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PARTICIPATION IN THE U.S. DEPARTMENT OF ENERGY REACTOR SHARING PROGRAM

Submitted to:

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SECTION II

PROGRESS REPORTS

FINAL PROGRESS REPORT
Oct. 1, 1995 - Sep. 30, 1996

and

INTERIM PROGRESS REPORT
Oct. 1, 1996 - Mar. 1, 1997

A. INTRODUCTION

The University of Virginia Reactor Facility is an integral part of the Department of Mechanical, Aerospace and Nuclear Engineering. As such, it is effectively used to support educational programs in engineering and science at the University of Virginia as well as those at other area colleges and universities. The expansion of support to educational programs in the mid-east region is a major objective.

B. SUMMARY OF OBJECTIVES AND UVA'S PARTICIPATION IN DOE'S REACTOR SHARING PROGRAM

The objective of the DOE supported Reactor Sharing Program is to increase the availability of university nuclear reactor facilities to non-reactor-owning educational institutions. The educational and research programs of these user institutions is enhanced by the use of the nuclear facilities.

Several methods have been used by the UVA Reactor Facility to achieve this objective. First, many college and secondary school groups toured the Reactor Facility and viewed the UVAR reactor and associated experimental facilities. Second, advanced undergraduate and graduate classes from area colleges and universities visited the facility to perform experiments in nuclear engineering and physics which would not be possible at the user institution. Third, irradiation and analysis services at the Facility have been made available for research by faculty and students from user institutions. Fourth, some institutions have received activated material from UVA for use at their institutions. These areas are discussed below.

B.1. TOURS BY COLLEGES AND PRIMARY/SECONDARY SCHOOLS

By far the most popular activity offered under the Reactor Sharing Program at UVA are tours of the reactor facility and associated laboratories. Many groups, either because of a lack of available time or a lack of the necessary background, do not desire to perform experiments but are most interested in a one to two hour tour. Much useful information can be conveyed during this time period and for many students this may be their only exposure to the research uses of nuclear fission.

B.2. STUDENT PARTICIPATION IN EXPERIMENTS

A part of the Reactor Sharing Program involves groups of students visiting the Reactor Facility as part of a tour and performing experiments involving the reactor or the use of radioisotopes. Over 1000 students have participated in these activities. A summary of all the colleges and universities that have participated in tours and laboratories as part of the Reactor Sharing Program is provided in Table 4.

The most common experiments fall into three general areas. These are: Radiation and Radioactive Decay; Radioisotope Applications in Science and Industry; and Reactor Operations. A brief description of several of the available experiments is provided in Table 5. In addition, special experiments can be arranged to meet the needs of classes in biology, chemistry, physics, and other disciplines.

The use of neutron activation analysis for identification of the elemental composition of materials continues to be the most popular experiment. This is a result of the wide application of neutron activation analysis for research in many areas of science. In addition to learning how to use neutron activation analysis, the students also increase their understanding of radioactive decay and interaction of radiation with matter.

The second most requested experiment involves measurements of the decay of radioactive isotopes. The half-life of various short-lived reactor produced isotopes, such as aluminum-28 and magnesium-27, can be determined. Also, the decay of one isotope into another radioactive isotope is measured, to demonstrate the concept of decay chains.

The University of Virginia supplies background information to the course instructors who use the material to prepare the students for a visit to the Reactor Facility. Once at the Reactor Facility, the students perform experiments under the direction of a reactor staff member or a faculty member.

Most faculty members and students participating in these experiments have stated that they were an important addition to their classes. The positive impact of these experiments is also indicated by the number of classes making repeat visits. Table 2 gives a listing of participants in the program for 1995-1996 and Table 3 shows those groups that have participated thus far this contract year. Letters of appreciation from many participating institutions are included in the Appendix.

B.3. ACADEMIC RESEARCH PROJECTS CONDUCTED AT UVA

Another objective of the Reactor Sharing Program is to offer the UVAR nuclear reactor and counting facilities for general use in research projects. For example, some experiments are being performed to determine the effects of radiation on materials. However, the major use is in the area of neutron activation analysis (NAA).

Neutron activation analysis is a method of determining the elemental composition of a sample by placing it in the neutron flux of a nuclear research reactor. The neutrons interact with elements in the sample, transforming a small fraction of these into radioactive isotopes. The quantity of isotopes produced is governed by the amount of each element present in the sample, the level of the neutron flux, and the irradiation time.

