salaries are paid from monies generated by service work. In effect, this is another method by which the Reactor Facility supports science education in the Univeristy of Virginia School of Engineering and Applied Science. Currently, two staff members are taking courses toward the completion of masters degrees.

VII. MEDICALLY-ORIENTED INTERDISCIPLINARY RESEARCH

A. Introduction

An extensive amount of interdisciplinary research directed towards the medical field is being conducted involving U.Va. Reactor Facility resources. Dr. Matthew Combs joined the reactor staff in 1992 and currently holds a joint position as Research Associate in both the MANE and Radiology departments. The interdisciplinary research involves work both at the U.Va. Reactor Facility and the U.Va. Nuclear Medicine Research Laboratory (NMRL), rooms 1138 and 1157 of the MR-4 annex.

The NMRL became fully operational in May, 1992 with the initiation of the Canine Gastric Emptying project. Since that time, many more projects involving the NMRL have been started. Dr. Combs is currently under the direct supervision of Dr. Robert Mulder, Assistant Professor of Mechanical, Aerospace and Nuclear Engineering (MANE) and Dr. David Teates, Professor of Radiology.

A second-year Nuclear Engineering undergraduate student, Mr. David Buck, has started working in the NMRL as a work-study student. It is anticipated that more students, both undergraduate and graduate, will be working in the NMRL since there are many potential projects.

The lab has equipment necessary to perform most nuclear medicine procedures. The equipment includes a small field-of-view Anger camera (Searle Pho-gamma 37) connected to a Sophy GX+ image acquisition and processing computer, a PMV-2250 macro-cryomicrotome for whole-body autoradiography, and hot lab equipment including a Capintec CRC-22B dose calibrator. Research contracts with hardware vendors and traditional funding sources will allow for future system upgrades.

Although still in the start-up phase, the NMRL has achieved success in attracting many projects in a short period of time. The projects cover a range of disciplines, including nuclear engineering, cardiology and surgery. Interdisciplinary projects are encouraged, and more can be expected due to communication between investigators and word-of-mouth advertising. The remainder of this section describes the projects underway in 1992.

B. Neutron Capture Therapy Project

1. Primary Investigators:

Robert U. Mulder, Ph.D. (MANE)
Matthew J. Combs, Ph.D. (Departments of MANE and Radiology)
George T. Gillies, Ph.D. (MANE, Dept. of Biomedical Engineering (BME))
Stuart S. Berr, Ph.D. (Departments of Radiology and BME)
Thomas A. Spraggins, Ph.D. (Departments of Radiology and BME)

2. Funding:

American Cancer Society #IRG-66878

3. Applications Pending:

EJ Lilly and Company Foundation

4. Project Outline:

Boron neutron capture therapy (BNCT) is a promising technique for cancer treatment receiving renewed worldwide investigation. The technique is based upon introduction of boron-containing compounds into tumor cells with a suitable carrier (i.e. chemicals or monoclonal antibodies) and subsequent irradiation of the tumor(s) with an energy-filtered neutron beam. The $^{10}B(n,a)^{7}Li$ reaction releases a large amount of energy ($\sim$2.3 MeV) which is deposited proximal to the boron binding (about 10 μm), resulting in a cancer-cell specific lethality. Normal tissue carrying a reduced boron concentration receives a much smaller radiation dose than highly boronated cancerous tissue and thus is likely to survive.

Successful clinical trials of BNCT applied to malignant melanoma have been performed recently(1). Our interests at this time are to investigate additional co-adjuvant aspects for BNCT of malignant melanoma. The most widely-used boronated compound for melanoma treatment is ^{10}B-para-boronophenylalanine (BPA), an L-stereoisomer analog of the melanin precursors phenylalanine and tyrosine. BPA is synthesized by the melanoma cells, resulting in tumor to non-tumor ^{10}B concentration ratios between 3:1 and 15:1 (1,2). Studies on melanoma treatment in animals have shown BPA-BNCT to be effective at killing melanoma cells, including eradication of the disease (1,2).

The use of hyperthermia as an adjuvant treatment of cancer has been studied extensively at the University of Virginia (3,4). However, a thorough literature search (5) found no published research linking hyperthermia and BNCT. It is our hypothesis that tumor boron concentration could be increased by altering the temperature around a tumor site following administration of BPA. An increase in ^{10}B tumor uptake will allow for reduced irradiation time and subsequently lower the radiation dose to healthy tissue, or make treatment possible at low-power research reactor facilities. Alternatively, increased BPA concentration in the tumor allows for a higher tumor dose with enhancement

of the cell-killing abilities of the treatment. Following the hyperthermia phase and maximum uptake, application of local hypothermia perhaps could be used to maintain the tumor to non-tumor boron ratio over longer periods of time. Low temperature is expected to reduce tumor blood flow, permitting boron to wash out of surrounding normal tissue.

