Amarillo National Resource Center for Plutonium
A Higher Education Consortium of The Texas A&M University System, Texas Tech University, and The University of Texas System

DOE/AL/85832--T9

Quarterly Technical Progress Report

February 1, 1996 - April 30, 1996

Submitted By

The Amarillo National Resource Center For Plutonium

600 South Tyler • Suite 800 • Mail Box 12098 • Amarillo, TX 79101 • 806-376-5533 • Fax 806-376-5561

Amarillo National Resource Center for Plutonium
A Higher Education Consortium of The Texas A&M University System, Texas Tech University, and The University of Texas System

Quarterly Technical Progress Report

Date Submitted 5/28/96

Program/Project Identification Number: DE-FC04-AL85832

Program/Project Title: Amarillo National Resource Center for Plutonium

Performer:

Roger Mulder
State of Texas, Office of the Governor
201 East 14th Street, P.O. Box 12428
Austin, Texas 78701

Period Covered: February 1, 1996 to April 30, 1996

FORMAT: The format of this quarterly report, as in previous reports, follows the same order as the five major technical tasks established in the Cooperative Agreement. However, the layout of this quarterly report has been changed to make it a more functional document. There are three main sections, the executive summaries, the detailed reports, and the DOE required forms. They can be found as follows:

- Executive Summaries for Tasks 1-5 (Tabs 1-5)
- Detailed Reports for Tasks 1-5 (Tabs 6-10)
- DOE Required Forms (Binder Pockets)
  - DOE F 4600.3A, Milestone Log
  - DOE F 4600.5, Federal Assistance Management Summary Report
  - DOE F 1430.22, Notice of Energy RD&D Project
  - SF-269, Financial Status Report

It is hoped that this new layout will allow managers to obtain a sense of the research accomplished during the quarter while saving the more detailed descriptions for those who have time to delve into the details. As this new format evolves, the number of milestones for each task will be paired back to a more manageable quantity. Feedback on this layout is requested.

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Technical Director
(806)-376-5533,, email: hartley@pu.org

DOE F 4600.3A
(09-92)

OMB Control No.
1910-0400

U.S. Department of Energy
Milestone Log

OMB Burden Disclosure Statement

Public reporting burden for this collection of information is estimated to average 10 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Office of Information Resources Management, AD-241.2-GTN, Paperwork Reduction Project (1910-0400), U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, DC 20585; and to the Office of Management and Budget (OMB), Paperwork Reduction Project (1910-0400), Washington, DC 20503.

Amarillo National Resource Center for Plutonium
Program/Project Title

Task 1: ID # 1.1 Plutonium Information Resource

Id No	Description	Planned Completion Date	Actual Completion Date	Comments
1.1.2	Electronic Resource Library			
1.1.2.1	Program Coordination - Develop needs assessment and complete a data and operational plan	4/96	4/96	Saffady Report Appendix 2
1.1.2.1	Program Coordination - Compare DOE reading room at Amarillo College to other DOE reading room sites	4/96	2/96	DOE Reading Room Survey, Appendix 3, tab 6
1.1.2.1	Program Coordination - Analyze Linda Hall Library of Science, University of Missouri	4/96	4/96	Linda Hall Library Brief, Appendix 4, tab 6
1.1.2.1	Program Coordination - Analyze Texas Tech Gov't Document Collection	11/96	2/96	Texas Tech Gov't Document Analysis, Appendix 5, tab 6
1.1.2.2	Electronic Database & Links - Collect, scan, index, and in some cases, abstract weapons-material documents. (Minimum of 100 documents at this time)	11/96	5/96	Sandia Laboratory, CA
1.1.2.2	Electronic Database & Links - Establish electronic links for the electronic library to existing electronic databases with information about plutonium	1/97		
1.1.2.2	Electronic Database & Links - Develop document search capabilities	1/97		
1.1.2.2	Electronic Database & Links - Establish use of document search capabilities (on-going as each document is scanned and created, and links are established)	1/97		

U.S. Department of Energy
Milestone Log

Task 2: ID # 1.2 Advisory Function

Id No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.2.1	**Senior Technical Review Group (STRG) - meetings as required**			
1.2.1	Meeting planned in Amarillo to discuss storage and transportation for 5/31/96	5/96		Arrangements complete, OFMD notified
1.2.1	Meeting planned in Atlanta to discuss technical cost and schedule report for 6/24/96	6/96		OFMD notified
1.2.2	**Multi Attribute Analysis**			
1.2.2	Final MAU report phase II complete	12/95	12/95	Paper, tab 7
1.2.2	Final MAU metrics phase III complete	5/96		
1.2.2	Final MAU analysis report phase III complete	7/96		
1.2.3	**State Support**			
1.2.3.1	Pantex Economic Analysis - compile and review material on relative benefits of each candidate site for each storage and disposition option	5/96		
1.2.3.1	Pantex Economic Analysis - conduct analysis of relative benefits of each candidate site for each storage and disposition option	6/96		
1.2.3.1	Pantex Economic Analysis - present findings of relative benefits of each candidate site for each storage and disposition option	6/96		

U.S. Department of Energy
Milestone Log

Task 3: ID #1.3 Environmental, Public Health and Safety

Id No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.3.2	**Perched Aquifer & Tracer Testing, Water Treatment**			
1.3.2	Report on evaluation of the treatment system and plans	3/96	pending	Delayed due to change in scope and time requirement to develop additional information. Report will be submitted third week in May.
1.3.2	Report on treatment of HMX and RDX contamination	3/96	5/1/96	Student completed defense and final editing of thesis in April
1.3.2	Report on sorption of HE on Pantex soils	8/96		
1.3.2	Preliminary report on combined oxidation/bioremediation of HE	8/96		
1.3.2	Report on evaluation of disposal of produced water through Pantex Plant treatment system	8/96		
1.3.2	Report on analysis and evaluation of ground water recirculation tracer test	10/96		
1.3.2.2	Report on modeling of ground water treatment system	12/96		
1.3.2.2	Report on combined oxidation/bioremediation of HE	12/96		
1.3.3	**Bioremediation of Contaminated Soil & Ground Water**			
1.3.3.1	Report on insitu cometabolism of chlorinated solvents	7/96		
1.3.3.1	Progress report on HE sorption and bioregeneration of GAC	10/96		
1.3.3.2	Report on current literature on biodegradation of HMX and RDX including toxicity and fate and transport	3/96		
1.3.3.2	Report on identification of HE-degrading bacteria in soil and water	6/96		
1.3.3.2	Report on degradation of HMX and RDX and intermediates	7/96		
1.3.3.2	Report on kinetics of HMX and RDX degradation	8/96		
1.3.3.3	Report on nutritional requirements of biofilm cultures	7/96		
1.3.3.3	Report on evaluation of the Netherlands method for biofilm generation	12/96		
1.3.3.3	Report on optimal conditions for biofilm degradation	1/97		
1.3.3.3	Report on feasibility of using biofilms to remediate HE contaminated soil and water at Pantex	1/97		
1.3.4	**Vadose Zone Remediation**			
1.3.4.1	Report on air permeability analyses of Pantex soil cores	5/96		
1.3.4.2	Report on single-component adsorption isotherms	5/96		
1.3.4.2	Report on multi-component adsorption isotherms	9/96		
1.3.4.2	Report on GUI interface for SVE system model	12/96		
1.3.4.2	Report on effect of water on VOC adsorption	12/96		
1.3.4.3	Report on the SVE tracer test study design and analysis	1/97		

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Id No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.3.5	**Chromium Remediation**			
1.3.5.1	Report on chromium QA/QC plan and laboratory comparison	3/96	pending	Delayed due to equipment problem at one of the universities. Work now completed and report will be submitted third week in May.
1.3.5.1	Report on Chromium Ion Exchange Characteristics	6/96		
1.3.5.1	Report on Kinetics of Chromium reduction by Ferrous Ion	7/96		
1.3.5.2	Report on Chromium sorption characteristics in Pantex soil	7/96		
1.3.5.2	Report on Reoxidation kinetics of Chromium in presence of aquifer material	10/96		
1.3.5.2	Report on application of ZVM to remediation of Pantex contaminants	1/97		
1.3.6	**Biological Risk Assessment**			
1.3.6	Summary of contaminants of concern, habitat/species matrices, and assessment endpoints for ecological risk assessment	4/96	5/1/96	
1.3.6	Report on sample analysis plan and data acquisition schedule for ecological risk assessment	7/96		
1.3.7	**Agricultural Studies**			
1.3.7.1	Phytoaccumulation of Heavy Metals in Plants			
1.3.7.1	Screen plants for Cr uptake	10/96		Seed collected and planted
1.3.7.1	Presentation		4/22/96	Los Alamos National Lab
1.3.7.1	Evaluate metal speciation data bases	7/96	5/96	Completed
1.3.7.1	Isolate and purify phytosiderophore	11/96		Isolation completed

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Task 4: ID # 1.4 Communication, Education, and Training

Id No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.4.2	**K-16 Science and Mathematics Education**			
1.4.2.2	Final summary report	5/96		Report should be completed by end of May
1.4.2.2	Computer based High School Physics curriculum and Middle School Science Career curriculum developed	9/96		
1.4.2.2.5	Panhandle area Math & Science Teachers Conference conducted	11/96		
1.4.3	**Academic Intervention/Tex PREP** (Texas Prefreshman Engineering Program)			
1.4.3.1	Funding request prepared and sent to potential donors: $125,000 solicited	2/1/96		Ongoing
1.4.3.1	All recruitment materials routed	2/1/96	2/28/96	
1.4.3.1	Applications received and organized	4/15/96	4/15/96	
1.4.3.1	125 participants chosen and confirmed at each of two sites	4/19/96	4/19/96	
1.4.3.1	Instructors and staff hired	5/1/96		
1.4.3.1	Curriculum finalized	5/7/96	Various dates	
1.4.3.1	Field trips and speakers scheduled	6/1/96		
1.4.3.1	PREP >96 completed: (two sites)	7/26/96		Complete delivery of the Tex PREP Program
1.4.3.1	Evaluation and final report complete, Dissemination of reports	9/15/96		Deliver the final report
1.4.4	**Graduate Education**			
1.4.4	Needs assessment report, inventory, and prototype delivery system	9/95	9/95	
1.4.4	Develop plan for future work (road map)	5/96	2/96	
1.4.5	**Communications Program**			
1.4.5.1	Deliver the public information/public outreach plan	5/31/96		
1.4.5.2	Produce Pantex Plant documentary	5/31/96		
1.4.5.2	Produce information video on ANRCP and produce video/television print materials	5/31/96		
1.4.5.3	Produce 3 public service Announcements on behalf of the Center	1/15/97		
1.4.6	**Science Information & Resource Center**			
1.4.6.1	Established a partnership and presence in the Discovery Center 2/96 with a wall display		2/96	
1.4.6.1	Deliver the Strategic SI & RL program plan	1/15/97		Note that a delay in funding delayed deliverables in the task plan but these 3 are good
1.4.6.3	Established a partnership with Mason & Hanger and constructed a transportable exhibit in time for the Pantex Information Fair and Pantex Public Hearing		3/96	
1.4.7	**Plutonium Textbook & Training**			
1.4.7.1	Initiate Pu text	11/96		
1.4.7.1	First Draft of Pu text for review	11/97		
1.4.7.2	Initiate training discussions with Pantex	6/96		
1.4.7.2	Collect, review and evaluate literature	8/96		
1.4.7.2	Develop Pu training program (if needed)	11/96		

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Task 5: ID # 1.5 Plutonium and Other Material Studies

Id No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.5.2	Russian Activities			
1.5.2.1	Accelerator based transmutation - project canceled		4/96	Canceled due to downselect by steering committee
1.5.2.2	Modular High-Temp Gas Cooled Reactors - - project canceled		10/95	Canceled due to downselect by steering committee
1.5.2.3	Evaluation of Fast Reactors - FFTF codes transferred from Hanford		6/96	
1.5.2.4	Support of Russian Joint Studies - Steering meeting in DC May 96		5/96	
1.5.3	Plutonium Storage			
1.5.3.2	Robotics - Write a report documenting Fault Management	1/98		
1.5.3.2	Robotics - Write a report analyzing existing and proposed systems	1/97		
1.5.3.2	Robotics - Document findings on Humans and Automation Integration	12/97		
1.5.3.2	Robotics - Write a final report documenting Interface Design (both subtasks same sequence)	1/98		
1.5.3.2	Robotics - Write a report documenting Domain Analysis	1/98		
1.5.3.2	Robotics - Write a report documenting Generic Manipulator/Gripper design Tools	1/98		
1.5.3.2	Robotics - Write a report documenting Trajectory Planning	1/98		
1.5.3.2	Robotics - Write a report documenting Navigation	1/98		
1.5.3.2	Robotics - Technical report for pilot experiment	1/97		
1.5.3.2	Robotics - Technical report describing detailed methods for synergistic set of 1997 experiments	1/98		
1.5.3.2	Robotics - Technical Report: "Preliminary Standards for Distributed, Networked Tele-robotics System Design to Support Real-time Quantitative Performance and Measurement in Nuclear Environments"	1/98		
1.5.3.2	Robotics - Write a report documenting Simulation and Training	1/97		
1.5.3.3.1	Air Monitoring - Develop optimized chromatography methods	3/97		
1.5.3.3.2	Air Monitoring - complete numerical analysis of particle transport in flow ducts	9/96		
1.5.3.3.3	Air Monitoring - select between steam introduction and impacting on passive packed beads	12/96		
1.5.3.4	Radiation Damage and Microstructural Change - Depth distribution of He-3 using NDP obtained for test samples	8/96		
1.5.3.4	Radiation Damage and Microstructural Change - Changes in surface conditions and microstructure of 316-stainless steel due to implanted He-3 observed for test samples	10/96		
1.5.3.4.	Radiation Damage and Microstructural Change - Depth distributions of lattice disorder produced by He implantation's of Fe determined for test samples	12/96		

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Id No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.5.4	**Plutonium Disposition**			
1.5.4.1	Water Reactor Options - First phase of data collection complete, report written	1/97		
1.5.4.1	Water Reactor Options - Final report on MOXDAR	7/97		
1.5.4.1	Water Reactor Options - Write report documenting Westinghouse results	8/96		
1.5.4.1	Water Reactor Options - Write report documenting ABB-CE results	1/97		
1.5.4.1	Water Reactor Options - Report on potential physical/chemical processes for Pu/GA separation and GA immobilization	1/97		
1.5.4.1	Water Reactor Options - Report on process impact on fuel fabrication and reliability	4/97		
1.5.4.1	Water Reactor Options - Report and recommendation gallium removal/immobilization	2/98		
1.5.4.1	Water Reactor Options - Write report documenting results	4/97		
1.5.4.1	Water Reactor Options - Write report documenting findings about multipurpose reactor	8/97		
1.5.4.1	Water Reactor Options - Report on methodology and results	2/98		
1.5.4.1	Water Reactor Options - Write report on transient calculations	2/98		
1.5.4.1	Water Reactor Options - Full report of results	2/98		
1.5.4.1	Water Reactor Options - Write report documenting chosen methodology for computing discharge isotopic, etc.	2/98		
1.5.4.1	Water Reactor Options - Special session at ANS Annual Meeting	June 1997		
1.5.4.2	Immobilization of Pu into Ceramic Media - A report covering the synthesis of Gd-Ce containing zirconolites will be prepared and submitted	last quarter of fiscal 97		
1.5.4.3	Deep Borehole - A complete report on the role of colloids in radionuclide transport in the geosphere	5/96		
1.5.4.3	Deep Borehole - Results from the computer program for different geologic and well options will be presented in a report	12/97		
1.5.4.4	Can-in-Canister Plutonium Immobilization - report on numerical simulations and results	10/96		
1.5.4.4	Can-in-Canister Plutonium Immobilization - Reports and numerical data will be made available, including an assessment of the importance of each parameter and proposed strategies for optimizing the can-in canister system performance.	1/97		
1.5.4.4	Can-in-Canister Plutonium Immobilization - A report describing the findings will be prepared	1/97		