Once produced, each radioisotope emits characteristic gamma-rays, by which the elements in the sample can be identified. When the sample is "counted", using sensitive solid state radiation detectors, the amount of each radioactive element present can be determined precisely.

At the University of Virginia we are currently able to analyze samples for over 50 different elements. This analysis is expedited by the use of dedicated computers which calculate the elemental composition directly from the gamma-ray spectra, sample mass and irradiation conditions.

Over the last eighteen years, many professors and students from various universities have carried out research projects utilizing the Reactor Facility. In most cases, the experimenters are not familiar with activation analysis techniques and depend on the reactor staff for advice on sample preparation, NAA procedures, data reduction and analysis. In a number of instances samples are supplied to the staff by the experimenters in bulk form.

Starting from this, the entire analysis procedure is done by one or more staff members. The results returned to the experimenters state the elemental concentrations found in the supplied samples.

In the current and previous contract years, several university-level students and/or faculty members completed projects utilizing reactor facility services. These projects are listed below in Table 1.

B.4. IRRADIATION SERVICES OFFERED TO USER INSTITUTIONS

Commonly, researchers from outside institutions request that their materials be irradiated at UVA, either with neutrons or gamma-rays. These materials are then shipped to their institutions for analysis or use. Materials activated with neutrons are either analyzed on gamma-ray spectrographic equipment or the emitted radiation used in various experiments. The UVA cobalt-60 gamma-ray irradiation facilities can be used for sterilization, inducing mutation of biological materials, or to study the effect of high doses of radiation, which can result in changes in electronic component characteristics and the cross-linking of polymers. Gamma-ray irradiation of seeds, for investigation of radiation-induced genetic mutations, continues to be a popular high school science activity. Those recently using these services are listed in Table 1.

C. FINANCIAL REPORT

As noted in the most recent proposal, the charges for services provided under the Reactor Sharing Program were based on the number of hours of reactor operation required, at the established use charge of $100.00 per hour of exclusive use. Other facility charges include those for use of irradiation facilities and counting equipment.

There were no direct charges for reactor services, from October 1994 through September 1995. Personnel charges covering the time of the research scientist responsible for conducting the program totaled $6,345.29. The charges were made against the program account for reports and mailings. The total charged against the Reactor Sharing account for services rendered during the 1994-95 contract year was $6,345.29.

Thus far in the 1995-96 contract year $3,500.37 has been spent on personnel charges and $1,115.00 has been utilized to complete research projects for a total to date of $4,615.37.

TABLE 1

SUMMARY OF REACTOR SHARING PARTICIPATION BY RESEARCHERS AND EXPERIMENTERS October 1, 1995 to March 1, 1997

Date	Participating Institution	Researcher	Grade Level	Description	Direct Cost
1995-96	Rutgers University Environmental Sciences	I. Wojentko	Grad. student	Gamma-ray irradiation of soil for sterilization. (many samples)	0.00
1995-96	Rutgers University Chemical Engineering	D. Berler	Grad. student	Gamma-ray irradiation of soil for sterilization. (many samples)	0.00
Feb. 96	Washington & Lee U. Geology	S. Kozak	Faculty	Neutron activation analysis of 30 rock samples	705.00
Feb. 96	Albemarle High School Science	P. Adair	H.S. student	Neutron activation analysis of environmental water samples.	330.00
Apr. 96	Longwood College	T. Flowers	College student	Gamma-ray irradiation of polymer solutions	0.00
Apr. 96	Longwood College	B. Bates	Faculty	Neutron activation analysis of lead shot from archeological site.	80.00
Sep. 96	Va. Math and Science Center	M. Hobbs	Staff	Gamma-ray irradiation of squash seeds	0.00
Nov. 96	Oakton High School	K. Davis	H.S. student	Gamma-ray irradiation of seeds	0.00
Feb. 97	Honaker High School	K. Stilwell	H.S. teacher	Gamma-ray irradiation of seeds	0.00
TOTAL					$1,115.00

Additional projects may be started if we are approached and asked for assistance. It is important to note that the sole funding received for these outreach services by the University of Virginia comes from the DOE Reactor Sharing Program. Thus, the continuation of these projects would be affected if Reactor Sharing funds were not available to cover the cost of the support.