One of the most challenging aspects of BNCT is quantification of tissue boron concentration. The method of analysis most readily performed at the Reactor Facility of the University is alpha-particle autoradiography(6). Another method, prompt-gamma analysis of blood and tissue, is expensive due to the required dedicated thin collimated neutron beam and associated gamma-ray detection hardware. A third method, permitting non-invasive quantification of boron concentration which is readily available at U.Va. is magnetic resonance imaging of boron. Some research has been performed on boron MRI, but with limited success (7,8).

The goals of this project are to investigate: 1) the effects of tumor temperature on boron uptake and retention, 2) the beneficial consequence of greater absolute boron amounts in cancer cells leading to assured lethality from BNCT, 3) the synergistic effect of BNCT and temperature and 4) new methods for quantification of boron concentrations in melanoma as compared with existing methods.

a. Facilities Currently Available

The University of Virginia Reactor (UVAR) is a pool-type light-water cooled and moderated reactor operating at a thermal power of 2 MW. The reactor is operated within the Department of Mechanical, Aerospace, and Nuclear Engineering (MANE). Several neutron beam ports are available to researchers, including a real-time and static neutron radiography facility. Neutron radiography has been studied extensively at U.Va. (9), one of only four US sites capable of real-time radiography using a digital camera. The possibility of measuring boron concentration ratios in tissues using neutron radiography will be explored. The neutron radiography port has a thermal (<0.025 eV) neutron flux of approximately 10^7 n/cm^2-sec, suitable for exploratory BNCT experiments. Higher neutron fluxes could be made available in the future by using other beam ports optimized for BNCT, should exploratory experiments be successful.

The U.Va.-Siemens Laboratory for Radiological Research has two instruments available for use in boron biodistribution studies. One instrument is a PMV-2250 macro-cryomicrotome suited for whole-body autoradiography. This instrument will provide tissue slices to be used in both neutron and alpha-particle autoradiography. The other instrument is a 4.7 Tesla small-aperture imaging and spectroscopy magnet suited for use with small animals. Acquisition and analysis sequences can be modified and implemented on this system, allowing for imaging of the boron as well as traditional proton MRI.

b. Proposed research

To date, MIT is the only university research reactor in the U.S. which has conducted animal BNCT studies. This U.Va. study will be a pilot project whose secondary purpose, (aside from obtention of valid research data), is to make functional the latent capabilities existing in various departments and promote a new area of interdisciplinary research.

Boron biodistribution studies

The biodistribution of BPA will be studied using mice inoculated with the B16 murine melanoma. The melanoma will be cultured in the leg of the animals for 14 days prior to BPA administration. Four groups of animals will be used (15 animals per group), each receiving one of the following treatments:

1) BPA administered orally (30 mg/mouse)
2) BPA plus raising the tumor temperature by 6 degrees C
3) BPA with the tumor temperature reduced by 6 degrees C
4) BPA plus raising the tumor temperature by 6 degrees C, then reduced by 6 degrees after boron concentration in tumor has reached a maximum (~6 hr).

Two mice from each group will be imaged in the small-aperture MRI unit following BPA administration to assess the unit's suitability for boron imaging. Three animals from each group will be sacrificed on the hour (1,2,3,4,5,6 hr) over a 6-hour period following BPA administration. The animals will be frozen and thin (~5-10 μm) whole-body slices of the animals will be obtained using the PMV-2550 macro-cryomicrotome. Boron concentration measurements in blood, normal and tumor tissues will be attempted using both alpha-particle and neutron autoradiography. Calibration standards of known boron concentration will be made on-site and will be placed on the film along with the tissue slice. For alpha-particle autoradiography, the tape-mounted slices will be dried and placed on alpha-particle sensitive film and irradiated in the UVAR for alpha-particle radiography.

A pilot study using several slices will be performed to determine the suitability of neutron radiography of boronated tissue slices. The slices will undergo neutron radiography in two ways: 1) conventional neutron radiography with the slices attached to pieces of x-ray film and 2) digital neutron radiography based on placement of slices onto the face of a real-time digital neutron radiography camera. All neutron radiography will be performed using the UVAR radiography beam port. After demonstrating the feasibility of the technique, quantitative information can be obtained by comparing relative image densities with boron standards placed with the tissue slice.