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Id. No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.5.5	**Cross-Cutting Issues**			
1.5.5.1	Non-destructive Analysis - Write report documenting the LSDTS engineering design	3/97		
1.5.5.1	Non-destructive Analysis - Write report documenting the construction, testing and performance of the newly constructed PP-HV supply	9/97		
1.5.5.1	Non-destructive Analysis - Write a report documenting the construction, testing and performance of the newly constructed LSDTS	1/98		
1.5.5.2.1	Transportation Analysis - Technical report documenting transportation analysis	1/97		
1.5.5.2.1	Transportation Analysis - Technical memoranda documenting transportation analysis	1/97		
1.5.5.2.2	Transportation Analysis - Complete one or more studies of comparative risks associated with different options conceivably arising under hypothetical scenarios of interest	1/97		
1.5.5.2.3	Transportation Analysis - Revised version of fire aerosol evolution code completed	1/98		
1.5.5.2.4	Transportation Analysis - Report on computer implementation of models	1/98		
1.5.6	**Other Material Studies**			
1.5.6.1.1	High Explosives - Establish contract with China Lake	12/96		
1.5.6.1.1	High Explosives - Establish fuel formulation set	3/97		
1.5.6.1.1	High Explosives - First Fuel burn	6/97		
1.5.6.1.1	High Explosives - Report on fuel burn demonstration	12/97		
1.5.6.1.2	High Explosives - Demonstrate 2-D experimental design including recovery and demonstration of diamond product	12/96		
1.5.6.1.2	High Explosives - Demonstrate 3-D experimental design including recovery of work piece	3/97		
1.5.6.1.2	High Explosives - Demonstrate 3-D experimental design including recovery and demonstration of diamond product	6/97		
1.5.6.1.2	High Explosives - Report on explosive compression	12/97		
1.5.6.2	HEU - Operating Experience and Events database on HEU collected		4/96	
1.5.6.2	HEU - vulnerability assessment orientation - April 1996, San Antonio		4/96	
1.5.6.3	MOX Evaluation - Literature review	6/96		
1.5.6.3	MOX Evaluation - database evaluation	8/96		
1.5.6.3	MOX Evaluation - analysis and conclusion	1/97		

Task 6: ID # 1.6 Reporting, Evaluating, Monitoring, and Administering

Id. No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.6	Does not lend itself to Milestones at this time			

(1/93)
Replaces EIA-459E
All Other Editions Are Obsolete

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

OMB Burden Disclosure Statement

1. PROGRAM/PROJECT IDENTIFICATION NUMBER
DE-FC04_95AL85832

2. PROGRAM/PROJECT TITLE
Amarillo National Resource Center for Plutonium

3. REPORTING PERIOD
02/01/96 THRU 04/30/96

4. NAME AND ADDRESS
State of Texas
Office of the Governor
P.O. Box 12428
Austin, Texas 78701

5. PROGRAM/PROJECT START DATE
November 1, 1994

6. PROGRAM/PROJECT COMPLETION DATE
October 31, 1999

7. FY 95-96

8. Quarters

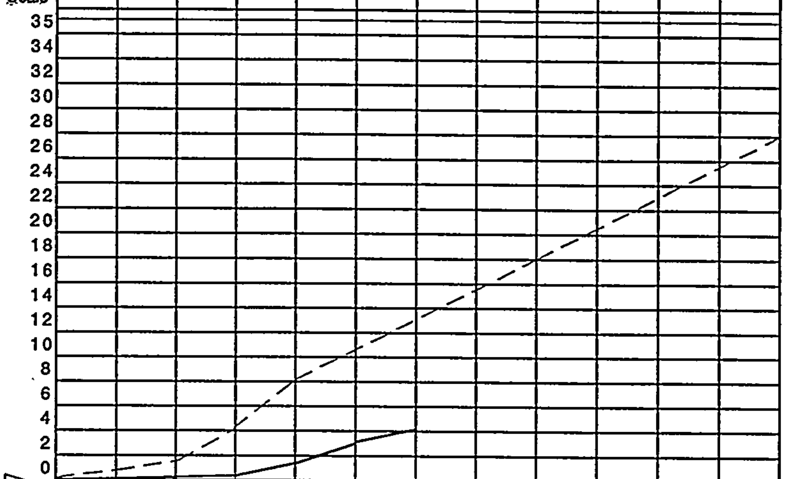
	FY95 1st	FY95 2nd	FY95 3rd	FY95 4th	FY96 1st	FY96 2nd	FY96 3rd	FY96 4th	FY97 1st	FY97 2nd	FY97 3rd	FY97 4th

9. COST STATUS
a. Dollars Expressed in Millions
b. Dollar Scale

10. Cost Chart

Fund Source		Cum Prior Qtrs	Quarter FY95 3rd	FY95 4th	FY96 1st	FY96 2nd	Cum to Date	Tot Plan
DOE	P	0	2,775,000	3,775,000	2,450,000	800,000	9,800,000	9,800,000
	A		713,365	882,587	1,185,464	1,301,918	4,083,334	
Match	P		225,000	225,000	0	40,000	490,000	490,000
	A		35,668	44,129	59,273	65,095	204,165	
	P							
	A							
	P							
	A							
Total	P	0	3,000,000	4,000,000	2,450,000	840,000	10,290,000	10,290,000
Total	A	0	749,033	926,716	1,244,737	1,367,013	4,287,499	
Variance		0	(2,250,967)	(3,073,284)	(1,205,263)	527,013	(6,002,501)	

P=Planned A=Actual



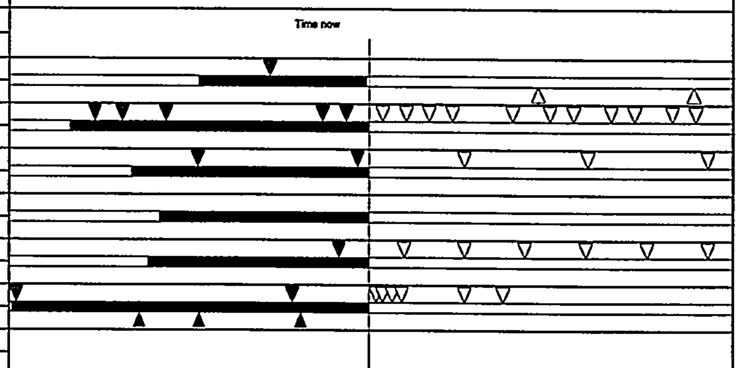
C Cumulative Accrued Costs

	FY95 1st	FY95 2nd	FY95 3rd	FY95 4th	FY96 1st	FY96 2nd	FY96 3rd	FY96 4th	FY97 1st	FY97 2nd	FY97 3rd	FY97 4th
Planned			3,000,000	7,000,000	9,450,000	########						
Actual			713,365	1,595,952	2,781,416	4,083,334						
Variance			########	########	########	########						

Total Planned Costs for Program Project
$51,450,000

11. Major Milestone Status

	Units Planned / Units Complete
Plutonium Information Resource	P / C
Advisory Function	P / C
Environmental, Public Health & Safety	P / C
Communication, Education, and Training	P / C
Plutonium and Other Material Studies	P / C
Reporting, Evaluation, Monitoring, and Administration	P / C
	P / C
	P / C
	P / C
	P / C



12. Remarks: Actual cost reported on this report are only those cost reported to the State of Texas as of April 30, 1996. The milestones are generally those activities managed by the Center Staff, such as the Senior Technical Review Group meetings, Quarterly meetings of the Nuclear Group, Semiannual meetings of the Environmental group, or the hiring of Center staff.

13. Signature of Recipient and Date
04/30/96

14. Signature of U.S. Department of Energy (DOE) Reviewing Representative and Date

DOE 1430-22
All other additions
are obsolete
(Replaces DOE F 538)

U.S. DEPARTMENT OF ENERGY
NOTICE OF ENERGY RD&D PROJECT

1. DOE CONTRACT OR GRANT NUMBER DE-FC04-95AL85832
Cooperative Aggreement
☐ New Contract ☒ Continuation/Revision

2. A. NAME OF PERFORMING ORGANIZATION State of Texas

B. Department or Division Office of the Governor

C. Street Address 201 East 14th Street, PO Box 12428

City AUSTIN State TX Zip 78701

D. Type of Performing Organization (circle only one two-letter code)

CU-College, University, or trade school
EG-Electric or gas utility
FF-Federally funded RD&D centers or laboratory operated for agency of US government
IN-Private industry
NP-Foundation or laboratory not operated for profit
(ST)-Regional, state, or local government facility
TA-Trade or professional organization
US-Federal Agency
XX-Other

3. PRINCIPAL OR SENIOR INVESTIGATOR

A. Last Mulder First Roger MI

B. Phone: Commercial (512) 463-2198 FTS

4. DOE SPONSORING OFFICE OR DIVISION Amarillo Area Office

5. TITLE OF PROJECT
Amarillo National Resource Center for Plutonium

6. DESCRIPTIVE SUMMARY (limit to 200 words)
The objective of this Cooperative Agreement is to demonstrate DOE's interest in protecting the environmental, health, and safety of populations adjacent to its sites and to provide financial assistance to the State of Texas for the development of a National Resource Center for Plutonium to facilitate the exercise of the State's responsibilities to its citizens and the public in general. The Center will be a scientific and technical information resource on issues relating to the storage, disposition, potential utilization and transportation of plutonium, high explosives, and other hazardous materials generated from nuclear weapon dismantlement. The Center will respond to needs for information and interpretation of technical and scientific data raised by interested and concerned citizens, oversight agencies of Federal, State and local governments, elected officials, and site specific advisory groups.

7. RESPONDENT INFORMATION. List name and address of person filling out this form. Give telephone number and extension where person can be reached. Record the date this form was completed or updated. This information will not be published.

Last Watson First David MI K

Address 600 South Tyler Suite 800

City Amarillo State TX ZIP 79101

Phone (806) 376-5533 Date 5/28/96

DOE F 4600.6
(09-92)
Replaces EIA-459F
All Other Editions Are Obsolete

OMB Control No
1910-0400

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE PROGRAM/PROJECT STATUS REPORT

1. Program/Project Identification No.	2. Program/Project Title	3. Reporting Period
DE-EC04-95AL85832	AMARILLO NATIONAL RESOURCE CENTER FOR PLUTONIUM	2/01/96 through 04/30/96

4. Name and Address	5. Program/Project Start Date / 6. Completion Date
Roger Mulder State of Texas, Office of the Governor PO Box 12428, 201 East 14th Street Austin, TX 78711	5. Program/Project Start Date: 11/01/94 6. Completion Date: 10/31/99

7. Approach Changes

To improve financial management, the Center is working with the Consortium Universities and the State of Texas to reduce the process time for invoicing and for payment vouchers.

☐ None

8. Performance Variances, Accomplishments, or Problems

Research proposals submitted by Principle Investigators totaled $11.5 Million for FY96. Of the $11.5 million, $9.4 Million in research contracts have been approved by the Center's Governing Board. These obligations of the Board exceed the $7.5 million in funds received during February, 1996 and will curtail award of subcontracts to Principle Investigators. The University of Texas will not allow the Center to commit funds exceeding $7.5 million by subcontract unless the funds have been received. All of FY95 funds are either spent or committed by subcontract.

☐ None

9. Open Items

DOE issues currently being addressed by the Center are (1) the holdback of FY1996 funds, (2) the impact on our ongoing research after funding is transferred from Materials Disposition to Defense Programs, and (3) the impact upon our operations if technical direction of this contract be moved to the Albuquerque Operations Office.

☐ None

10. Status Assessment and Forecast

The Center has made significant progress in hiring administrative and technical support staff during this period. The following five positions were filled from February through April: Technical Director, Education Program Coordinator, Computer Resource Specialist, and two Administrative Assistants. A Human Resource Coordinator, Communication Program Writer, Informational Writer, Nuclear Manager, Environmental Manager, and one more administrative assistant will be hired during the next period.

☐ No Deviation from Plan is Expected

11. Description of Attachments

The Technical Progress Report, Milestone Log (DOE 4600.3A), Federal Assistance Management Summary Report (DOE 4600.5), Financial Status Report (SF-269), and Notice of Energy RD&D Project (DOE 1430.22), and April Newsletter are included with this submission.

☐ None

12. Signature of Recipient and Date	13. Signature of U.S. Department of Energy (DOE) Reviewing Representative and Date

Amarillo National Resource Center for Plutonium
Research Efforts

Tue 5/28/96
3:22 PM

ID (WBS)	Task Name	University	Investigator
1	**Amarillo National Resource Center**		
1.1	**Plutonium Information Resource**		
1.1.1	**Program Managment/Center**	**Center**	**E. Zounar**
1.1.2	**Electronic Resource Library**	**TTU**	**D. Cluff**
1.1.2.1	Program Coordination/Scanning Station	TTU	D. Cluff
1.1.2.2	Electronic Database & Links	AC	G. Huffman
1.2	**Advisory Function**	**UT**	
1.2.1	**Senior Technical Review Group (STRG)**	**UT**	**B. Harris**
1.2.2	**Multi Attribute Analysis**	**UT**	**J. Dyer**
1.2.3	**State Support**	**Center**	**B. Harris**
1.2.3.1	*Analysis for State*	*Center*	*B. Harris*
1.2.3.2	Aircraft Overflight	TEES	J. Rock
1.3	**Environmental, Public Health and Safety**		**R. Charbeneau**
1.3.1	**Program Managment**	**UT**	**R. Charbeneau**
1.3.1.1	Program Management/Center	Center	R. Hartley
1.3.1.2	Environmental Program Coordination	UT	R. Charbeneau
1.3.1.3	Additional funding needs for Texas Tech	TT	Rainwater
1.3.2	**Perched Aquifer & Tracer Testing, Water Treatment**	**UT**	**R. Charbeneau**
1.3.2.1	Produced Water Treatment	UT	Speitel
1.3.2.2	Aquifer Pumping Test	TTU	Rainwater
1.3.2.3	Texas A&M University		
1.3.3	**Bioremediation of Contaminated Soil and Groundwater**	**UT**	**G. Speitel**
1.3.3.1	In Situ Cometabolism of Chlorinated Solvents	UT	Speitel
1.3.3.2	Identification of HE Degrading Microorganisms	TTU	C. Heintz
1.3.3.3	Treatabilities Studies for HE Biodegradation	TEES	R. Autenreith
1.3.4	**Vadose Zone Remediation**	**TTU**	**K. Rainwater**
1.3.4.1	Air Permeability of Pantex Soil Cores	UT	D. McKinney
1.3.4.2	Soil Vapor Extraction Model Development	TTU	K. Rainwater
1.3.4.3	Sorption of Volatile Organic Chemicals at Pantex	TEES	A. Akgerman
1.3.5	**Chromium Remediation**	**TAMU**	**B. Batchelor**
1.3.5.1	Ion Exchange for Chromium Remediation	UT	D. Lawler
1.3.5.2	Chromium Sorption on Pantex Soils	TTU	K. Rainwater
1.3.5.3	Chemical Models for Chromium Behavior	TEES	B. Batchelor
1.3.6	**Biologicial Risk Assessment**		
1.3.6.1	Texas A&M University	TAMU	
1.3.6.2	Texas Tech University	TTU	
1.3.7	**Agricultural Studies**		
1.3.7.1	**Phytoaccumulation of Heavy Metals in Plants**	**TAMU**	**L. Hossner**
1.3.7.1.1	Identify plants/Ag Crops, Accumulation, Boimobilization	TAMU	L. Hossner
1.3.7.1.2	Identify Plants/Ag Crops, Eval Accumulation of Pu, U, Cr	TTU	D. Kreig
1.3.7.1.3	Evaluate use of Chelates to Increase Biomobilization	UT	P. Szaniszlo
1.3.7.1.4	Consult on problems related to Pu & U analysis	LANL	M. Attrep
1.3.7.2	*Other Agricultural Studies*		
1.4	**Communication, Education, and Training**		**P. Nash**
1.4.1	**Program Management**	**TTU**	**E. Zounar**
1.4.1.1	Project Management/Nash	TTU	P. Nash
1.4.1.2	Program Managment/Center	Center	Center
1.4.1.3	Graduate Student	WT	C. Alcanter
1.4.2	**Education Program**	**TTU**	**P. Nash**
1.4.2.1	*Planning Grant*	*TTU*	*G. Skoog*
1.4.2.2	K-16 Science and Mathematics Education	WT	J. Kelley
1.4.2.3	Amarillo Area Center for Advanced Learning	Center	E. Zounar