TABLE 2

SUMMARY OF REACTOR SHARING PARTICIPATION
October 1, 1995 to September 30, 1996

University	: Univ. of Virginia	Location	: Charlottesville, Virginia
Program Director	: Dr. Robert Mulder	Telephone No.	: (804) 982-5440
Grant Number	: DE-FG05-92ER75813	Reactor Type	: 2 MW Pool Reactor (UVAR)

Date	Participating Institution	Instructor	Grade	Student/ Teachers	Program Description	Direct Cost
	COLLEGES					
12/01/95	Va. Commonwealth Univ.	Steve Herr	UGS	7 / 1	Facility tour	0.00
02/16/96	Piedmont Va. Comm. College	John Miller	UGS	2 / 1	Facility tour	0.00
02/26/96	James Madison University	Dan Downey	UGS	13 / 1	Facility tour, laboratory	130.00
03/29/96	PVCC student, Frances Rees	-----	UGS	1 / 0	Facility tour	0.00
03/06/96	Piedmont Va. Comm. College	Ray Bratton	UGS	3 / 1	Facility tour	0.00
Apr. 96	Piedmont Va. Comm. College	-----	UGS	3 / 0	Tour, NAA Lab. (3 visits)	44.58
06/20/96	Research Experiences for Und.	John Gordon	UGS	13 / 1	Facility tour	0.00
07/11/96	Research Experiences for Und.	Jim Demas	UGS	10 / 1	Facility tour	0.00
		SUBTOTAL		52 / 6		$174.58
	PRIMARY/SECONDARY SCHOOLS					
10/05/95	Blue Ridge School	. Dunphy	PCS	37 / 3	Facility tour	0.00
11/08/95	Cape Henry Collegiate School	A. Datesman	PCS	8 / 1	Facility tour	0.00
12/01/95	St. Anne's - Belfield	Elizabeth Kutchai	PCS	13 / 2	Facility tour	0.00
12/14/95	St. Anne's - Belfield	Elizabeth Kutchai	PCS	14 / 2	Facility tour	0.00
01/23/96	St. Anne's - Belfield	M.V. Liew	PCS	32 / 2	Facility tour (2 groups)	0.00
01/24/96	St. Anne's - Belfield	Elizabeth Kutchai	PCS	12 / 1	Facility tour	0.00
02/21/96	St. Catherine's	Nancy Habenicht	PCS	18 / 1	Facility tour, laboratory	0.00
02/28/96	Tandem School	Peter Clark	PCS	23 / 1	Facility tour	0.00
03/01/96	Albemarle High School	Dave Ridenour	PCS	13 / 1	Facility tour, laboratory	25.00
03/06/96	Jack Jouett Middle School	Carla Myrtle	PCS	22 / 1	Facility tour	0.00
03/08/96	St. Paul's High School	Terry Vencil	PCS	11 / 1	Facility tour	0.00
03/25/96	Albemarle High School	Dave Ridenour	PCS	14 / 1	Facility tour, laboratory	0.00
03/30/96	Chatham Hall	Molly Thomas	PCS	8 / 1	Facility tour	0.00
05/08/96	Gretna High School	Wayne Robertson	PCS	44 / 2	Facility tour	0.00
05/09/96	Albemarle High School	Dave Ridenour	PCS	13 / 1	Laboratory	160.00
05/17/96	Fork Union Military Academy	Chris Nothnagle	PCS	7 / 1	Facility tour	0.00
05/22/96	Woodberry Forest	Paul Vickers	PCS	7 / 1	Facility tour	0.00
05/24/96	Shen. Valley Governor's Sch.	Thomas O'Neill	PCS	8 / 2	Facility tour	0.00
07/09/96	MITE Program	Ros Hobson	PCS	12 / 0	Facility tour	0.00
07/10/96	MITE Program	Ros Hobson	PCS	12 / 0	Facility tour	0.00
07/10/96	SHARP Program	Rhea Miles	PCS	23 / 1	Facility tour	0.00
07/18/96	RAPME Program	Iris Darby	PCS	29 / 1	Facility tour	0.00
		SUBTOTAL		380 /27		$185.00

SUMMARY	Groups	Students	Teachers
Faculty (F):	0	0	0
Graduate students (GS):	0	0	0
Undergraduate students (UGS):	10	52	6
Pre-college students (PCS):	23	380	27
Total:	33	432	33