Variables to be measured (for each imaging modality) will be: a) absolute uptake of ^{10}B in the tumor tissue (μg ^{10}B /g tumor), b) ratio of tumor to normal tissue ^{10}B concentration (T/N), and c) ratio of tumor ^{10}B concentration to blood ^{10}B concentration (T/B). The means of each of the four groups will be compared using analysis of variance, and similarly the neutron radiography values will be compared to those obtained using the gold standard alpha-particle radiography.

Neutron capture therapy (NCT) studies

Following a 2-week tumor incubation period, six groups of mice (15 mice/group) will be irradiated in the neutron radiography beam of the UVAR. The groups are as follows:

1) Control group (no irradiation)
2) Neutrons only
3) BPA (30 mg/mouse) and neutrons at room temperature
4) BPA and neutrons with tumor area 6 degrees above normal
5) BPA and neutrons with tumor area 6 degrees below normal
6) BPA and tumor area 6 degrees above normal until maximum ^{10}B concentration, then cooling tumor 6 degrees below normal and irradiating with neutrons.

Following irradiation, the animals will be monitored for adverse reactions. The cutoff time for the experiment will be when the tumor grows to 500 mm^3 at which time the animal will be sacrificed. A morbidity index M(t) outlined in (2) will be used to rank the animals, living or dead at any time t following treatment. The M(t) values for each group will be compared every 10 days using a non-parametric Kruskal-Wallis test (10) until all animals have been sacrificed.

The experiments will be performed at the U.Va. Reactor Facility and the MR-4 building by Drs. Robert Mulder and Matthew Combs. Use of the laboratory animals is dependent upon protocol approval assuring that all experiments will be conducted according to U.Va. and NIH approved guidelines. Implementation of MRI pulse sequence and image analysis software will be performed by Dr. Stuart Berr. Dr. Jack Brenizer will consult with the investigators on the application of neutron radiography as well as on alpha-particle track-etch counting.

c. Expected Results

The proposed study would be the first of many BNCT projects at U.Va. The information gained through this pilot study is expected to aid long-term research funding, clinical trials and ultimately routine treatment.

As regards new scientific data, it is expected that the tumors in the hyperthermic group (15 mice) will take up and retain BPA more readily than the hypothermic and room temperature groups. No research group has yet combined hyperthermia or hypothermia with BNCT. We believe

this to be an interesting and potentially important step in enhancing treatment efficacy by 1) reducing normal tissue damage, 2) potential synergistic effects of hyperthermia and radiation treatment (11) and 3) allowing BNCT to be performed at a larger number of (low-power) research reactors, or a larger number of treatments at the higher power reactors like the UVAR.

Neutron radiography of whole-body slices has been performed recently at the University of Missouri Research Reactor (12), with quantification of gadolinium (another neutron capture element) being performed. However, the use of neutron radiography to determine boron concentration in tissue and body fluids has not yet been established. We are interested in a comparison of conventional alpha-track etch autoradiography with neutron radiography and MRI to determine boron concentration. It is necessary to broaden the current choice of boron analysis methods.

d. Collaborative Relationships

Robert Mulder, Ph.D., (Reactor Director, MANE Assistant Professor) has extensive experience in reactor design, operation and safety, dosimetry, and more recently in the design and implementation of human research protocols. Although his research has been in areas other than BNCT, only now has interest in BNCT risen to levels where consistent funding opportunities can be expected, allowing him to devote more resources into BNCT research. His dosimetry and reactor operations experience will be critical to this project to satisfy safety and regulatory requirements of experiments involving the UVAR and will compliment those of the research associate.

Matthew Combs, Ph.D., (Research Associate, MANE and Radiology) divides his time between medically-related reactor applications and directing the Nuclear Medicine Research Lab in the U.Va.-Siemens Laboratory for Radiological Research under the supervision of David Teates, M.D. (Radiology Professor). Dr. Combs has extensive experience in human and animal protocol design as well as executing such protocols. His interdisciplinary background provides ties between MANE and the Department of Radiology.

Within MANE, a number of faculty are establishing cooperative plans with Professor Mulder for the implementation of the non-medical requirements of BNCT. Roger Rydin, Ph.D. and Albert Reynolds, Ph.D., MANE Professors and MIT graduates, will participate in a beam design project should funding from DOE or other sources become available. George Gillies, Ph.D. (Assistant Professor in MANE and Biomedical Engineering), is a major contributor to the Video Tumor Fighter Project and is currently active in designing a funding search campaign for the BNCT project. Jack Brenizer, Ph.D. (MANE Professor) has extensive background in neutron radiography and health physics, which will be useful to this work. Additionally, there is fertile terrain for graduate student teaching and research in the field of reactor applications.