ID (WBS)	Task Name	University	Investigator
1.4.2.4	West Texas A&M Student Research Conference	Center	E. Zounar
1.4.2.5	Panhandle Regional Math & Science Conference	Center	E. Zounar
1.4.2.6	Center's Education Program	Center	E. Harle
1.4.3	**Academic Intervention: Tx Prep**	**TTU**	**P. Nash**
1.4.3.1	TxPrep/Lubbock	TTU	C. Kellog
1.4.3.2	AmarilloPREP	AC	
1.4.3.3	*School Year Enhancement*	*AC*	*T. Jones*
1.4.4	**Graduate Education**	**TTU**	**P. Nash**
1.4.5	**Communication**	**TTU**	**P. Nash**
1.4.5.1	*Information/Public Outreach Plan*	*TTU*	*J. Oskam*
1.4.5.2	*Education Program Video*	*AC*	*J. Herring*
1.4.5.3	Center Exhibit Costs	Center	E. Zounar
1.4.6	**Science Information & Resource Center**	**TTU**	**P. Nash**
1.4.6.1	*Communication*	*TTU*	*Z. Curry*
1.4.6.2	*Survey*	*WT*	
1.4.6.3	Transportable Unit	Center	
1.4.7	**Plutonium Textbook and Training**	**Center**	**E Zounar**
1.4.7.1	Plutonium Textbook	Center	E. Zounar
1.4.7.2	Training	Center	E. Zounar
1.4.8	***Opinion/Editorial Writing***	***TTU***	***J. Beckman***
1.4.9	***Other Communications Expenses***	***Center***	***B. Harris***
1.5	**Plutonium and Other Materials Studies**	**TAMU/TEES**	**P. Nelson**
1.5.1	**Program Management**		
1.5.1.1	Nuclear Program Coordination/Center	Center	R. Hartley
1.5.1.2	Coordination and Technical Information Support	TAMU/TEES	P. Nelson
1.5.1.3	Laboratory Leverage	SNL	T. Sanders
1.5.2	**Russian Activities**	**TAMU/TEES**	**P. Nelson**
1.5.2.1	**Accelerator Based Transmutation**	**TAMU/TEES**	**T. Parish**
1.5.2.1.1	Subcritical Configuration	TEES	T. Parish
1.5.2.1.2	Gather Information	TTU	R. Wigmans
1.5.2.2	**Modular High-Temp Gas Cooled Reactors**	**TAMU/TEES**	**F. Best**
1.5.2.2.1	Gather & Assess Information	TAMU/TEES	F. Best
1.5.2.3	**Evaluation of Fast Reactors**	**TAMU/TEES**	**W. Reece**
1.5.2.3.1	Technical Feasibility & Cost Study	TAMU/TEES	W. Reece
1.5.2.4	**Support of Russian Joint Studies**	**TAMU/TEES**	**P. Nelson**
1.5.2.4.1	Joint Technical Work Groups	TAMU/TEES	P. Nelson
1.5.2.4.2	Administration		P. Nelson
1.5.2.4.3	*Russian Support*	*UT*	*Dale Klein*
1.5.2.4.4	IPPE/A. A. Bochvar Institute	UT	Dale Klein
1.5.3	**Plutonium Storage**		
1.5.3.1	**Planning**		D. Boyle
1.5.3.2	**Robotics**	**TAMU/TEES**	**A. Barhorst**
1.5.3.2.1	Robotics, Automation, and Tele-Operations	TTU	A. Barhorst
1.5.3.2.2	Test Bed, Integration, Safety & Automation Studies	TAMU/TEES	R. Volz
1.5.3.2.3	Performance Evaluation and Prediction	UTArl	G. Kondraske
1.5.3.2.4	Planning, Navigation, and Control of Mobile Robots	UT	S. Sreenivasan
1.5.3.3	**Air Monitoring**	**TAMU/TEES**	**H. Liljestrand**
1.5.3.3.1	Inert Tracer Fingerprinting System	UT	H. Liljestrand
1.5.3.3.2	Aerosol Sampling Studies	TAMU/TEES	A. McFarland
1.5.3.3.3	Monitoring system for Accidental Plutonium Release	TTU	P. Dasgupta
1.5.3.3.4	Plutonium Leak Detection by Conductivity Methods	TAMU/TEES	W. Marlow
1.5.3.3.5	Radioactive Aerosol Monitoring with LANL (DOE/DP Matching)	UT	H. Liljestrand

ID (WBS)	Task Name	University	Investigator
1.5.3.4	**Radiation Damage and Microstructural Change**	**TAMU/TEES**	**Unlu/Hart**
1.5.3.4.1	Surface Analysis of Stainless Steel	UT	K. Unlu
1.5.3.4.2	Stainless Steel Irradiation/Implantation	TAMU/TEES	R. Hart
1.5.3.5	**AT400 Heat Analysis**	**TAMU/TEES**	**D. Boyle**
1.5.3.6	**Aerosol Dispersal Analysis**	**UT**	**D. Klein**
1.5.4	**Plutonium Disposition**		
1.5.4.1	**Water Reactor Options for disposition of Pu**	**TAMU/TEES**	**bdurrahman/Adams**
1.5.4.1.1	Gather Information & Assess Technical Issues	UT	N. Abdurrahman
1.5.4.1.2	Neutronic Parameters & Cost Study	TAMU/TEES	M. Adams
1.5.4.1.3	Effectiveness	TTU	D. Roundhill
1.5.4.1.4	Gallium interactions with zircalloy cladding	UT	K. Unlu
1.5.4.2	**Immobilization of Pu into Ceramic Media**	**TAMU/TEES**	**A. Clearfield**
1.5.4.3	**Disposition in Deep Boreholes**	**UT**	**M. Sharma**
1.5.4.4	**Can-in-Cannister Plutonium Immobilization**	**UT**	**K. Ball**
1.5.4.4.1	Simulate Canister Filling Process	UT	K. Ball
1.5.4.4.2	Radiative Heat Tranfer Component	TTU	E. Anderson
1.5.4.5	**Cesium Encapsulation**	**TAMU/TEES**	**C. Philip**
1.5.4.6	**LWR MOX Fuel Irradiation Experiment**	**TAMU/TEES**	**W. Reece**
1.5.4.7	**Fuels Technology (Xferred to Water Reactor Options)**	**TAMU/TEES**	**Nelson**
1.5.4.8	**Front End Systems Engineering**	**TAMU/TEES**	**Parlos**
1.5.5	**Cross-cutting Issues**		
1.5.5.1	**Non-Destructive Assay**		
1.5.5.1.1	Development of Non-destructive assay methods	UT	N. Abdurrahman
1.5.5.1.2	Uncertainties in Noninvasive Assay Methods of Plutonium	TTU	R. Wigmans
1.5.5.2	**Transportation Analysis**	**UT**	**M. Mahmasanni**
1.5.5.2.1	Modeling for Safe Routing	PVAMU	R. Radhkrishnan
1.5.5.2.2	Qualitative Surety Assessment	TTU	D. Wunsch
1.5.5.2.3	Transportation of Mixed-Oxide Fuel	UT	H. Mahmasanni
1.5.5.2.4	Development of Source Term Components	TAMU/TEES	W. Marlow
1.5.5.3	**New Polymers and Extractants for Plutonium Separations**	**TTU**	**R. Bartsch**
1.5.5.3.1	Texas Tech	TTU	R. Bartsch
1.5.5.3.2	UT Elpaso	UT Elpaso	H. Pannell
1.5.5.4	**Health Issues Planning Grant**	**TAMU/TEES**	**Poston**
1.5.6	**Other Materials Studies**		
1.5.6.1	**High Explosives**	**UT**	**G. Willson**
1.5.6.1.1	Explosives testing at Naval Warfare Center	Navy	J. Lindsey
1.5.6.1.2	Develop Compaction Processes	TTU	D. James
1.5.6.1.3	Program Coordination/Feasibility/Benefit Analysis	UT	G. Willson
1.5.6.2	**Highly Enriched Uranium**	**TAMU/TEES**	**L. Peddicord**
1.5.6.2.1	Assess Vulnerability to Residual HEU	TAMU/TEES	P. Nelson
1.5.6.3	**Mixed Oxide Use Evaluations**	**TAMU/TEES**	**L. Peddicord**
1.6	**Reporting, Evaluation, Monitoring, and Administration**	**Center**	**B. Harris**
1.6.1	**Governing Board**	**Center**	**D. Klein**
1.6.1.1	Peddicord	TAMU	L. Peddicord
1.6.1.2	Bryant	TTU	F. Bryant
1.6.2	**Center Administration**	**Center**	**B. Harris**
1.6.3	**External Advisory Committee**	**Center**	**B. Harris**
1.6.4	**State of Texas**	**State**	**R. Mulder**

Table of Contents

"This report was prepared with the support of the U.S. Department of Energy (DOE), Cooperative Agreement No. DE-FC04-95AL85832. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE. This work was conducted through the Amarillo National Resource Center For Plutonium."

WORK PLAN PROGRESS REPORT
Electric Resource Library

Institutions:	Texas Tech University and Amarillo College
Principle Investigator (P.I.):	George Huffman
Researcher/Information Scientist:	Dr. Karen Ruddy
Co Principal Investigator:	Dr. Dale Cluff
Sub-Contract Number:	UTA-95-0206. Electric Resource Library
Identification #:	1.1.1.

1. Summary of Research Activities

Digital Library Consultant's Summary Report:

- The Electronic Resource Library addressing an "important, unfilled need in scientific research and public policy."

- The "mission, subject content, and technical characteristics...well suited to a digital library implementation."

- The "collection development plan...intelligently conceived, clearly articulated, and manageable within the resources and time frames outlined in the proposal."

- Please see complete document Appendix 2 in tab 6 of this report. Appendix 3 in tab 6 presents the Digital Library worksheet document completed for Dr. Saffady's review.

Focal Points of the collection development assessments:

- The DOE Reading Room collection at Amarillo College (AC) was compared with the other ten (10) DOE Reading Rooms.
  - The AC collection is the only one that has cataloged records in the OCLC international cataloging network called WorldCat that ties in with the international Interlibrary Loan System which is the first and usually the last resort for locating titles of material in collections.

  - AC has received requests from all over the world asking for DOE Reading Room materials as a result of AC being a single source in the OCLC lending string for these titles.

  - Please see DOE Reading Room Survey results in Appendix 3 in tab 6 of this report.

- Analysis of The Linda Hall Library of Science, Engineering, and Technology collection (on the campus of the University of Missouri in Kansas City)

    - Analyzed using part of a 1957-1964 bibliography published by the United Kingdom Atomic Energy Authority Research Group entitled, "Bibliography of Unclassified Report and Published Literature on the Transplutonium Elements" compiled in 1964 by R.W. Clarke.

    - The Linda Hall Library collection could produce the full text document, article, conference paper, patent, trademark, or technical report for all but three (3) of the sixty-one (61) citations used as a sample set.

    - The Linda Hall Library will prove to be a valuable resource for obtaining the full text of titles in future ERL "collection sets" developed for scanning into the ERL Archive.

    - In a joint venture with the United Engineering Trustees, Inc., the library opened the Linda Hall Library - East/Engineering Societies Information Center, located in the United Nations Plaza in New York City. This will significantly increase the holdings of the library and add depth to the research collections.

    - Please see Appendix 4 in tab 6 for full report.

- The Texas Tech University Government Document Collection was analyzed by Dr. Charles David Stoune, Reference Librarian.

    - It uses Citation Analysis to target universe of literature on plutonium by using the GRAI index (Government Reports Announcement Index) to track citation <u>couns</u> that begin to rise significantly in 1980.

    - He recommends that the Texas Tech scanning site restrict their digitizing efforts to the government reports published in 1980 and later stating that "we may still be able to find a digital copy of the original which would further reduce our costs."

    - Please see Appendix 5 in tab 6 for the full report.

WORK PLAN PROGRESS REPORT
Multi-Attribute Analysis

Institution:	The University of Texas at Austin
Principle Investigator (P.I.):	Dr. James Dyer
Sub-Contract Number:	26-422291xx. Multi-Attribute Analysis
Identification #:	1.2.2.

1. Summary of Research Activities

- The Multi Attribute Utility (MAU) team continued work on the disposition of surplus plutonium project. The most recent document, a draft entitled *Preliminary Multi-Attribute Utility Analysis of Alternatives for the Disposition of Surplus Plutonium*, was completed on January 19, 1996. This report revealed initial results of the project.

- Personnel from the Office of Fissile Materials Disposition (OFMD) and various alternative and cross-cutting teams within the Department of Energy (DOE) continue to review the report and analyze data to provide appropriate input to select a viable disposition alternative later this year.

- The MAU team is currently conducting additional sensitivity analyses and is working with other teams and experts to further refine and evaluate alternatives.

- The project is anticipated to culminate with the announcement of a selected disposition alternative and a briefing to the Secretary of Energy in the Fall of 1996.

WORK PLAN PROGRESS REPORT
State Support

Institution: Amarillo National Resource Center For Plutonium

Principle Investigator (P.I.): Bill Harris

Sub-Contract Number: UTA 96-0190. State Support/Pantex Economic Analysis

Identification #: 1.2.3.1

1. Summary of Research Activities

During this quarter, the Contract for the Pantex Economic Analysis was finalized.

The Pantex Economic Analysis includes the following tasks:

- Focus of effort:
  - Perform a scientific review of the key interests of the State of Texas in the future of Pantex, including public health and safety, environment, jobs, and economic activity, as well as a study of potential future activities at Pantex and within the entire Nuclear Weapons Complex, including assessments of each of the functions contemplated in the Stockpile Stewardship and Management Programmatic Environmental Impact Statement (PEIS) and the Fissile Material Storage and Disposition PEIS.

- Planned Activities include:

  - Compile and review existing information regarding the Nuclear Weapons Complex and future anticipated programs including information regarding ongoing EIS projects as well as many details currently available on the scope and nature of various future functions of the Complex

  - Begin the study with a national security policy analysis of the current and anticipated functions addressed in both the Stockpile Stewardship and Management PEIS and the Fissile Material Control and Disposition PEIS to develop the underlying assumptions on which the study is based.

  - Conduct an analysis of the relative benefits of each "candidate site" for each of these functions. For each function provide scientific data on the relative merits of each candidate site, including assessments of: federal budgetary impact; environment, safety, and health impacts; transfer costs; new/improved capital requirements; operating costs; existing facilities; safeguards and security; training and economic dislocation; existing work and safety culture; state and community involvement; labor costs; utility costs; transportation; strategic location; and other relevant considerations. In addition analyze how the sitting of a particular function at a site is consistent with the national security goals expressed in the report.

- Include in the study the key interests of the State of Texas in the future of Pantex, including public health and safety, environment, jobs and economic activity.

- Present the study's findings in a clear, concise report, which will include narrative descriptions of the analysis for each function, and "side-by-side" charts comparing the relative benefits for each function at each site.