TABLE 3

SUMMARY OF REACTOR SHARING PARTICIPATION
October 1, 1995 to April 30, 1996

University	: Univ. of Virginia	Location	: Charlottesville, Virginia
Program Director	: Dr. Robert Mulder	Telephone No.	: (804) 982-5440
Grant Number	: DE-FG05-92ER75813	Reactor Type	: 2 MW Pool Reactor (UVAR)

Date	Participating Institution	Instructor	Direct Grade	Student/ Teachers	Program Description	Cost
	COLLEGES					
1995	Rutgers University	Dan Berler	GS	1 / 0	Gamma irradiation of soil (many)	0.00
1995	Rutgers University	Isabela Wojenko	GS	1 / 0	Gamma irradiation of soil (many)	0.00
12/01/95	Va. Commonwealth Univ.	Steve Herr	UGS	7 / 1	Facility tour	0.00
02/16/96	Piedmont Va. Comm. College	John Miller	UGS	2 / 1	Facility tour	0.00
02/26/96	James Madison University	Dan Downey	UGS	13 / 1	Facility tour, laboratory	0.00
03/29/96	PVCC student, Frances Rees	—	UGS	1 / 0	Facility tour	0.00
03/06/96	Piedmont Va. Comm. College	Ray Bratton	UGS	3 / 1	Facility tour	0.00
Apr. 96	Piedmont Va. Comm. College	—	UGS	3 / 0	Tour, NAA Lab. (3 visits)	0.00
		SUBTOTAL		31 / 4		0.00
	PRIMARY/SECONDARY SCHOOLS					
10/05/95	Blue Ridge School	. Dunphy	PCS	37 / 3	Facility tour	0.00
11/08/95	Cape Henry Collegiate School	A. Dunsmun	PCS	8 / 1	Facility tour	0.00
12/01/95	St. Anne's - Belfield	Elizabeth Kutchai	PCS	13 / 2	Facility tour	0.00
12/14/95	St. Anne's - Belfield	Elizabeth Kutchai	PCS	14 / 2	Facility tour	0.00
01/23/96	St. Anne's - Belfield	M.V. Liew	PCS	32 / 2	Facility tour (2 groups)	0.00
01/24/96	St. Anne's - Belfield	Elizabeth Kutchai	PCS	12 / 1	Facility tour	0.00
02/21/96	St. Catherine's	Nancy Habenicht	PCS	18 / 1	Facility tour, laboratory	0.00
02/28/96	Tandem School	Peter Clark	PCS	23 / 1	Facility tour	0.00
03/01/96	Albemarle High School	Dave Ridenour	PCS	13 / 1	Facility tour	0.00
03/06/96	Jack Jouett Elementary School	Carla Myrtle	PCS	22 / 1	Facility tour	0.00
03/08/96	St. Paul's High School	Terry Vencil	PCS	11 / 1	Facility tour	0.00
03/25/96	Albemarle High School	Dave Ridenour	PCS	14 / 1	Facility tour, laboratory	0.00
03/30/96	Chatham Hall	Molly Thomas	PCS	8 / 1	Facility tour	0.00
03/22/95	St. Catherine's	Nancy Habenicht	PCS	20 / 1	Facility tour, laboratory	0.00
		SUBTOTAL		245 / 19		0.00

SUMMARY	Groups	Students	Teachers
Faculty	0	0	0
Graduate students (GS):	0	2	0
Undergraduate students (UGS):	6	29	4
Pre-college students (PCS):	15	245	19
Total:	21	276	23

TABLE 4
Summary of Participation in Laboratories, Projects and Tours Under the Auspices of the Reactor Sharing Program (September 1978 - March 1997)