Stuart Berr, Ph.D. (Director of the Small-Aperture Magnetic Resonance Imaging and Spectroscopy Center, Assistant Professor of Radiology and Biomedical Engineering) will be assisting in the MRI portion of this project. Barbara Croft, Ph.D. (Associate Professor, Radiology) will be consulted for advice on whole-body microtomy, and autoradiography.

e. Potential for Routine BNCT at U.Va.

The UVAR is one of only a few US reactors with sufficient power (hence, neutron beam flux) to be a candidate provider of neutron beams for NCT. It is fortunate to have proximal location to a major medical center, the U.Va. Health Sciences Center. Remote siting of certain US government research reactors has prevented their entry into the clinical treatment phases.

The U.Va. Cancer Center has a rapidly growing reputation for broad-based cancer treatment capability. It is well known that the Gamma Knife is a premier facility which allows application of focused gamma-ray beams to certain medical problems best treated with photons. It is suggested that the addition of a treatment program based on reactor-produced neutron beams for the treatment of maladies not covered by existing facilities might help catapult the U.Va. Cancer Center to Comprehensive Center status.

Application of neutrons to BNCT of malignant acral lentigo melanomas as well as inoperable astrocytomas of the brain appears certain by the favorable reports coming from Japan (13,14). Future applications of neutrons with other suitable isotopes and perhaps the concurrent use of monoclonal antibodies (MoAbs) to deliver these isotopes to a broad range of human tumors holds forth considerable promise for an extension of NCT beyond these initial applications(15,16). The University has a Lymphocyte Culture Center that might well be interested in collaborative effort on a novel front.

f. Future Directions

The present proposal is a "kick off" in a new direction of interdisciplinary research at U.Va. A small pilot research project is necessary in making contributions to the knowledge base of the NCT field. On this first work, more ambitious, long-term and well-financed studies can be engineered.

In addition to the study goals presented in Section 1, the following capabilities will have been established through this work:

1) Local expertise with melanoma inoculations in mice.
2) NCT irradiation techniques and protocols.
3) Perfected boron imaging using either standard or new autoradiography techniques.
4) Established dosimetry techniques and beam characteristic verification.
5) Evaluate cell-lethality criteria.

After successful completion of this project, the following work should be attempted at U.Va.:

1) Additional animal studies involving BNCT of brain tumors.
2) *Invitro* and *invivo* studies to gauge MoAbs (or other boronated compounds) as vehicles to deliver ^{10}B to tumors, including tumors other than astrocytomas and melanomas.
3) Conductance of a funding campaign for:
   a) research study support
   b) capital for construction of filtered neutron beam ports and operating rooms at the UVAR
   c) beam characterization studies
   d) personnel training
   e) regulatory approval and licensing

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C. Hydrogel Bead (HGB) Imaging Project

1. Primary Investigators:

Matthew J. Combs, Ph.D. (Departments of MANE and Radiology)
Keith Chan, Ph.D. (CIBA-GEIGY Corporation)
C. David Teates, M.D. (Department of Radiology)
Robert U. Mulder, Ph.D. (MANE)
Barbara Y. Croft, Ph.D. (Department of Radiology)
Richard W. McCallum, M.D. (Gastroenterology Division)

2. Funding:

CIBA-GEIGY Corporation

3. Applications Pending:

None at this time

4. Project Outline:

We have previously investigated the gastric emptying (GE) of two sizes of hydrogel beads (HGBs), a novel swelling-controlled drug release mechanism developed by CIBA-GEIGY Corporation (HIC # 4835). This work demonstrated the GE characteristics of 0.79 mm and 1.90 mm diameter HGBs delivered in a gelatin capsule in both the fed and fasted states. Transit times were compared with respect to bead size and the state of the stomach at time of administration.

The meal delayed GE of the HGBs by 1-2 hours. There was no significant difference in transit time between 0.79 mm and 1.9 mm diameter HGBs. The HGBs were administered orally together in a single gelatin capsule. It is believed that the gelatin capsule played a dominating role in the GE of the particles, masking any possible differences in GE (1,3). It has been reported previously that a critical diameter exists at 1.4 mm ± 0.3 mm at which particles similar to HGBs empty at the same rate as food (4). Unfortunately, the study of this purported critical diameter (under protocol 4835) was not possible due to the influence of the gelatin capsule on emptying of HGBs from the stomach.

Likewise, under the previous protocol information regarding the GE of the two sizes of HGBs with respect to solid food was not obtained, since the study sought to compare the simultaneous transit of two sizes of HGBs which prevented the labeling of a solid meal for comparison.