- Prepare slides and materials from the study which are suitable for public presentations.. Perform at least five (5) presentations of the study at sites selected by the ANRCP.

- Three meetings were held to clarify the scope, identify informational needs and sources, and to provide initial information. Most of the required information and documentation has been delivered to the Perryman Group, and they have completed more than half of the analysis.

WORK PLAN PROGRESS REPORT
Environment, Public Health and Safety

Institution: University of Texas at Austin

Principle Investigator (P.I.): Dr. Randall Charbeneau

Sub-Contract Number: UTA95-0176, UTA95-0177, UTA95-0275
Environment, Public Health and Safety

Identification #: 1.3

1. Summary of Research Activities

1.3.2 Aquifer Testing, Tracer Tests, and Produced Water Treatability

- Drs. Rainwater and Charbeneau met in Austin to discuss the proposed work plan for the perched aquifer tracer test planned for the Zone 12 Treatability Site. Mr. Scot Laun of engineering-environmental Management (e^2M) was also present as representative of the operating contractor. The work plan was completed and submitted to the proper Pantex personnel for review.

- The TTU team procured a new pressure transducer and provided it and the previously purchased Hermit data recorder to e^2M for their use in the injection of treated effluent at well PTX-06-1004. The devices allowed e^2M to determine the build-up water level during injection. The devices were provided at no charge to e^2M, and they have since been returned.

- Equilibrium isotherm tests are nearly complete for sorption of HMX and RDX on eight selected core samples from the perched aquifer and fine-grained zone. These tests will allow estimation of retardation factors that affect the vertical and horizontal transport of the HE.

- Treatability studies for produced water have been delayed due to funding delays which prevented necessary upgrade of analytical equipment. Analytical procedures have been developed, and a source for supply of HE has been identified.

1.3.3 Bioremediation of HE and Chlorinated Solvents

- A report on current literature on the biodegradation of HMX and RDX including toxicity information and fate and transformation data has been completed and submitted to DOE Pantex.

- Studies of microbial degradation kinetics of RDX are nearing completion. Loss rates have been quantified, and duplicate studies are ongoing. Additional detailed information is appended to this report.

- Determination of the preferred form of nitrogen was determined. The organisms' ability to consume nitrogen in the form of ammonia, nitrate, and nitrite were evaluated. The organisms acclimated to the degradation of HMX and RDX originated from the Alderson Playa in Lubbock, Texas. Further, the optimal carbon to nitrogen ratio was determined, and the combination of nitrogen source type (e.g. ammonia, nitrate, nitrite) to carbon source in the form of glucose was evaluated.

- Identification of the microorganisms using the biolog system was accomplished. The organisms originating from the Alderson Playa that acclimated to RDX and HMX were tested for their genus species identification.

- Batch TCE biodegradation assays were completed. The results show TCE losses for all vials under consideration. However, the only vial series with significant losses as compared with controls was the series containing sediments that were simulated with phenol and supplemental nutrients. Additional detailed information is appended to this report.

1.3.4 Vadose Zone Remediation

- The UCLA Soil Vapor Extraction (SVE) model was used to predict contaminant recovery from the existing SVE pilot system at Pantex.

- Modeling studies were performed to aid in design of the proposed vadose zone partitioning interwell tracer test (PITT). This test will provide critical information, such as water saturation and permeability heterogeneity of vadose zone soils, that can be used in the design of a full-scale SVE remediation system. UTCHEM, a three-dimensional, multi-component, multi-phase finite difference numerical simulator, was used to assist in the design of the PITT. The sensitivity of the predicted tracer response curves to several uncertain model parameters was quantified. Laboratory column studies have begun in order to determine several critical parameters for the PITT design. These include the detection limits that can be expected in the field, a critical parameter in determining the total mass of tracer to be injected into the vadose zone. Funding has been secured to purchase needed field analytical equipment for the tracer test. Once delivered, this equipment will be tested and configured for field operation and final details of the tracer test work plan worked out.

- Work has continued on development of a two-dimensional model of soil vapor extraction to assistance with the PITT design and operation. The major subroutines of the two-dimensional model, SVX, were completed individually. These subroutines include those responsible for the solution of the vapor flow and transport equations. Work began on assembly of the complete program, connecting the computational routines to input and output controls. Work is on schedule.

- Drs. Rainwater and McKinney met in Austin to discuss the partitioning interwell tracer test design. A work plan is being developed to submit to appropriate Pantex Plant personnel.

- No progress was made during this quarter on the volatile organic chemical (VOC) sorption studies. FY 95 funds had previously been exhausted, and FY 96 funds were not yet available.

1.3.5 Chromium Remediation

- The quality control/quality assurance evaluation has been completed and a report will be submitted in May.

- The chemical models for chromium have been expanded to include amorphous chromium-iron hydroxide solid solutions.

- Ion exchange column studies for removal of chromium have been completed, and theories to explain the gradual breakthrough are being explored.

- Experiments were initiated on the ability of iron to reduce hexavalent chromium.

- Estimates have been made for the range of flows and concentrations in the blowdown water emitted from the former cooling tower during its operational life. This cooling tower is a likely source of chromium contamination in the Zone 12 area. A milestone report will be generated and submitted during the next quarter.

- Additional detailed information on the chromium remediation activities is appended to this report.

1.3.6 Ecological Risk Assesment

- Dr. John Bickham has made two visits to the Pantex Plant. From these visits and meetings with Plant personnel, he developed initial recommendations regarding the contaminants of concern, assessment endpoints, and measurement endpoints. These were submitted through a brief memorandum.

WORK PLAN PROGRESS REPORT
Agricultural Studies

Institution: Texas A&M University

Principle Investigator (P.I.): L.R. Hossner, Soil and Crop Sciences Department, Texas A&M University

Sub-Contract Number: UTA96-0043. Agricultural Studies/Phytoaccumulation of selected heavy metals, uranium, and plutonium in plants

Identification #: 1.3.7.1

1. Summary of Research Activities

1.3.7.1.1 Screening Plants for Cr Hyperaccumulation

- Seeds from 10 agricultural plant species have been collected for screening to Cr and U.
    - Wheat (*Triticum vulgare*), sorghum (*Sorghum bicolor*), sunflower (*Helianthus annus*), barley (*Hordeum vulgaris*) corn (*Zea Mays*), rye (*Secale cereale*), safflower (*Carthamus tinctorius*) clover (*Trifolium incarnatum*), oat (*Avena sativa*) and tobacco (*Nicotiana tabacum*) are representative agricultural plants.
    - All plants are currently being screened for their ability to accumulate Cr and U.
    - Several pea (brz and dgl) and tomato (chloranerva) mutants have been obtained for study because of their previously established Fe utilization characteristics.
    - A replicated study has been initiated using wheat, canola, sorghum, and sunflower on two contrasting soil textures (a loamy fine sand and a clay loam) with applied Cr(III) levels of 0, 10, and 100 mg/kg soil. These crops are representative of cool and warm season agricultural crops in the Amarillo area.

- Seeds of 47 native plant species have been collected and the plants are being screened for accumulation of Cr and U.
    - Species were selected based on reports in the published literature which indicated the tendency of the plant to extract metals from soils.
    - Plants include Indian mustard (*Brassica juncea*), saltbush (*Atriplex canescens*), alkali sacaton (*Sporobolus airoides*), common bermudagrass (*Cynodon dactylon*), big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), seashore paspalum (*Paspalum vaginatum*) and a number of species of *Alyssum*, *Silene*, and *Thlaspi.*

1.3.7.1.2 Evaluate Mechanisms of Cr Hyperaccumulation by Plants

- Selected plant species are being tested for characteristics associated with Cr absorption by using tissue culture procedures.
    - Cultivars exhibiting a wide range in capacity of the Fe deficiency induced root plasma membrane H^+ pump have been selected to evaluate the influence of this

factor on Cr uptake. Cultivars exhibiting a wide range in capacities of the Fe deficiency induced exudation of phytosiderophore are being utilized to evaluate the influence of this important property on Cr tolerance and Cr uptake.

- We are especially interested in the plasma membrane enhanced H^+ pump and phytosiderophore release because of the role of these processes in metal mobilization and uptake. These experiments are being conducted with Cr(OH)3, $CrCl_3$, and Cr-DTPA to evaluate the influence of Cr source on Cr utilization and uptake.

1.3.7.1.3 Evaluation of Metal Speciation in Plants and Soils

- Database evaluation:
    - A comparison of the existing MINTEQA2, GEOCHEM-PC and NIST thermodynamic databases for evaluation of Cr, Ce, U and Pu solubility and speciation has been completed.
    - Evaluation of the EQ3/EQ6 database is currently in progress.
- The MINTEQA2 speciation program, with the database adjusted as required, has been utilized to determine the nutrient solution conditions required (especially with regard to pH) to minimize the precipitation of dissolved Cr.
    - A critical evaluation of thermodynamic constants of Cr-organic complexes, including DTPA, citrate, malate, oxalate and mugineic acid, is currently in progress.
    - It is anticipated that it may be necessary to determine thermodynamic constants for Cr-DTPA and Cr-mugineic acid.

1.3.7.1.3 Chemistry of Metal Chelation and Plant Metal Chelators

- Experiments have been performed to isolate approximately 500 mg of mugineic acid, 2'-deoxymugineic acid, and 3-epi-hydroxymugineic acid from the root exudates of barley plants in hydroponic culture (a portion of these materials is being purified for subsequent thermodynamic studies).
    - These compounds may play a major role in uptake of Cr and the actinides by plants.
    - A HPLC procedure involving derivatization with PicoTag has been developed to qualitatively and quantitatively assay the individual phytosiderophores of interest.
        - This procedure represents a significant improvement over other commonly used procedures.
        - A modification of the procedure has been developed to evaluate whether a specific chromatographic peak is attributable to a metal complexing component.

WORK PLAN PROGRESS REPORT
Project Management

Institution: Texas Tech University

Principle Investigator (P.I.): Phillip T. Nash

Sub-Contract Number: UTA-95-0206. Project Management

Identification #: 1.4.1

1. Summary of Research Activities

- FY 96 project continuance proposal:
  - Submitted to the Amarillo National Resource Center for Plutonium (ANRCP) on February 16, 1996 for the following subprojects:
    - Project Management
    - Academic Intervention
    - K - 16 Math and Science Education
    - Graduate Education
    - Electronic Resource Library
    - Science Information and Resource Center
    - Public Outreach
  - Subproject proposals were reviewed by the ANRCP staff and several revisions were recommended and accomplished. The revised proposals were presented to the ANRCP Governing Board (GB) on April 16, 1996. Final decisions for each subproject pending.

- The following two letters of intent to submit new proposals were received:

  - Courses on Maintenance Engineering, Power Transmission Elements, HVAC Engineering, and Fluid Flow Measurements for Pantex employees, submitted by S. Midturi, Texas A&M University

    - Dr. Midturi was advised the planned course work did not match with graduate education needs and he should discuss education needs with the project manager.

  - School Year Enhancement, submitted by Therese Jones, Amarillo College

    - Ms. Jones was encouraged to submit a proposal. She worked closely with the ANRCP to develop her proposal and the final decision concerning the proposal is expected soon.

- Dr. Charlie Johnson (Public Policy Research Institute, Texas A&M University) began reviewing the ANRCP Communication, Education and Training Program.

WORK PLAN PROGRESS REPORT
K-16 Math & Science Education

Institution:	West Texas A&M University
Principle Investigator (P.I.):	Judy Kelley
Sub-Contract Number	UTA-95-0206. K-16 Math & Science Education
Identification #:	1.4.2

1. Summary of Research Activities

- Needs Assessment:
  - Distributed to elementary science and mathematics teachers, to secondary science teachers, and to secondary mathematics teachers across the Panhandle.
  - Data from 479 elementary science and mathematics teachers, 150 secondary science teachers, and 151 secondary mathematics teachers was received, compiled, and organized in various categories.
  - Detailed data can be found in tab 9 (appendix 1).
- Needs Assessment Interpretation:
  - The planning grant steering committee met on April 25 at KACV-TV at Amarillo College to review the data and make recommendations for science and mathematics education in the Texas Panhandle. A complete report of those recommendations is being prepared. Some of the conclusions drawn are given below.
    - General characteristics of teachers:
      - very little ethnic diversity
      - great majority are females
      - many older teachers with fewer years teaching experience
      - stable--tend to remain in same locations
      - little knowledge about national science and mathematics standards
      - need to recruit new teachers because of numbers of teachers age 40 and older
    - Science and mathematics backgrounds:
      - elementary science and mathematics teachers have inadequate science and mathematics training
      - all groups had little knowledge of national science and mathematics standards
      - over 40% had taken no college science or mathematics course in the last 9 years

- Technology
    - most teachers surveyed either use computers frequently or do not use them at all
    - age of teachers corresponds to amount of usage of computers--"Older teachers are afraid of technology."
    - computers are used primarily for word processing and record keeping and not for instruction
    - teachers need training in how to use technology as instructional tool
    - teachers must understand benefits of technology
    - access to technology and training must go hand in hand
    - teachers need training in using internet

- Professional development
    - must be relevant to what teachers do--course specific topics are most important— not generic professional development
    - should be modeled after business world--teachers compensated for time and focused on issues important to their tasks
    - teachers want to know about resources, programs, and speakers that are available locally
    - teachers want to learn about new teaching methods
    - teachers want to know about real world applications
    - teachers need a newsletter (both hard copy and electronic) to communicate information about resources, programs, and speakers, to provide insights into national standards and new teaching methods, and to share information about professional development opportunities

- The steering committee was also presented information about science and mathematics resources available over cable television, satellites, and public television. They watched a demonstration of using the internet to access information about these resources. Even though the members of the committee are recognized leaders in science and mathematics education in the Panhandle, they were not aware of these resources.

WORK PLAN PROGRESS REPORT
Academic Intervention

Institution: Amarillo College and Texas Tech University

Principle Investigator (P.I.): Therese Jones

Participants: Charles N. Kellogg

Sub-Contract Number: UTA - 95 - 0206. Academic Intervention: Texas Prefreshman Engineering Program Participants/Institution Affiliations

Identification #: 1.4.3

1. Summary of Research Activities

- Two proposals were developed during this quarter:
    - A project continuance proposal was submitted to ANRCP on February 16, 1996 for Academic Intervention: Texas Prefreshman Engineering Program. The proposal was for funding TexPREP '96, summer program at Amarillo College and Texas Tech University.
    - A proposal for School Year Enhancement was submitted by Therese Jones, Amarillo College. The proposal was developed in conjunction with ANRCP.
- Recruitment efforts and planning for the summer program were the main activities during this quarter.
    - Contact with school representatives is ongoing; application packets were sent to counselors at area schools; applications were completed and returned to the PREP office; applications were received and evaluated. Approximately 100 applications were received at each site.
- Panhandle Regional Planning Commission contacted the AmarilloPREP program director upon receipt of Job Training Partnership Act/Summer Youth Education and Training Program (JTPA/SYETP) funding.
    - A contract was developed and signed so that an $85.00 a week stipend and transportation costs as needed, would be provided to students qualifying for both programs - AmarilloPREP through required academic interests and grades and SYETP through financial need. The TexPREP-Lubbock program director has contacted the SYETP office in Lubbock and is negotiating a contract for student stipends for qualified participants at that site.

WORK PLAN PROGRESS REPORT
Academic Intervention

Institution:	Texas Tech University
Principle Investigator (P.I.):	William Marcy
Sub-Contract Number:	UTA-95-0206. Graduate Education
Identification #:	1.4.4

1. Summary of research activities

- Two research assistants were employed during the spring semester (Dean Fontenot and John Chandler) to facilitate faculty development of multimedia course materials to be placed on the world wide web server.
  - These two individuals conducted a series of training sessions and seminars for 18 faculty that are developing the distance education graduate courses to be offered during the fall semester 1996 and the spring semesters of 1997.
- When the current activities are completed at the end of May this will complete the graduate education project for FY 96.
  - No further work funded under ANRCP is anticipated with regard to Graduate Education.