University or College	This year	Discipline	Number of Interactions	Faculty Contact
Bridgewater College		Chemistry	1	J. Martin
		Physics	2	D. Neher
		Physics	1	P. Spickler
		Physics	4	J. Ulrich
Emory & Henry College		Physics	1	C. Nelson
George Mason University		Physics	2	Physics club
Hampton University		Physics	1	K. Han
James Madison University		Physics	9	J. Gordon
		Physics	1	R. Serway
		Nuclear Chemistry	7	D. Downey
		Biology	3	M. Gordon
J.S. Reynolds Comm. College		Chemistry	1	J. Martin
Longwood College		Physics	2	L. Fawcett
		Education	1	L. Banton
	*	Archaeology	1	B. Bates
Lynchburg College	*	Chemistry	19	N. Summerlin
Mary Washington College		Physics	7	R. Atalay
		Physics	1	G. King
Piedmont Va. Comm. College	*	Chemistry	30	R. Bratton
		Physics	1	J. Wallpole
		Physics	4	T. Lowe
Randolph Macon College		Physics	1	W. Temple
Randolph Macon Women's College		Physics	2	B. Mattson
Roanoke College		Physics	1	W. Baldridge
		Physics	1	J. Adams
Rutgers University		Chem. Engr.	1	D. Berler
Rutgers University		Civil & Environmental Engr.	1	I. Wojentko
Shepherd College		Chemistry	1	W. Crum
S.W. Va. Community College		Chemistry	2	R. Epling
Sweetbriar College		Chemistry	8	H. Gager
University of Richmond		Physics	1	W. Major
		Physics	1	M. Vineyard
University of Houston		Civil & Envir. Engr.	1	S. Garg
Virginia Commonwealth Univ.		Physics	2	S. Herr
		Chemistry	2	K. Goins
Virginia Military Institute		Chemistry	2	R. Minnix
		Chemistry	5	H. Schreiber
		Physics	2	P. Peters
		Psychology	1	D. Foster
Virginia Polytechnic Institute		Physics	14	T. Parkinson
		Env.&Haz.Mat.	1	D. Orvos
Washington & Lee	*	Geology	1	S. Kozak
College of William & Mary		Marine Science	3	J. Warinner

Notes to Table 4:

* These institutions and faculty members participated in the Reactor Sharing Program during the current and/or previous contract year.

Additionally, numerous high school groups have toured the facility and some of these have also participated in laboratory exercises. In the 1995-96 contract year, 465 primary and secondary school students and their teachers visited the reactor.

TABLE 5

EXPERIMENTS PERFORMED FOR THE UNIVERSITY OF VIRGINIA REACTOR SHARING PROGRAM

A. RADIATION AND RADIOACTIVE DECAY OF ISOTOPES

1. Radiation Counting Statistics

Demonstration of the random nature of radioactive disintegrations at both low and high disintegration rates. Using a multi-scaler, series of counts are taken which, respectively, approach a Poisson distribution and a Gaussian distribution.

2. Radioisotope Decay and Half-Life Determination

Demonstration of radioactive decay and determination of reactor produced, short-lived isotope half-life, using a multi-scaler. More complex decay chains may also be demonstrated, such as decay of two isotopes with differing half-lives or decay of two isotopes, one of which is transformed by decay to the other.

3. Types of Radiation

Characterization of different types of radiation including determination of alpha- and beta-particle energy spectra, using silicon surface barrier devices, and gamma-ray spectra, using either a sodium-iodide scintillator or a germanium detector. Effectiveness of shielding materials for the various radiation types may also be demonstrated.

4. Radiation Intensity and Shielding

Demonstration of the decrease in radiation intensity as a function of the inverse square of distance from the radiation source. Determination of source activity from measured dose rates and radiation energy. Effectiveness of radiation shields may also be included.

B. RADIOISOTOPE APPLICATIONS IN SCIENCE AND INDUSTRY

1. Neutron Activation Analysis

Demonstration of trace element analysis using neutron activation analysis. A sample is activated in the UVAR and its constituents determined from the nature of its radioactive decay. Activation analysis of a coin, lipstick, hair, environmental samples, or other samples may be performed.

2. X-Ray Fluorescence Analysis

Demonstration of the chemical analysis of thin samples using an Am-241 x-ray exciter source and a germanium-lithium low-energy photon spectrometer. The x-ray spectrum measured from the material is used to determine the chemical composition of the surface.

TABLE 5 (continued)

3. Industrial Applications of Radioisotopes

Demonstration of the use of radioisotopes in industrial applications, such as thickness gauging, liquid level sensing and flow detection. Beta, gamma and neutron sources are used.

C. REACTOR EXPERIMENTS

1. Approach to Critical

Demonstration of the subcritical multiplication of neutrons until a self-sustaining fission reaction is obtained.

2. Reactor Dynamics and Safety Systems

Demonstration of changes in reactor power resulting from control rod position changes. Calibration of control rods and demonstration of reactor safety systems.

3. Decay Heat Following Reactor Shutdown

Measurement of heat generation from fission and fission product decay following a reactor shutdown. Measurements are read from nuclear instrumentation and calculated from primary system heat balance.