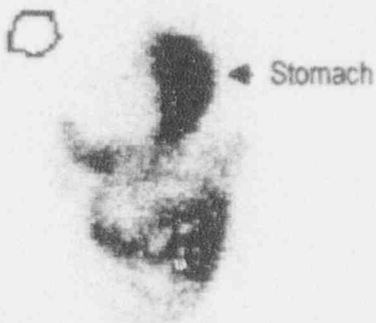
It is conjectured that radiolabeled HGBs would act as an easy to use total GI transit marker suitable for widespread use and standardization. Previous results indicate suitability of HGBs as a small intestinal and colonic transit marker. This new study will determine the rate of HGB GE compared to that of solid food. It is hoped that the study results would indicate suitability of

this marker for GE, small intestinal and colonic transit measurements in a single administration, unlike current methods which require different markers for each portion of the gastrointestinal tract.

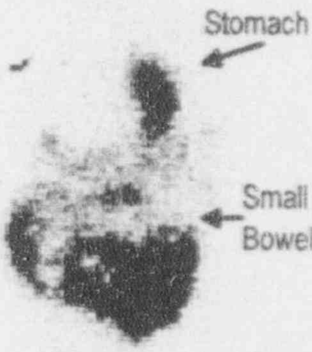
This work is designed to: 1) compare the simultaneous GE of solid food and HGBs and, 2) compare the GE of 0.79 mm and 1.9 mm diameter HGBs. A protocol designed to achieve the above goals has been submitted and approved by the U.Va. Human Investigations Committee (HIC# 4594). The protocol is described below.

Note: A total of three administrations of radioactive material and subsequent imaging will be performed. The two HGB administrations will be separated by no more than two weeks. The other administration (GI outline procedure) will be performed prior to the first HGB imaging session.

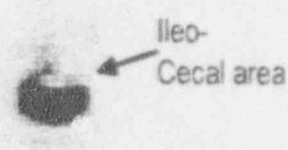
Gastrointestinal outline procedure: The subject will be asked to drink an 8 oz. cup of water labeled with 900 μCi Tc-99m DTPA. Images of the abdomen will be acquired intermittently with the subject in the supine position until the colon is fully visualized to provide definition of the subject's GI anatomy and act as a training session. A representative set of images are shown below.



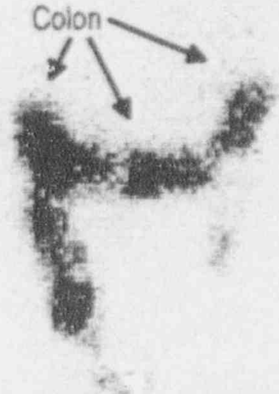
15 min Post-Tc-DTPA Administration



60 min Post- Tc-DTPA Administration



90 minutes Post Tc-DTPA Adminisrtation



110 minutes Post- Tc-DTPA Administration

a. Hydrogel bead procedure:

1) *Hydrogel bead preparation:* CIBA-GEIGY will provide U.Va. with 0.79 mm dia. and 1.9 mm HGBs containing 2% by weight of Er-170 oxide (Er_2O_3). Approximately 0.5 g HGB of one size will be irradiated in the thermal neutron irradiation facility of the University of Virginia Reactor (UVAR) to provide an activity of no more than 150 μCi Er-171 at time of administration to the subject. One administration will use 0.79 mm diameter HGBs, and the other will use 1.9 mm diameter HGBs.

2) *Test meal preparation:* Following an overnight fast, the subject will consume 2 scrambled eggs, one piece of white toast, two strips of bacon, one cup of milk, one cup of orange juice and 100 ml water. Nine hundred (900) μCi Tc-99m sulfur colloid will be mixed in with the eggs during preparation. The Tc-99m will be used to identify transit of eggs relative to HGB since the camera can discriminate between the high energy (300 keV) Er-171 and lower energy Tc-99m (140 keV) and simultaneously acquire images of both eggs and HGBs. The radioactive materials are followed through the stomach and small bowel until 90% of the activity is in the colon.

This information will be used to better understand GI physiology, in examining further the existence of a critical diameter for emptying of particles from the stomach. This study will also provide medical knowledge regarding the transit times of HGB from the stomach compared with the transit times of food, which will allow for the use of radiolabeled HGBs as a single marker for all GI transit studies. This information will also support the development of an optimal delivery mechanism (mixed in food versus encapsulation) for the beads when used as a drug delivery mechanism.

To date, four subjects have enrolled and been imaged in this protocol, with interesting results. At this time it appears that the meal empties form the stomach more slowly than anticipated (~3 hr versus 90 minutes for 50% emptying). 50% colonic arrival has been about 5 hr. for all volunteers.