WORK PLAN PROGRESS REPORT
Science Information Resource Center

Institution:	Texas Tech University
Principle Investigators (P.I.):	Dr. Marie Gentry and Dr. Zane D. Curry
Sub-Contract Number	UTA-95-0206. Science Information Resource Center
Identification #:	1.4.6

1. Summary of Research Activities

- Visited and assessed science/information centers in Albuquerque and Los Alamos, NM. These included the National Atomic Museum, Albuquerque Museum of Natural History, Explora, and the Bradbury Science Museum.

- Established relationships with the Director and exhibit staff at Bradbury Science Museum and with a vendor specializing in exhibit fabrication/digital imaging.

    - A direct result of these relationships was the acquisition and installation of a transportable exhibit at both the Pantex Information Fair and the U. S. Department of Energy Public Hearings.

    - The relationships will continue to be an important resource during the design development phase.

- Assisted in the establishment of a working partnership among, Mason & Hanger, the ANRCP, and TTU investigators through the acquisition of a transportable exhibit structure and graphics. Procurement of the exhibit required several meetings with Mason & Hanger and ANRCP personnel in Plainview, Amarillo, and Lubbock. Additionally, numerous conference calls with personnel from ANRCP, Mason & Hanger, Bradbury Science Museum, and the exhibit/graphics fabricator were necessary.

- Submitted a supplement to the 1995-96 proposal for a transportable exhibit structure to the ANRCP.

- Supported collaborative efforts with nuclear experts to review transportable exhibit text.

- As a component of the pre-design process, the collection of information regarding science/information centers continues.

WORK PLAN PROGRESS REPORT
Communication

Institution: Texas Tech University and Amarillo College

Principle Investigators (P.I.): Dr. Judy Oskam and Dr. Joyce Herring

Sub-Contract Number: UTA-95-0206. Communication/Public Outreach

Identification #: 1.4.5.1

1. Summary of Research Activities:

- During the last quarter, communication outreach faculty and staff have been involved in the production phase of the project.
    - This includes research, script and concept development , video shooting and production, graphic design, interview selection and coordination, editing and post production.
    - Various meetings between collaborators have been held to discuss the project, elements of the ANRCP information video and design a print piece.
    - Outreach faculty also continued to conduct research for the development of the public information plan.

- During the last quarter, outreach faculty and staff at TTU and KACV-TV have conducted the following tasks:
    - Introduced ANRCP video scriptwriting project to Telecommunications 3370 (Writing for Electronic Media) and Public Relations 4310 (Public Relations Administration) classes.
    - Conducted/compiled research for Pantex documentary.
    - Scheduled and conducted on-camera interviews for ANRCP information video.
    - Scheduled and conducted on-camera interviews for Pantex documentary.
    - Submitted draft script of information video to ANRCP.
    - Scheduled Phil Nash to lecture class about the ANRCP project.
    - Scheduled and shot video for ANRCP information video.
    - Scheduled and shot video for Pantex documentary.
    - Consulted with TTU project coordinator and ANRCP staff on video script development.
    - Developed FY 1996 funding request.
    - Continued the development of the public information plan.
    - Continued coordination with project collaborators (Herring, Oskam, Teague, Nash, etc.)
    - Coordinated with Texas A & M, UT System and TTU on availability and use of video footage.
    - Drafted print piece to support video materials.

WORK PLAN PROGRESS REPORT
Plutonium & Other Material Studies

Institution: Texas A&M University

Principle Investigator (P.I.): Dr. Paul Nelson

Sub-Contract Number: UTA95-0278
Plutonium & Other Material Studies

Identification #: 1.5

1. Summary of Research Activities

1.5.2 Russian Activities

1.5.2.1 Support of Russian joint studies accelerator-driven transmutation

- On 28-29 March 1996 presented a talk on direct (through neutrons produced in spallation reactions) Accelerator Driven Transmutation (ADT) of excess weapons grade plutonium and high-level radioactive waste. Tc-98 (not a fission product) is created from Tc-99 using the (n,2n) reaction and is considerably more dangerous and long-lived than Tc-99.

- Presented results of calculations on the production of tritium by accelerator produced (spallation) neutrons -- this process prohibitively expensive, and that neutron generation through fission is an unavoidable ingredient of any reasonable tritium production scheme.

- On 12 April 1996 traveled to Los Alamos National Laboratory to visit with Gary Doolen and other workers associated with the Accelerator Driven Transmutation Technologies project (ADTT). Other meetings were conducted with Charles Bowman, Brian Newman as well as a brief discussion that included Bill Sailor, Francesco Vanneri and Newman. Several potential areas of cooperation were identified, including independent peer review of several technical aspects of the project, including neutron economics and electric power economics.

- On 18 April 1996 the ANRCP notified the group of not being able to continue funding of research related to ADT since these technologies fall outside the scope and time-frame of the ANRCP.

1.5.2.2 Support of Russian joint studies: evaluation of modular high-temperature gas-cooled reactors for utilization of plutonium

- This project was intended to support information-gathering activities by the Center representative to the corresponding US/Russian Joint Study Team.

- This Study Team was canceled by the Joint Steering Committee in early October.

- Collecting material related to the disposition of weapons plutonium in CANDU reactors.

    - This is a redirect of the earlier project of using HTGR reactors.

    - In the process of obtaining AECL documents related to the plutonium consumption program.

    - Currently forming an archive of documents related to the CANDU plutonium consumption program.

1.5.2.3 Support of Russian joint studies: evaluation of fast reactors for the utilization of plutonium

- Efforts to collect the areas of expertise on fast reactors in this country have made considerable headway.
    - The expertise and experience at Hanford's Fast Flux Test Facility (FFTF) has been folded into the joint work with the Russians.

    - While meeting with the LWR-MOX group in ORNL, met with David Mose on the fast reactor work, including contacting Russian investigators.

    - Will meet with Dr. Moses and Russian counterparts in Washington DC next week to continue investigating areas of collaboration.

- Working with FFTF to transfer analysis codes used in design and operation of FFTF to Texas A&M.
    - Codes can be used to train graduate students so that the lessons learned at FFTF will not be lost, and for certain applications, can be used to help analyze the Russian's BN600 for safety concerns, etc.

    - The transfer has been agreed to in principle and the details of physical transfer and training are being worked out.

1.5.2.4 Support of joint US/Russian technical working groups for the study of alternatives for the disposition of excess weapons-grade plutonium

- The majority of the effort directed toward providing administrative and logistical support for visits to the U.S. by Russian participants, or toward travel to Russia in support of the study.

  - Professors Dale Klein and K. L. Peddicord represented the Center at the Joint Steering Committee meeting in Russia February 23, 1996.

  - Arranged for Drs. Vladimir Chitaikin, Vadim Ptashny and Gennady Pshakin of the newly formed Non-proliferation team to attend meeting at the Rosslyn (Virginia) office of the Sandia National Laboratories on March 4-7, 1996. The Center was represented by Drs. Paul Nelson and Igor Carron.

  - Arranged for Dr. Vladimir Kagramanian to visit Steve Passman and Dr. Matthew Bunn in Washington, D.C. for the preparation of the executive summary of the US/Russia Joint Study activities. The Center was represented by Dr. Igor Carron.

  - Arranged for Yuriy Matyunin and Ludmila Petrova of the Immobilization team to meet with the U.S. Co-chair Dr. Tom Gould (Savannah River Laboratory) and Dr. Leonard Gray (Lawrence Livermore Laboratory) in Livermore, California, April 1-4, 1996. The Center was represented by Dr. Igor Carron.

  - The Center currently is coordinating with Steve Passman and all the U.S. Co-chairs for the upcoming Co-chairs meeting and the subsequent Joint Steering Committee meeting. The meeting will be held in Arlington, Virginia and scheduled for May 13-17, 1996.

- Additional effort directed toward support of preparation of the individual Study Team reports, and of proposals for subsequent related projects intended to address issues of mutual interest that have been identified in the course of these studies.

  - Dr. Marvin Adams worked with Mr. Bruce Bevard (US Co-chair for the Water Reactor Study) to refine the four currently extant proposals for future efforts related to water reactors, particularly in regard to ensuring that ANRCP capabilities will be brought fully to bear on these projects if they are approved and funded.

  - Dr. W. Dan Reece worked with Dr. David Moses (US Co-chair for the Fast Reactor Study) to identify sources of information and expertise within the US that have the potential to bear on any subsequent joint projects related to fast reactors.

  - Dr. Mukul Sharma worked with Dr. Carron and Dr. Les Jardine (LLNL, US Co-chair of the Borehole Study) to coordinate plans for an extended visit by Dr. Tatyana Gupalo (Russian Co-chair of the Borehole Study) following the scheduled May 13-17 meeting of the Joint Steering Committee and the Co-chairs.

1.5.3 Plutonium Storage

1.5.3.1 Overview of storage-related work

- This report covers tasks originally aimed at supporting the Joint US/Russian Study of the HTGR but as redirected now encompass:
  - Programmatic coordination of ANRCP storage-related activities, and
  - Generation of a college-level academic program addressing materials disposition.

- In March attended a conference addressing weapons materials storage and disposition issues in Lansdowne, VA with various DOE and laboratory personnel to coordinate storage program.

- Conducted meetings between Pantex engineers and ANRCP PIs working on storage monitoring projects to improve understanding of actual storage scenarios among the PIs and to focus the ANRCP research on the highest value-added tasks.

- LANL requested that the ANRCP perform independent thermal and nuclear criticality analyses for a proposed national consolidated storage facility design now under review. Working with Warren Wood (LANL storage POC) and Bill Gregory (LANL thermal analyst) to obtain the necessary design drawings from Fluor Daniels, Inc. and have identified ANRCP experts at Texas Tech and UT to perform the work.

- Arranged a visit to Pantex and the ANRCP by COL. E.J. Stobbs, from the Office of the Assistant to the Secretary of Defense (Atomic Energy), who manages the Russian surplus weapon materials storage effort of the Comprehensive Threat Reduction Program (Nunn-Lugar). He will participate in technical exchange meetings with key ANRCP personnel on 14 May and with Pantex officials on 15 May.

- In response to a request by the State of Texas, conducted a review of DOE's recently released Draft Stockpile Stewardship and Management Programmatic Environmental Impact Statement (PEIS). On 17 April, presented the results of this review to the Pantex Plant Citizens Advisory Board and answered questions at a public meeting. Review of Stockpile Stewardship and Management PEIS and associated public briefing forwarded to the State of Texas.

1.5.3.2 Robotics, automation, and tele-operation program for safe handling and long-term storage of nuclear components

- General Information:
  - Training on most of the commercial software required has been completed.

  - Numerous meetings between Texas A&M University (TAMU) and Texas Tech University (TTU), constant contact through the use of e-mail, individual weekly meetings, and a meeting between Sandia, Pantex, and DOE are being accomplished to discuss closer collaboration and how to complement efforts.

- Storage Automation
  - Contacts established within the DOE complex and Fluor-Daniel, the Architect and Engineering firm, relative to the design of the storage facility, design documents acquired. Discussions on how the present research in interface design, navigation, and material handling can be integrated into the design specification are ongoing.

  - Contacts with DOE Laboratory Robotics and Automation groups, specifically with Sandia and Los Alamos, to compare whether their systems might be useful for future storage systems, the DOE Labs have each forwarded specifications on various automated programs within and without the nuclear industry.

  - In addition to systems developed by DOE National Labs, contact established with several vendors who supply services such as decontamination to the nuclear power industry. There has been less success in acquiring capabilities in this sector due to proprietary obligations of the vendors, however, several alternatives are being investigated, e.g., how DOE handles similar situations.

  - International sources of technology are proving to be very difficult to acquire for a variety of reasons including language barriers and classification problems.

  - Development of navigation algorithms:
    - Completed calibration of structured-light vision system for 3-dimensional ranging.

    - Completed a hand-eye calibration method on a 2-dimensional plane for Staubli robot.

    - Accomplished robot tracking of 2-dimensional curves using wrist attached CCD camera.

  - Mobile platform modeling and navigation
    - Continued to develop a simulator for studying planning and control of wheeled mobile robots in a nuclear facility with emphasis on interactive graphical software to investigate motion of various mobile robot configurations.

    - Developed dynamic modeling schemes for wheeled mobile platforms by treating it as a multi-rigid body system.

- <u>Simulation Testbed</u>
  - Simulation and training work consisted of installing a newer version of TELEGRIP at both site to allow us to integrate models of our equipment into the TELEGRIP Consolidated Storage Facility (CSF) simulation.
  - CSF simulation models received from Sandia National Laboratory have been installed and will help to enhance the usability of TELEGRIP and avoid any overlap in the development of simulation packages for specific functionality.
  - Use of virtual reality (VR) technology in conjunction with the CSF simulation is being explored. Progress is discussed in Section 3: Human & Automation Integration tab 10.
  - Work is progressing in developing a virtual robot (the RX-130) for the bi-directional telerobotic interface. This tool will be used in the interim while hardware is being delivered and configured to bring both the Staubli and PUMA at TTU on line with the InterAgent protocol.

- <u>Human & Automation Integration</u>
  - Development of a control interface for a simulated teleoperation system has been pursued with a working paper prepared to document preliminary design features to include:
    - graphical/camera views of the teleoperator environment,
    - displays of forces and torques at the telemanipulator,
    - displays of task status in terms of elapsed time, parts completed and errors, and
    - system menus for selecting different combinations (levels) of human and/or computer control of teleoperator functions and choosing types of grippers and materials to be used in teleoperations.
  - A dissertation on "Neuromotor Workload Measurement" was completed and defended. This work represents a major step in the continuing process of validating our new model and contains a major data analysis of real telerobotic experiments.

- <u>Component and Material Handling</u>
  - Experiments are being performed on a simple manipulator/gripper design tool.
  - Work is progressing towards the implementation of general contact models for robots in the TELEGRIP simulation language.
  - In regard to path planing, working on PID and neural network based controller to close the loop for robot contact force trajectory planning applications. The hope is with the proposed algorithm will enable the use of a vision guidance and pressure sensor mechanism to control the robot contact trajectory within predefined range.

- <u>Safety/Reliability Studies</u>
  - A literature study regarding robot safety has been completed (study covers the entire process of weapons transportation, disassembly, and storage). A study regarding material flow and operations is in progress.
  - Real-time reliability models compatible with system self-assessment of survival (over a given mission) have been reviewed and are in the process of modification and extension.
  - Research and development efforts continue on technology in combining evolutionary computation techniques and neural networks for the purpose of addressing multivariate process control in automated systems, as are likely to be encountered in hazardous waste materials handling.
- <u>Automation Studies</u>
  - A complete step-by-step analysis of storage and inventory operations has been completed, including a preliminary dose analysis. Continuing toward this goal, numerous dismantlement procedures, which are currently considered classified, are going through a declassification process and will be available as of May 6, 1996.
  - Additionally, dose information associated with those procedures will be available by the end of May, 1996. At that time further domain analysis can be performed within the Zone 4 weapons dismantlement area.
  - The results from this work will better help us to determine areas in which process automation is most appropriate.

1.5.3.4 Radiation damage and microstructural changes of stainless steel due to long-term irradiation by alpha particles from plutonium

- This is a study to determine the alpha-particle-induced radiation damage and microstructural changes of the stainless steel cover that encloses weapons grade Pu using an ion accelerator to implant Helium to levels that would be received by the stainless steel cover during long term storage of Pu pits and measuring the effects using Neutron Depth Profiling, Rutherford Backscattering and Channeling Analysis, Scanning Electron Microscopy, and Transmission Electron Microscopy.
- Sample preparation equipment was delivered, setup and tested.
- 316-Stainless Steel samples were cut; optimum sample polishing techniques were established; and initial samples were polished.
- Using a surface implanted aluminum sample, preliminary NDP measurements were performed to prepare the facility for stainless steel sample measurements.