A second HGB protocol to compare colonic transit of ^{175}Yb HGBs (<2 mm diameter) with ^{111}In encapsulated in pieces of nasogastric tubing (2 cm long 8 french) will be initiated later in 1993. This protocol will also be funded by CIBA-GEIGY.

These particles have been also been studied at the Medical College of Virginia (MCV). In the studies at MCV, radioactive HGBs (irradiated in the UVAR) are given to normal volunteers along with non-radioactive HGBs containing drugs. The drug release characteristics (examined by blood sampling) are correlated with positional information gathered using scintigraphy of the HGBs. It is anticipated that more of these collaborative studies will be performed.

D. Examination of Other CIBA-GEIGY Drug Delivery Formulations

1. Primary Investigators:

   Matthew J. Combs, Ph.D. (Departments of MANE and Radiology)
   Keith Chan, Ph.D. (CIBA-GEIGY Corporation)
   C. David Teates, M.D. (Department of Radiology)
   Robert U. Mulder, Ph.D. (Department of MANE)
   Barbara Y. Croft, Ph.D. (Departments of Radiology and BME)
   Stuart S. Berr, Ph.D. (Departments of Radiology and BME)
   Thomas A. Spraggins, Ph.D. (Departments of Radiology and BME)

2. Funding:

   CIBA-GEIGY Corporation

3. Applications Pending:

   None at this time

4. Project Outline:

   We are currently working on further radiolabeling and MRI-based techniques for monitoring the biodistribution of oral and transdermal formulations. The ability to monitor new formulations as they travel through the body (with or without the drug of interest), is of great benefit to CIBA-GEIGY. This work is funded by CIBA-GEIGY, who pays for investigator time and expenses. Should the information gained prove interesting, more substantial funding will be given.

E. Femoral Hematoma/Fibrin Glue Project

1. Investigators:

William Spotnitz, M.D. (Department of Surgery)
Suad Ismail, M.D. (Division of Cardiology)
Matthew J. Combs, Ph.D. (Departments of MANE and Radiology)
Craig Goodman (Cardiology and Surgery)
Eric Powers, M.D. (Division of Cardiology)
C. David Teates, M.D. (Department of Radiology)
Barbara Y. Croft, Ph.D. (Department of Radiology)

2. Funding:

USCI Catheter Division of Bard, Inc.

3. Applications Pending:

Virginia Section of the American Heart Association

4. Project Outline:

This project involves the use of fibrin glue (a mixture of human fibrinogen and thrombin) to prevent hematoma formation following cardiac catheterization. The ultimate goal of the project is to allow patients to leave the hospital within 1-3 hours following cardiac catheterization instead of the current 4-12 hour observation period. The fibrin glue is injected just outside the femoral artery at time of catheter withdrawal and will aid in keeping the catheter insertion site closed.

5. Current protocol:

A large dog ($\sim$ 50-70 lbs) is anesthetized and femoral catheter sheaths (8 french) are placed in each leg of the animal. The sheaths are removed after 30 minutes and 8 ml of either fibrin glue or saline is inserted into each femoral puncture area. Pressure is held on each leg for 20 minutes, with occasional additional pressure until bleeding has stopped. Both legs receive pressure for the same period of time.

The animal is then transported to the NMRL and injected with $\sim$20 mCi ^{99m}Tc-labeled erythrocytes. The animal is imaged in the supine position to ensure the femoral arteries are stable (no bleeding), as Figure 1A shows.

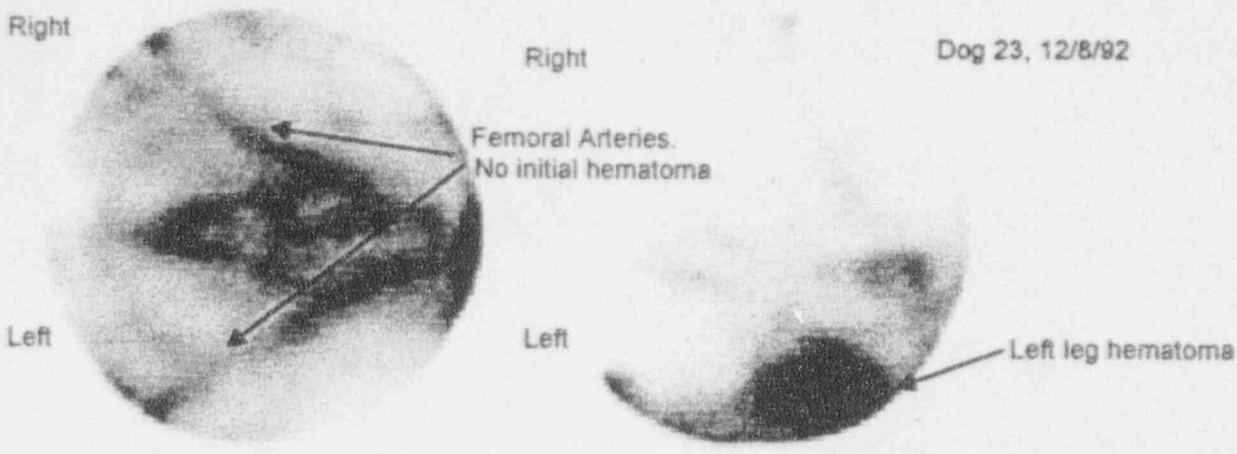


Figure 1A. 5 min Post-injection of 17 mCi ^{99m}Tc-PYP

Figure 1B. 16 hr Post-injection of 17 mCi ^{99m}Tc-PYP. Pronounced left leg hematoma.

The dog is then allowed to wake up on its own and returned to the vivarium. The animal is imaged the following morning, looking for the appearance of a hematoma, as indicated by Figure 1B. The trained observer (M. Combs) is blinded with regards to the leg containing fibrin glue. Currently this is a qualitative estimate of hematoma volume (no bleeding, light bleeding, heavy bleeding) due to the varying ^{99m}Tc blood pool concentration, although improvements to allow for quantitative hematoma volume are currently being investigated.

The current protocol has shown that fibrin glue helps prevent hematoma formation. In eleven animals, no hematomas were detected on the fibrin glue side, while bleeding was observed on the control side in 7 of eleven animals. A comparison of lcontrol versus fibrin glue bleeding resulted was statistically significant at the 0.01 level using McNemar's test. The results are currently being prepared for publication.

The project is currently on hold while USCI develops a catheter more suited for fibrin glue administration. We believe this specially designed catheter will provide more effective delivery of fibrin glue, and should improve results.

There will likely be many phases of this project, since it could be of great commercial benefit to USCI. Some of the related projects include iodinating the fibrin glue and tracking its path either by scintigraphy or autoradiography after injection. Traditional grant support is also being sought for this project.

F. Canine Gastric Emptying Project

1. Primary Investigators:

Bruce Schirmer, M.D. (Department of Surgery)
Robert Schmieg, M.D. (Department of Surgery)
Matthew Combs, Ph.D. (Departments of MANE and Radiology)

2. Funding:

U.S. Surgical Corporation, Department of Surgery

3. Applications Pending:

National Institutes of Health

4. Project Outline:

The causes of postoperative ilieus and whether laparoscopic surgery prevents ilieus from occurring are being investigated by Dr. Schirmer.

5. Current Protocol:

Female dogs undergo cholecystectomy and electrode implantation in the stomach, small bowel and colon using laparoscopic techniques. The cholecystectomy simulates a typical laparoscopic operation. Twenty-four hours after surgery, a gastric emptying test is performed on the unanesthetized animal using 30 g chicken livers labeled with 2 mCi ^{99m}Tc-sulfur colloid. The radiolabeled livers are given in a beef stew meal. The animal is imaged in the left lateral and 30 degree left posterior oblique views with the animal in a Pavlov sling. One minute images are acquired every 10 minutes for a total of 2 hours. Percent solids retained by the stomach are obtained from the images and retention curves generated. A baseline study is performed 3 weeks to 2 months following surgery.

Studies on five animals have been performed so far, with great success. Postoperative tests have been performed on four more animals, with baseline studies to be performed in early 1993. Dr. Schirmer recently submitted an NIH renewal application which calls for studies on at least 20 more dogs. This area of research is very promising, with many possibilities to study prokinetic agents as well as other drugs and their effect on GI motility.

G. ^{99m}Tc-Nimodipine Project

1. Primary Investigators:

Biray Caner, M.D. (Department of Radiology)
Jayashree Parekh, M.D. (Department of Radiology)
Matthew Combs, Ph.D. (Departments of MANE and Radiology)
C. David Teates, M.D. (Radiology)
Barbara Y. Croft, Ph.D. (Radiology)

2. Funding:

Society of Nuclear Medicine Pilot Research Grant

3. Applications Pending:

None at this time

4. Project Outline:

Nimodipine (NM), a calcium antagonist with cerebral selectivity, has an antispasmodic effect that has been demonstrated in-vitro and in-vivo. Previous studies have demonstrated the efficiency of nimodipine in preventing the occurrence of spasm or its consequence; the delayed ischemic syndrome. Nimodipine powder has been donated to our lab by Bayer AG (Miles Pharmaceuticals in the U.S.).