- Dr. Hart and Dr. Ünlü participated in a meeting with ANRCP participants and ORNL personnel at Oak Ridge, TN on April 17, 1996.

- Rutherford backscattering analysis was begun using a test implant of 100 keV Ze into Si. The measurement beam was 150 keV He.

1.5.4 Plutonium Disposition

1.5.4.1 Water reactor options for disposition of weapons-grade plutonium

- MOX Data Repository (MOXDAR)
  - A dedicated web server has been established for MOXDAR.

  - A preliminary database model has been completed and implemented. The database has been modeled as a relational database with a simple user interface.

  - Continued our effort to gather data and documents on MOX fuel primarily from domestic sources. We are still trying to get some data from foreign sources, especially the Belgian and the French.

- Design of Within-assembly Enrichment Distributions
  - Spent approximately six weeks in Monroeville using Westinghouse codes to finalize his design of MOX assemblies for use in transition cores (1st, 2nd, and 3rd transition cycles).

  - ABB-CE has reaffirmed its desire for us to fulfill the same function with them.

- Sol-gel Processes for MOX Fabrication
  - Presented results of sol-gel process results at an AIChE meeting.

- Design of Transition-Cycle Loading Patterns
  - Reactor vendors tasked with designing transition fuel cycles from full-U to partial- or full-MOX cores, with no integral burnable absorbers.

    - Westinghouse and ABB-CE expressed great interest in a collaborative effort in which ANRCP would design transition cycles with integral burnable absorbers present.

    - Much of the groundwork needed to perform this task:
      - Obtained verbal commitments from Westinghouse and ABB-CE to provide consulting-type assistance to us at no cost to ANRCP or DOE;

- Obtained consensus among ORNL researchers (Don Spellman, Trent Primm) and MD staff (Pat Rhoads) that the project has value to the program
- Identified student to do the work.

- Design of Multipurpose Reactor
  - Maintained contact with ABB-CE, who affirm their continued interest in this task. They have agreed to collaborate with us at no cost to us or to DOE.

  - Identified contacts at Pacific Northwest Lab, where the design of tritium targets is underway.

- Study of VVER Utilization of MOX Fuel
  - Held discussions with European reactor analysts familiar with VVERs, and obtained some plant-simulation input files from them. Have held discussions with ORNL researchers to determine the scope of work. It appears appropriate for ANRCP to focus its efforts on transient analysis; this should become clearer during the next quarter, with increased clarification of the US-Russian joint study proposals.

  - Participated in the creation of the US-Russian joint study proposals, by providing input to Bruce Bevard and David Moses of ORNL.

- Characterization of Spent MOX Fuel
  - Selected SCALE 4.3 as the principal tool for fuel depletion and spent fuel characterization. The code installed and tested with sample depletion problems. Part of the design and operating data for BWRs (GE) have been obtained. Have been trying to get W and CE PDS reports for similar PWR data but no success yet.

- Evaluation of Analysis Tools
  - Selected two critical experiments programs that were carried out in the US in the sixties that involved mixed-oxide fuels (at the Westinghouse Rector Evaluation Center (WREC) in 1965 and 1967).

    - The first WREC experimental program (1965) consisted of critical experiments with water moderated single-region and multi-region MOX fueled cores to verify the nuclear design of the Saxton partial plutonium core. Measurements included buckling, power distribution, reactivity, control rod worth, soluble poison, and power peaking.

    - The second WREC program (1967) consisted of a series of critical experiments using two plutonium fuels with a variation in the Pu-240 isotopic content and one low enrichment uranium fuel and included buckling, reactivity, and power distribution measurements.

- Have started performing MCNP benchmark calculations using the Saxton experiments. Intend to continue this effort with other calculations and for the various lattices and configurations for both experiments.

- MOX Fuel Demonstration
  - Held extensive discussions with ORNL, MD, and LANL staff to determine the goals of the MOX fuel demo. Obtained a planning grant to determine the details of a multi-capsule test that could be started in the Texas A&M TRIGA as early as this fall. Preliminary calculations have shown that temperature and heat-flux constraints on the fuel, cladding, and pool water can be satisfied simultaneously.
  - Have been asked by ORNL to determine the feasibility (cost & schedule) of building a pressurized water loop in the Texas A&M TRIGA facility.

- Exploration of Gallium Removal
  - Developed solid ties and coordination with LANL, the lead lab on MOX fuel fabrication. Brought Max Roundhill of Texas Tech, who has experience with gallium chemistry, on board.

- Tangible Accomplishments
  - We played a significant role in the Westinghouse design of a MOX fuel assembly for use in transition-cycle cores, and in the design of the transition-cycle loading patterns. We expect to co-author a paper with Westinghouse documenting the non-proprietary portions of this work.
  - We also made further progress toward recognition as a key player in the water-reactor disposition program, and toward tight coordination with the many entities involved (DOE/OFMD, ORNL, LANL, Westinghouse, GE, ABB-CE, AECL). Through our efforts and the efforts of OFMD and ORNL (mainly Pat Rhoads, Sherrell Greene, Trent Primm, and Don Spellman), we have now established a sort of management structure that provides us technical guidance and helps ensure that our efforts are coordinated with the rest of the program. In this structure, our primary point of contact is Don Spellman of ORNL, who also has the responsibility of coordinating the efforts of the fuel vendors. To kick this off, several professors from ANRCP (Naeem Abdurrahman and Kenan Ünlu from University of Texas; Marvin Adams, Fred Best, Ron Hart, Yassin Hassan, Ted Parish, and Dan Reece from Texas A&M) met with ORNL staff in April. We now stay in close contact with Don Spellman and others (such as Trent Primm and Bruce Bevard) at ORNL.

1.5.4.3 Immobilization studies: geologic disposal of immobilized plutonium in deep boreholes

- The experimental apparatus to measure diffusion rates of plutonium surrogates in bentonitic type materials used to measure the diffusion rate of tritium and chloride 36 in a bentonitic shale at a confining pressure of 5000 psi. These results indicate that the transport of ions is significantly retarded. This hydrodynamic retardation of tritium indicates that in microporous rocks such as shales and granites the pore size is small enough to reduce the diffusion rates of ions by several orders of magnitude. The experiments are being repeated for smaller confining stresses to check the influence of microcracks on ion transport.

- Recruited Dr. Suhas Bodwadkar as a Post Doctoral Fellow to conduct research on geochemical modeling for plutonium transport.

1.5.4.7 Thermal and mechanical analysis of the can-in-canister option

- Past efforts have been:
  - developing global models for the thermal response of the glass jet,
  - building low temperature experiments so that void formation can be observed,
  - developing a detailed model to predict void formation, and
  - developing high temperature experiments so that actual glass pours can be made. Progress to date in each category will now be briefly summarized.

- Global Models
  - Global models have been developed so that the temperature of the glass jet, upon impacting the canister or cooler molten glass pool, can be estimated.
  - The "landing temperature" determines the viscosity of the molten glass upon impact, which varies by about several orders of magnitude over the temperature range of the glass pour (1050 °C to 750 °C).
  - Viscosity is an important parameter leading to void formation because (as will be shown) the low temperature experiments have revealed sensitivity of void formation to viscosity.

- Room Temperature Experiments
  - Room temperature experimentation using analogous liquids was developed. Based upon old experiments at Sandia, 42/43 corn syrup was identified as a good analogous liquid due to its extreme variation of viscosity with temperature. This liquid's viscosity can be varied by two orders of magnitude for temperatures ranging from 0 °C to 40 °C. The corn syrup viscosity and density are the same order as that of the glass.
  - An injection apparatus was built to force steady flows of the liquid through a nozzle to produce a jet of controlled thickness (similar to that of the real glass). Dimensionless parameters (of the glass and corn syrup) are approximately matched, since the dimensional parameters are all of the same order of magnitude.

- Experiments investigating jet instability and the void distribution in pours were made with 133 poise, 931 poise and 2590 poise viscosity syrup for a pour rate of 10 cc/s.
  - The jet begins to meander as the higher viscosity liquid impacts the pool. This jet instability entraps voids near the surface of the liquid pool. At the highest viscosity, a tall mound of liquid develops and then collapses, entrapping big voids.
  - Small voids occur in the low viscosity pours, medium voids in the medium viscosity pours, and a wide range of void sizes in the high viscosity experiments.

- Detailed Modeling
  - FIDAP is used to model the experiments. The predicted behavior agrees qualitatively with the behavior observed experimentally.

- High-temperature Experiments
  - An experimental apparatus is being fabricated to allow the same type of experimental observation using molten glass as has been observed with the syrup.

- Tangible Accomplishments
  - The global modeling has shown that engineering models can predict that sensitivity of the jet "landing" viscosity to operating conditions (pouring temperature and pouring rate are the most important parameters).

  - Low temperature experiments have allowed us to observe new and unexpected mechanisms for void formation (a jet instability coupled with a mound collapsing phenomenon). The particular void formation mechanisms are directly related to "landing" viscosity and, in turn, "landing" temperature.

  - The detailed models have revealed similar jet instabilities and void entrapment as observed experimentally. Parametric simulations performed with the detailed model have shown similar sensitivity to the liquid viscosity. The high-temperature experiments have shown whether similar phenomena occurs in the molten glass pour.

  - The combination of global and detailed modeling, along with low and high temperature experimentation, will allow us to develop a global understanding of void formation mechanics and, then, engineering approaches to minimize void formation.

  - Extensive interactions with Lawrence Livermore National Laboratory (LLNL) and Westinghouse Savannah River Company (WSRC). The modeling effort at LLNL is led by Peter Raboin and Werner Stein. The can-in-canister demonstration program and test pours have been coordinated by Nick Kuehn, and the glass characterization has been led by Gene Ramsey.

1.5.5 Cross-cutting Issues

1.5.5.1 Development of nondestructive assay methods for weapons plutonium and MOX fuel safeguards

- The objective is to investigate and develop nondestructive fissile assay (NDA) methods capable of determining the fissile contents of plutonium pits and fresh as well as spent mixed-oxide (MOX) nuclear fuel for verification and safeguards.

- Continued to investigate the technological safeguards issues related to weapons plutonium and mixed-oxide nuclear fuels and to conduct an assessment of current measurement technologies for fissile assay and isotopic determination.
  - A report on safeguards issues and technologies, with emphasis on the light water reactor option, is near completion.

  - Focus of investigation is on the lead slowing down time spectrometer (LSDTS). Have completed the evaluation of the various accelerator and neutron generator options for neutron production that would constitute suitable neutron sources for the LSDTS.

    - Completed scoping neutronics calculations of an idealized spherical LSDTS. These results have shown that a 14 MeV neutron source is a suitable source for the proposed LSDTS.

    - Next phase of computational program will address the neutronics of a more realistic geometry, and will investigate the various design parameters required to determine the engineering feasibility of the proposed system.

- Exploring collaboration opportunities with the DOE National Labs (LANL/NIS-5: Safeguards Science & Technology Group, LANL/NIS-7: Safeguards Systems Group, SNL/05000: National Security Programs). We have scheduled visits to LANL and SNL May 7-9, 1996 to meet with some of these groups.
  - LANL appear to be interested in our work on the LSDTS.

1.5.5.2 Transportation analysis

Transportation of Mixed-Oxide Fuel:

- The objective of this project is the identification and study of transportation-related issues that arise in conjunction with the disposal of spent plutonium.

- The UT-Austin team has continued in its advisory role to the efforts of the Prairie View A&M team in reviewing methodologies for routing hazardous substances, especially nuclear fuels. Several references were shared, and interaction has increased between the two groups.

- The TRANSNET program, developed at Sandia labs, has been obtained and set up at UT-Austin, as it has by the Prairie View and TAMU teams.

- The UT-Austin team continued the development of practical procedures for transport route generation when the network experiences dynamically varying risk characteristics -- the problems relevant to the transport of plutonium, and characterizing the type of solution were formulated.

- Interaction occurred with researchers at Sandia Laboratories in Albuquerque to exchange information on ongoing activities and identify issues of mutual and complementary interest, and establish a framework for continued interaction and exchange.

<u>Modeling for Safe Routing and Transport Surplus Weapons Fissile Materials:</u>

- The A&M Transportation Group has further defined its project to cover the risk analysis associated with the hypothetical transportation of plutonium pits and/or the fabricated MOX fuel to the Savannah River DOE facility and to the Palo Verde Nuclear Generating Station from the Pantex facility.
  - The risk associated with these routes will be evaluated using RADTRAN 4, a transportation radiological risk computer code developed at Sandia National Laboratories.

- Supporting documentation for "Risk Analysis Data for Transportation of HEU and Pu Pits for Tritium Supply" was located.
  - Volumes 2,3, and 4 of the RADTRAN 4 manuals have been received.
    - These manuals have furnished much needed definitions of the variables used in RADTRAN 4, along with RADTRAN 4's input parameters and defaults.

- Access to TRANSNET (of which RADTRAN 4 is part) has been accomplished. TRANSNET also contains the codes HIGHWAY, used to determine the routes along which the shipments will travel, and TICLD, used to assess the transportation individual centerline dose for individuals downwind from hypothetical accident release sites.

<u>Development of Source Term Components for Formation and Initial Release of Plutonium-Containing Aerosol for Conditions and Effects Not Treated by Existing Models for Transportation Incidents:</u>

- Dr. Ervin Copus of Sandia National Laboratories, Albuquerque, New Mexico, is the principal contact with DOE/National Laboratory programmatic interests. He is supported by DOE/MD under the Fissile Materials Disposition Program.

- Dr. Copus pointed out that fire-driven source terms would be much more important for local human exposure than an explosion-driven source term; this source term is not currently available, and if we developed this term, it would be a useful addition to existing modeling capabilities.

    - On 22 March 1996 we discussed the work proposed above and how to coordinate our developments with DOE/MD needs. Dr. Copus pointed out that what we are proposing is work on the local scale, while their work is on the national scale, including classified information.

- On 30 April, traveled to SNL to meet with Drs. Copus and Miller and Mr. Kevin Seager of the Transportation and Packaging Technologies Project.
  - The importance of the information to be developed in this project was pointed out as being governed by order-of-magnitude issues for risk to the public.

    - At present, public health risk from explosive dispersal of plutonium is at least an order of magnitude less that other factors associated with transportation.

    - Thus, for a plutonium fire to have an impact, it would require elevation of the current risk factor by 100.

    - They indicated both metallic and oxide forms of plutonium should be included in calculations of fire-driven aerosol formation.

<u>Investigation of Neural and Fuzzy Logic Analysis Techniques for Surety Issues in Transportation of Fissile Materials:</u>

- See preprint entitled, "Quantitative Assessment for Nuclear Surety in Transportation Applications: Fuzzy and Neural Network Approaches."

1.5.5.3 Use of computer-based molecular modeling to study the microenvironment of plutonium encapsulated in SYNROC

- To support the experimental investigations on the feasibility of immobilizing plutonium by incorporation in the ceramic medium called SYNROC, computer-based molecular modeling studies of the microenvironment of plutonium encapsulated in SYNROC are being undertaken.
  - It had been established that in SYNROC, plutonium can be substituted isomorphically into zirconium, calcium, barium sites depending on the mineral phase and the oxidation state of the plutonium.

  - The first phase of the subproject was to conduct a literature survey to learn the methodology by which computer-based molecular modeling of cation-doped mineral phases can be conducted.

- From this survey, we determined that molecular modeling studies should be feasible for the immobilization of plutonium in SYNROC.

- In the second phase of the subproject, the native crystal structure of zirconolite, the primary mineral phase in SYNROC, was taken from the Cambridge Crystallographic Database.
    - The zirconolite structure is now being studied by molecular mechanics and dynamics simulations. These simulations will provide a model for the behavior of an "ideal" equilibrium system.

    - Plutonium(IV) is being doped randomly into the zirconium sites in this mineral with variations in the ratio of the doped actinide to the bulk crystal. The goal is to determine the effect of such doping on the thermodynamic stability of the system.

    - The computational simulations are being performed using the CAChe molecular modeling system running on a Power Macintosh computer. The molecular dynamics and mechanics simulations utilize the CAChe Dynamics and Mechanics modules, respectively.

<u>1.5.6 Other Material Studies</u>

1.5.6.1 High Explosives:

- Industrial use of High Explosives:
    - A series of design and test experiments have been carried out with designs for both "3-D" (Spherical wave) and "2-D" (plane wave) work pieces for explosive compression of materials to supply sufficient energy in the form of heat and pressure to convert carbon, in the form of C-60, into diamond and to successfully recover the samples.

        - Work has been guided by application of sophisticated "hydro-code" that was acquired from Sandia National Laboratories.

            - Code developed for modeling the explosive compression of plutonium but little or no work has been done to model the decompression cycle since compression of plutonium initiates other energetic processes.

            - Compression of non-fissionable materials is followed by a decompression that imparts strong shear stresses on materials resulting in mechanical failure and dispersion over great distances.

        - Design work has progressed to the state that the 2-D devices can be detonated and the sample recovered. Detonation of the latest iteration of the 3-D design resulted in formation of but two large hemispherical fragments which were split at the point of assembly. We are confident that the next test will allow us to recover an intact sample holder after detonation.

- A collaboration has been established with Hoechst A.G., a supplier of C-60.
  - The arrangement provides cost free samples of C-60 for testing.

  - Sources of "nano-cobalt" and nano-nickel" have been established. These finely divided metals are efficient catalysts for allotropic conversion of C-60 to diamond.

  - Protocols have been established for handling these high surface area metals under inert atmosphere, compressing the samples of metal and C-60 to maximum density and hermetically sealing them in the work pieces under oxygen and water free conditions.

  - Protocols for recovery and analysis of the materials from the explosively compressed work pieces has been established.

  - A series of "2-D" experiments have been statistically designed that will allow establishment of the influence of materials parameters and sample formulation on diamond yield at maximum compression and compression duration.

- Use of High Explosives as a supplemental fuel
  - Met with Amarillo based power company which led to the conclusion that it would be difficult to create a coal analogous fuel formulated from waste high explosives that met the requirements for use in a system that generates temperatures that are above the decomposition point for most organic materials.

  - Have located three generation facilities in Texas that are licensed to burn municipal waste for power generation. These appear to be ideal for combustion of the pelletized fuel we propose to create from the recovered high explosives and recycled plastics.

  - A procedure has been established at Pantex that allows the recovered high explosives to be reduced to rubble using hydrojet machining. Identified a group at the Naval Air Warfare Center Weapons Division, China Lake (NAWCWPNS) that has the experience, equipment and expertise to carry out the experiments required to establish specification limits on the explosive rubble and on the formulated fuel that will insure that it is impossible for the material to detonate. This same group is equipped to establish the thermodynamic properties of the fuel and to establish the detailed nature of the combustion products.

    - Knowledge of the combustion products is required to insure that combustion of the fuel derived from recovered explosives is not a source of new pollutants and that use can be made of the fuel without exceeding currently established and/or planned environmental guidelines.

    - Unfortunately, this entire project has been slowed by an inability to establish a contract between The University of Texas at Austin and NAWCWPNS.

1.5.6.2 HEU vulnerability assessment

- The objective is to assess the environmental, safety, and health (ES&H) aspects associated with DOE's storage and handling of its current HEU holdings to identify and prioritize ES&H vulnerabilities and to identify corrective actions for the safe management of HEU.

- An important aspect of this effort is the gathering and assessment of site-specific information and HEU data. One of these databases is the Operating Experience and Events Database, which contains information concerning HEU-related historical events which have impacted ES&H. This database provides a record of past problems with HEU storage and handling and can therefore serve to guide the current assessment.

  - Have been working on this database for DOE Germantown on behalf of ANRCP since mid-February. Conducted searches of both DOE and international databases which include: Office of Scientific and Technical Information, DOE's OPENNET database, DIALOG database, the International Atomic Energy Agency's INIS database, as well as general internet searches.

  - The result is a 150 page document which contains the abstracts of pertinent material as well as source information. This report has been submitted for publication as an ANRCP document and has also been submitted to DOE-EH in Germantown. It was distributed to the sites at the HEU Vulnerability Orientation in San Antonio on April 8, 1996.

- Successfully completed the HEU Vulnerability Assessment Orientation, held April 9 - 12, 1996 in San Antonio, Texas. The ANRCP played a major role in the planning, development, and execution of this training.

  - The participants at the training included DOE personnel from both headquarters and the area offices; laboratory representatives; independent consultants, and external stakeholders. The total number of participants was estimated to be around 150.

  - The response and feedback from the participants was overwhelmingly positive. Essentially all of the participants indicated in a formal evaluation that the training was useful and effective.

- The ANRCP has offered to DOE a great deal of expertise in the form of experienced personnel who have volunteered their services to the ongoing HEU Vulnerability Assessment. Below is a list of experts whose resumes were submitted to DOE Germantown for the purpose of this Assessment can be found in tab 10.

- Following the successful completion of the training in San Antonio, the real work of the Assessment lies ahead. Future responsibilities include:

  - Dr. R. E. Canaan, will serve as a member of DOE's Home Team, which assesses the 14 Sites which do not receive a Working Group Assessment Team Visit.

- Dr. K.L. Peddicord, will coordinate ANRCP activities and participate directly in site evaluations.

- Dr. W. W. Pitt is also a member of the Home Team and a deputy team leader for scheduled Home Team site visits.

- Dr. R. Bass, will lead TEEX efforts to provide follow-up to the team building/conflict resolution course during the actual site assessments.

1.5.6.3 Fuel Performance of Weapons MOX Fuel:

- The project deals with the modeling of the thermal and mechancial performance of mixed oxide fuel manufactured from weapons plutonium to apply current fuel performance codes to the irradiation of weapons MOX fuel under typical power reactor conditions. The MOX fuel evaluation project focuses on the material performance of weapons MOX fuel in light water reactors. The behavior of this fuel under prototypic power reactor conditions is evaluated through the use of the Comethe fuel performance code from Belgonucleaire.

- During this quarter, the Comethe computer code from Belgonucleaire has been identified as the most appropriate state-of-the-art modeling code existing which incorporates the in-reactor irradiation experience of reactor grade mixed oxide fuel.

  - Several discussions have taken place with Belgonucleaire. The basis of the collaboration which is currently under consideration is that in exchange for the most recent version of the code, the Amarillo Center would contribute to the development of high burnup thermal models which could be incorporated into Comethe.

  - ANRCP could then use Comethe for the analysis of weapons MOX in both U.S. LWR's and Russian VVER-1000 reactors to identify and analyze potential fuel performance issues.
    - The project consists of the following tasks:

    - Mounting the Comethe code on a computer at TAMU

    - Model development of fuel behavior at high burnup conditions which weapons MOX fuel will experience

    - Develop and incorporate as needed models to describe the impact of gallium in weapons MOX fuel

    - Review the modeling of fuel performance in Russia

    - Evaluate the performance of weapons MOX in U.S. LWR's and in VVER-1000 reactors

Appendix 6

Electronic Resource Library

Dr. William Saffady
Digital Library Consultant Report

Attachment A1:
The Digital Library Consultant Report

CONSULTANT'S REPORT ON THE ELECTRONIC RESOURCE LIBRARY FOR PLUTONIUM

Prepared by

William Saffady, Professor
School of Information Science and Policy
State University of New York at Albany
Albany, NY 12222

NOTE: Did not have digitized copy, tried to scan paper copy and insert could not accomplish this task, paper copy accompanying this report

CONSULTANT'S REPORT ON THE ELECTRONIC RESOURCE LIBRARY FOR PLUTONIUM

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PURPOSE AND ORGANIZATION OF THIS REPORT

I have been asked to provide an evaluation of and advice about the Electronic Resource Library for Plutonium proposed by Amarillo College as a national archive for historical, policy, and technical information about nuclear weapons materials. In preparing this evaluation, I did a thorough review of the proposal and related documents provided to me by Amarillo College. I also discussed the proposal and related documents with Amarillo College personnel to confirm my understanding of the project's mission, scope, and technical components. In addition, I performed additional background research, as necessary, to evaluate specific aspects of the proposal.

This report evaluates the following aspects of the proposed Electronic Resource Library: (1) the project's mission, including its intended audience, the need for a computerized storage and retrieval system for plutonium-related documents, and the suitability of the proposed project for a digital library implementation; (2) the project's collection development plan, including its subject scope, procedures for new and archival documents, and prioritization of collection development; (3) the project's technology plan, including proposed online access methods, document storage formats, document conversion methods, and retrieval component; and (4) the project's implementation plan.

SUMMARY OF CONCLUSIONS

- The proposal for an Electronic Resource Library for Plutonium addresses an important, unfilled need in scientific research and public policy. The creation of an authoritative computerized repository of bibliographic data and full-text documents pertaining to nuclear weapons materials will be a significant achievement and a valuable addition to the nation's information resources.

- The mission, subject content, and technical characteristics of the proposed Electronic Resource Library are well suited to a digital library implementation. A well-focused collection of high-impact documents pertaining to nuclear weapons materials will be subject to active reference by a geographically dispersed community of scientific researchers, policy analysts, government decision makers, and other users. This is exactly the type of application for which digital library concepts and technologies are suitable.
- The collection development plan for the proposed Electronic Resource Library is intelligently conceived, clearly articulated, and manageable within the resources and time frames outlined in the proposal. Its subject scope is appropriately defined and fully compatible with the stated mission. The collection development plan encompasses both archival and new documents. Collection development tasks are appropriately prioritized.
- The proposed Electronic Resource Library will employ an effective combination of information management technologies and methodologies to convert pertinent documents to computer-processible formats and make them conveniently accessible to online users.
- The implementation plan for the proposed Electronic Resource Library presents

realistic timelines for the completion of specific tasks.

PROJECT MISSION

The mission of the proposed Electronic Resource Library for Plutonium is clearly stated and addresses a significant, unfilled need in scientific research and public policy. The mission fulfills the requirements of five decades of U.S. legislation concerning the dissemination of scientific and technical information to promote scientific progress and public understanding. The convenient retrievability of accurate, complete information about nuclear weapons materials is critical to the effective understanding and management of nuclear technology. The development and implementation of mechanisms that provide such convenient retrievability are consequently in the national interest.

Audience and Need: The audience for the proposed Electronic Resource Library is both large and broad. It includes scientists and other researchers; policy makers and analysts in government agencies, universities and other organizations; elected officials; educators; and concerned citizens. The concept of a "one-stop-search" for information about nuclear weapons materials will save time and improve the productivity of these users.

At present, plutonium-related information is widely dispersed, both bibliographically and geographically. Bibliographic control (cataloging and indexing) is scattered in various scientific and technical data bases, while the collections of disparate academic and special libraries each contain a subset of the world's plutonium-related publications. Coverage of plutonium-related documents in existing data bases and other indexing sources is limited to bibliographic records and, in some cases, abstracts; the documents themselves are not available online, nor are their library locations noted in bibliographic records.

As a further complication, much important information about nuclear weapons materials is contained in unpublished documents, such as contractor reports, that are difficult for individual researchers to locate. There is no comprehensive repository of plutonium-related documents and no single data base that catalogs such documents. The logistic complications and high cost associated with the creation of such a comprehensive repository argues for its implementation by a single entity rather than fragmentation and duplication of effort by multiple libraries, government agencies, research institutions, or other organizations.

Suitability for Digital Library Implementation: The mission, subject content, and technical characteristics of the proposed Electronic Resource Library are well suited to a digital library implementation in which complete documents are stored in computer-processible form for online access. Digital library concepts and technologies offer significant potential for the enhancement of library services. In particular, improved information retrieval and enhanced document distribution capabilities are widely encountered objectives of digital library implementations. To realize these objectives, however, digital library applications must be well selected. Certain digital library projects undertaken to date have involved limited-interest materials, such as historical manuscripts or rare books from library special collections, that are noteworthy but seldom referenced. Such implementations have little, if any, direct impact on the work of researchers or policy makers. While they may be technically interesting, their value is questionable, particularly in relation to their high implementation costs.

In contrast, the creation of an Electronic Resource Library for Plutonium will be a major accomplishment of unquestionable value. The proposal for an Electronic Resource Library for Plutonium involves a well-focused collection of high-impact documents that will be subject to active reference by a geographically dispersed community of scientific researchers, policy analysts, government decision makers, and other users. This is exactly the type of application for which digital library concepts and technologies are suitable. Information contained in the Electronic Resource Library will be of direct significance and critical utility for scientific research and policy actions. The Electronic Resource Library will be an important addition to the nation's information resources and an excellent implementation of digital library technology.

COLLECTION DEVELOPMENT PLAN

The collection development plan for the Electronic Resource Library is intelligently conceived, clearly articulated, and manageable within the resources and time frames outlined in the proposal. The proposal outlines a meaningful subject scope. It includes provisions for acquiring and distributing new and archival documents, and it defines collection development priorities to maximize value to the Electronic Resource Library's intended audience.

Subject Scope: The subject scope for the proposed Electronic Resource Library is appropriately defined and fully compatible with the stated mission. It will satisfy the information requirements of a broad spectrum of researchers, policy analysts, and other users. The collection development plan encompasses documents from core scientific disciplines, such as nuclear science, physics, and engineering. These documents will provide an authoritative source of technical information about plutonium-related topics. The collection development plan also includes information from additional subject areas, such as biology and environmental science, that address health and safety concerns, policy issues, and other topics pertaining to the storage, handling, and dismantling of nuclear weapons materials.

Archival vs. New Documents: The collection development plan has retrospective and prospective components. It provides for the creation of an archival collection of plutonium-related legacy documents (published and unpublished items currently in existence) of technical or historical significance. It also proposes an electronic publishing program for the dissemination of new documents produced by government agencies, research institutions, and other sources. Funded researchers will provide technical reports and other documents in a prescribed electronic format, thereby eliminating the time and cost associated with document conversion. This plan for the distribution of new research, as a complement to the storage and retrieval of previously published documents, will place the Electronic Research Library in the forefront among digital library implementations and will give scientists, policy analysts, and other users timely online access to the latest information about nuclear weapons materials.

The collection development plan recognizes that the identification, procurement, and indexing of plutonium-related legacy documents will be a significant undertaking. As noted above, such documents are widely dispersed and often obscure. Certain documents will prove difficult to locate. The collection development plan takes a realistic approach to these problems. Significant background research has been done to determine the locations and characteristics of pertinent document collections at DOE/Sandia Laboratory, Linda Hall Scientific and Technical Library, and elsewhere.

Prioritization and Selectivity: The collection development plan has appropriately prioritized the implementation tasks associated with the Electronic Resource Library. The proposal identifies four "tiers" or target audiences for documents maintained by the Electronic Resource Library. The collection development plan will initially concentrate on documents for the tier one group, which consists of scientists and other researchers. Much of the information collected for the tier one audience should also prove useful to the other tiers.

Because there is an enormous body of published works and unpublished documentation about plutonium, selectivity is essential to achieve a manageable scope and an affordable implementation without compromising the proposal's mission. By initially limiting the Electronic Resource Library to unclassified English-language materials, the collection development plan will provide maximum value to prospective users.