The goals for this project are:

1. Determine if the stability of ^{99m}Tc-NM is equal or better than existing brain imaging agents.
2. Determine if the fraction of ^{99m}Tc-NM which accumulates within the brain will be higher than that of existing brain radiopharmaceuticals.

The two goals are being studied by performing biodistribution studies using scintigraphy, blood sampling and whole-body autoradiography.

H. ^{99m}Tc-Sestamibi (cardiolite) Biodistribution Project

1. Investigators:

Jayashree Parekh, M.D. (Department of Radiology)
Matthew J. Combs, Ph.D. (Departments of MANE and Radiology)
Biray Caner, M.D. (Department of Radiology)
Barbara Y. Croft, Ph.D. (Radiology)
C. David Teates, M.D. (Radiology)

2. Funding:

The DuPont-Merck Pharmaceutical Company
Radiology internal funds

3. Applications Pending:

None at this time

4. Project Outline:

A new myocardial perfusion imaging agent, ^{99m}Tc-hexaxis 2-methoxyisobutyl isonitrile (^{99m}Tc-sestamibi or trade name Cardiolite) is currently being used in many laboratories world-wide. The radiation absorbed dose estimates for this compound have been based on human organ uptake curves generated by Anger camera imaging. Intra- and inter-organ uptake of radiotracers cannot be adequately performed with an Anger camera due to its relatively poor spatial resolution.

To accurately assess the biodistribution of this radiotracer (and ultimately other radiopharmaceuticals), two 250 g rats will be sacrificed at each of the following time points after injection of 30 mCi ^{99m}Tc-sestamibi: 15, 30, 60, 90, 120 and 180 minutes. Immediately after euthanasia, each rat will be embedded and frozen in a carboxy-methyl cellulose medium. The animal will then be sliced using a PMV-2250 macro-cryo-microtome. Whole-body autoradiographs will be obtained from the slices. The autoradiographs will be digitized and quantitative uptake information will be obtained by densitometry comparison using known standards. The uptake information will then be used to calculate radiation absorbed dose estimates for comparison with existing values.

This project is the first of potentially many studies of this nature, investigating the biodistribution of new and existing radiopharmaceuticals. We are fortunate to have a whole-body microtome, and the NMRL is cultivating a rapport with radiopharmaceutical manufacturers that will hopefully lead to more substantial projects.

I. Radiolabeling of Carboplatin (Paraplatin)

1. Investigators:

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2. Funding:

Bristol-Myers Squibb, Radiology internal funds

3. Applications Pending:

None at this time

4. Project Outline:

The goal of this project is to monitor the biodistribution of carboplatin (trade name Paraplatin), a chemotherapy agent. The compound will be radiolabeled, injected arterially, and then imaged using Anger camera scintigraphy.

The most convenient method of radiolabeling the compound is that of neutron activation. There are several isotopes of platinum that will capture a thermal neutron, thereby transmuting into an isotope of platinum with mass number increased by 1 (i.e. Pt-196 (n,g) Pt-197). Several of the isotopes produced are radioactive and suitable for imaging with standard nuclear medicine instrumentation, allowing for activation, then injection and *invivo* imaging of Paraplatin. The overall outline of this project is as follows:

1. Irradiate Paraplatin (powder form) in the University of Virginia Reactor (UVAR) to verify calculations. Neutron activation analysis (NAA) will be performed using gamma-ray spectroscopy equipment to determine other activation products, if any.

2. Analyze the irradiated compound to determine any chemical changes.

3. If the radiopharmaceutical is stable and has suitable radiological characteristics, perform animal then human imaging trials using radioactivated Paraplatin.

Dr. Terry Dugan of Bristol-Myers Squibb was contacted regarding the labeling of carboplatin (trade name Paraplatin) and offered to supply the pharmaceutical for irradiation. The material will be irradiated as soon as it arrives.

Dr. Walter Wolf has labeled a similar substance called Cisplatin by irradiating a target of Pt-194 and then making the Cisplatin using the irradiated platinum (*Cancer Research* 49, 1877-1881, 1989). Although different than our proposal, this finding is encouraging, and we will be able to learn from Dr. Wolf's experience.

After the initial irradiation it will be determined if sufficient Pt-197 will be produced. If so, further support will be requested from Bristol-Myers Squibb. If the radiolabeling can be performed adequately, this project should be of great interest to the manufacturer, providing valuable information regarding the biodistribution of carboplatin, and aiding in more effective delivery of this and other therapeutic agents.