TECHNOLOGY PLAN

The proposed Electronic Resource Library will employ an effective combination of information management technologies and methodologies to convert plutonium-related documents to computer-processible formats and make them conveniently accessible to online users. The proposal's technology plan provides for integration with Amarillo College's existing library automation system and with the Internet. Document conversion, storage, and retrieval methods are intelligently conceived. While the Electronic Resource Library will be based on leading-edge technologies, implementation risks are minimized by relying on proven hardware and software components from well-established suppliers and by conforming to national policies and standards that pertain to specific aspects of system operation.

Integration with Online Catalog: Amarillo College's existing information infrastructure will provide an effective foundation for the Electronic Resource Library. The Electronic Resource Library will be integrated with the DRA library automation system that currently serves as the host computer for Amarillo College's online catalog. Data Research Associates (DRA) is a leading supplier of computer systems and related services to medium-size and larger academic and public libraries. The DRA library automation system offers state-of-the-art cataloging and information retrieval capabilities appropriate to the Electronic Resource Library application. MARC-format bibliographic records for plutonium-related documents will be integrated with and searchable through the College's online catalog. The DRA library automation system supports the Z39.50 standard, which permits catalog searches between compliant library automation systems of different vendors. This feature will facilitate inter-library searches for plutonium-related documents.

Internet Access: The Amarillo College online catalog is currently searchable through the Internet, and cataloging records pertaining to plutonium-related documents will be retrievable by interested parties in that manner. The technology plan for the proposed Electronic Resource Library also provides for keyword searching through a homepage on the World Wide Web.

This portion of the technology plan will permit convenient retrieval of plutonium-related documents by scientific researchers, policy analysts or other users in government agencies and universities where Internet access is routinely available.

The AlphaServer 1000A computer to be used as an Internet server is the world's fastest single-processor computer. It is well suited to the Electronic Resource Library implementation. Data Research Associates supplies software that supports Internet access. As a particularly interesting feature, the Electronic Resource Library will employ virtual library concepts to provide access through hypertext linkages to plutonium-related information maintained by computer systems at other Internet sites. This combination of virtual library and digital library concepts will place this project at the leading edge of library automation.

Document Storage Formats: The Electronic Resource Library will store plutonium-related documents in two computer-processible formats: (1) as digitized images generated by document scanners, and (2) as character-coded text. This portion of the technology plan is unusual among digital library implementations and should serve as a model for others to follow. The dual-format storage plan will allow the Electronic Resource Library to address the broadest spectrum of document retrieval requirements. Each computer-processible format has distinctive functionality for scientific researchers or other users; digitized images of plutonium-related documents will preserve the appearance of pages that have illustrations or other graphic elements, while the character-coded format will permit full-text retrieval of documents.

The Electronic Resource Library will rely on hard disk storage for both the document-image and character-coded text versions of plutonium-related documents. While document imaging implementations often utilize optical disk autochangers as mass storage devices, hard disk drives offer much faster retrieval performance -- an important consideration in implementations involving Internet access. In addition, the cost of hard disk storage is lower than optical disk storage in the capacities required by the Electronic Resource Library. In the hardware configuration outlined in the proposal, the AlphaServer 1000a computer will provide sufficient hard disk capacity to accommodate a collection of 10,000 documents. Should greater capacity be required in the future, it can be added at that time.

Document Scanning: Plutonium-related documents acquired for the Electronic Resource Library will be converted to digitized images by scanners to be installed at Amarillo College and Texas Tech. Optical character recognition software will generate character-coded text from the digitized document images.

The scanning equipment proposed in the technology plan is well suited to its intended purpose. For conversion of paper documents to digitized images, the Fujitsu 3099G+ scanner is an excellent choice. Fujitsu is the leading supplier of production-level scanners for document imaging installations. Its products have a well-established reputation for reliable operation. As its main feature, the 3099G+ is a duplex scanner that can digitize both sides of a page in a single pass. Since many plutonium-related documents are two-sided, a duplex scanner is a requirement. The HP ScanJet 4C, which is specified in the proposal as an auxiliary scanner, is a low-cost device that can accommodate bound volumes.

The fact that a substantial percentage of technical reports and other plutonium-related documents are on microfilm, microfiche, or microcards poses a complication for the Electronic Resource Library that is not present in other digital library implementations; to date, such implementations have typically involved paper documents. The technology plan addresses this problem in the most effective way: A multi-format microform scanner will be used to convert those materials to digitized images. The proposal identifies a microform scanner, the SRI-50 from SunRise Imaging, that is well respected in the document imaging industry and appropriate for the Electronic Resource Library implementation. In-house procurement and operation of the microform scanner is the preferred approach to conversion of documents from microfilm, microfiche, or microcards.

As an alternative, the Electronic Resource Library might obtain microform scanning services, on a cost-per-page basis, from a document conversion company, but that approach poses logistical problems. Because there are no microform scanning service bureaus in the Lubbock or Amarillo areas, the microforms would have to be shipped to a service bureau in another location. There is risk that the microforms, which are essential to this project, may be lost or damaged in shipment or at the service bureau's facilities. Further, service bureau charges, on a cost-per-page basis, to digitize a microform collection will likely equal or exceed the cost of purchasing the SRI-50 microform scanner.

Portable Document Format: One of the most interesting and valuable aspects of the technology plan is the proposed use of the Adobe Acrobat series of software products to generate and retrieve documents in image and text formats. Documents, as both digitized images and character-coded text, will be stored in the Adobe Portable Document Format (PDF), a platform-independent format that permits retrieval by a variety of computing devices, including Windows-based computers, Unix workstations, and Macintosh systems. This is an important consideration for a document collection to be accessed through the Internet by a geographically dispersed user base working in an undetermined and uncontrolled variety of computer environments, including systems to be developed in the future.

For a digital library implementation to be truly effective, documents must be stored in a computer-processible format that is accessible by its intended audience. As noted above, the Portable Document Format will achieve that objective for the Electronic Resource Library. Further, the document storage format selected for a digital library implementation must remain viable for retrieval purposes for the foreseeable future. Otherwise, conversion of the document collection must be repeated, at considerable time and cost, at multi-year intervals. As a $600-million company with a large customer base, Adobe has the resources to support and enhance its products. Adobe software and the Portable Document Format are currently utilized in document retrieval and distribution applications implemented by government agencies, corporations, and information publishers. Examples include the Internal Revenue Service, the Centers for Disease Control and Prevention, the Department of Commerce, the Department of Defense, United Airlines, Hughes Aircraft, Intel Corporation, 3M Company, and R.R. Donnelly Financial. Some of these applications involve Internet access. Adobe's software capabilities are tested and proven in such implementations, and Adobe is committed to enhancing its Internet-related components. As a significant additional feature, the Adobe Portable Document Format is compatible with the industry-standard Group 4 compression method for document image storage.

<u>Indexing and Retrieval Component</u>: As noted above, the Electronic Resource Library will catalog plutonium-related documents in the full MARC format. It will also support full-text indexing and retrieval of plutonium-related documents. Adobe Acrobat software provides an excellent full-text retrieval component that is licensed from Verity Corporation, a leading developer of document retrieval technology. It supports a full range of text retrieval features plus hypertext linkages, bookmarking, thumbnail page displays, and other state-of-the-art capabilities that Internet users increasingly expect. The displays and printers proposed for retrieval workstations in the technology plan are appropriate to their intended purpose.

IMPLEMENTATION PLAN

The proposal for the Electronic Resource Library establishes the foundation for an effective implementation. As noted above, the project scope is clearly articulated and manageable within the proposed resources. Project investigators have identified the brands and models of hardware and software components required for the implementation. The multi-year implementation plan and project management timelines presented in the Electronic Resource Library proposal are intelligently conceived. The major implementation tasks are clearly delineated and well understood. The tasks can be completed with the proposed resources. Effort, time, and cost estimates for document preparation, scanning, data entry, and supervision are realistic.

Attachment A2:
The Digital Library Profile for the Electronic Resource Library prepared for Dr. Saffady's review

Note: This is the document the ERL management completed and submitted to the consultant along with numerous other documents that he studied and made recommendations and upon which he based his final report..

The Electronic Resource Library (ERL)
Line Item Application of Saffady *Digital Libraries* review
Subset: Image-Based Implementation

1. Definition and system overview

The Electronic Resource Library for Plutonium (ERL)will feature an archive of digitized legacy documents and technical reports as well as currently released information from governmental agencies, institutions and other sources. These documents will be accessible through a keyword index on the Internet Homepage for the ERL as well as through a Z39.50 compliant online catalog containing full MARC records. Documents will be stored in PDF image as well as text files to enhance the retrievableness and usability of the information with varied client software and hardware capabilities

1.1. Customized configurations

NONE

1.2. Preconfigured systems

Server

The server has been specified by Data Research Associates to be compatible with the software requirements for the Z39.50 compliant search strategy. It will include DRAWEB and DRAFIND software for this purpose. Specifications for this server are as follows:

DEC Alpha 1000A Internet Server, 266mhz, 2MB cache CPU, 320MB memory, integrated SVGA graphics, 1.44 MB floppy, 600MB CD-Rom, mouse and keyboard, 32.2 GB hard disk storage, 4mm DAT tape loader. Windows NTS , Serverworks and Netscape Communications Server Licenses.

1.3. Imaging software packages

Adobe Acrobat family of products will be used to create and read high quality electronic documents using virtually any word-processing, page-layout or graphics program. Acrobat Capture uses page recognition to precisely preserve the entire page. It coverts the paper document into Adobe's portable document format (PDF) file that is fully searchable and compressed. It does not require a dedicated operator or specialized training. Acrobat Distiller easily turns postscript language file originally prepared for print into PDF files. Acrobat Exchange allows sharing PDF files by building in navigational links, annotations and security. Acrobat Search provides full-text search capabilities for PDF files that have been indexed with Acrobat Catalog. VerTec Solutions "VerZions" is a network-based software program designed to automate and manage the Adobe Acrobat family of products. VerZions includes Queue Manager, Capture Server and Distiller Server, and QA Server. Reviewz is a quality assurance program which enhances the productivity of the review process and the resulting image. Other tools include Job Ticket Processor, Pagemapper, and Pagefinder.

1.4. Image-enabled applications

Purchasing Adobe Acrobat family of products to digitize legacy materials. DRAFIND and DRAWEB are client and server tools to access image and fulltext databases with bibliographic records contained in the DRA/Atlas library automation system at Amarillo College/ Harrington Library Consortium, and Texas Tech University Libraries.

2. Imaging system components

2.1. Computer system

Adobe software is currently in 16 bit format although it is being converted to 32 bit. The initial configuration will include a P166 Intel based server for the Adobe Catalog software that will create and execute the full text search index. This server will share disk drives with the Dec Alpha 1000a server. When the Adobe Catalog software is ported to the Alpha hardware, the index will be moved to that system. All servers and workstations will be using Windows NT operating system software and networked with NT via Ethernet.

2.2. Document scanning workstations

These workstations will be P166 Intel based machines. This is the optimum configuration recommended by VerTec for the Adobe/VerTec software. Specifications include: 128mb memory, 256k cache, 9GB fast SCSI-2 hard drive, 1.44 floppy, 6X CD-Rom drive, 16 bit sound card, 21" .28NI SVGA monitor, 3 PCI and 3 ISA and 1 ISA/PCI slots, PCI Ethernet card to meet demand for higher bandwidth and faster access to larger databases and high-speed real-time data access devices.

2.2.1. Document scanner

Three scanner types will be used. For standard sized single and duplex documents, the Fujitsu 3099G+ will be used. This duplex scanner has capacity to scan 100 images per minute in duplex mode. It utilizes two IPC II boards to maximize image quality and reduce scan errors. Selectable resolutions capabilities ranging from 200 to 400 dpi allows fine tuning for optimum throughput and quality and includes a 500 sheet ADF. For non standard documents, a HP ScanJet 4C will be used. It will also have the transparency adaptor for film up to 8.5 X 11.7 inches. Scan resolutions can be selected ranging from 200 to 600 dpi. It features a 50 sheet ADF. For microfilmed documents, the SunRise Imaging SRI-50 scanner will be used. This scanner will process film, fiche and cards giving maximum flexibility to accommodate form type. It will process 80 to 130 ppm at 200 dpi depending on film type.

2.2.2. Inspection and data entry device

Vertec VerSions software *QA Server* runs on any workstation(s) where Acrobat Capture Reviewer and VerZions' ReviewZ module have been installed. The QA server will list the document files awaiting correction and run either Acrobat Capture's Reviewer or VerZions' ReviewZ to check and correct an ACD file for conversion errors. REVIEWZ allows a workstation operator to quickly correct text "suspects" in a captured document. It does this by presenting a column of the raster (scanned) images which are below Capture's confidence threshold along with a corresponding "best guess" in the opposite column. The user can then accept, change, or delete the right column entry.

2.3. Image-capable retrieval workstations

2.3.1. Bit-mapped displays

The P166 Intel based machines with 21" monitors will be equipped with a Diamond Stealth 64 Video VRAM with 4MB video adapter card for high resolution video display. The Alpha 1000a server comes with an integrated SVGA graphics board.

2.3.1. Printers

2 HP LaserJet 4 Plus printers will provide necessary output at each of the two scanning sites.

2.4. Storage devices and media

The Alpha 1000a server has 64MB plus 256MB memory modules with one 2.1 GB 3.5" SCSI disk pack. Each disk is mounted in a single 3.5" storage building block snap in carrier. A 4mm DAT tape loader in a table top enclosure contains a four cartridge magazine providing 32 GB storage capacity. It also has a RRD45 4x SCSI CD-ROM drive with 600-MB capacity. Seven 4.3 GB 3.5 disk drives with a 16 bit single-ended "Wide" SCSI interface mounted in a wide modular storage snap-in carrier is also included in the Alpha package.

3. Calculating storage requirements

The basic formula -- $s = \frac{(H \times R) \times (W \times R) \times B}{8} \times \frac{1}{C}$

3.1. Electronic Resource Library (ERL)

H= page height in inches or millimeters ___11___
W=page width in inches or millimeters ___8.5___
R=scanning resolution in dots per inch mil___200___ *In most cases identical for horizontal and vertical dimensions
*200 or 300 dpi
B=number of bits that encode each dot ___2___
Binary mode =1
Grayscale mode =2
Color mode =24
C = Image compression factor___4___
Purpose

Most common algorithm: Group 4
Variable nature of compression
For library test pages, average of 9:1, median of 8:1 at 200 dpi; average of 13:1, median of 11:1 at 300 dpi.

3.2. ERL Collection Analysis

NOTE: The total universe of documents to be scanned can only be estimated, since we are still trying to analyze bibliographic databases to determine the full count. We will use the 10,000 figure for planning purposes. Also, since the Adobe imaging software produces both a text file and a PDF file, we are using the combined estimates for image and text to produce a benchmark figure to plan against.

ERL gov doc example:
Image

10,000 technical reports averaging 35
single-spaced, typewritten pages each
20 GB at 200 dpi, G.4

Text
10,000 technical reports averaging 35 pages each with 3200 characters per single spaced typewritten page 2.8 GB with full text indexing

Total initial storage needed for ERL project 22.8 GB
This leaves ample storage for the next three years of scanning
3.2.Storage Device ERL hard disk devices totaling <u>41.2 GB</u>
3.3.Comparison with text storage requirements ERL growth factor of <u>18.4 GB</u>
4. Document Conversion
4.1.Special problems of library materials
4.1. Bound volumes
We estimate that:
40% of Tech Gov Doc collection is paper
60% of Tech Gov Doc collection is microfiche
98% of AC DOE Reading Room Collection (1990-) is paper.
2% is computer files on 1.44 floppy.

Pre 1990 is 100% microfiche

4.2.
Size variations
90% of paper is 8.5x11 or smaller
10% of microform is card fiche
90% is film fiche

4.3.
Two-sided pages
90% of paper documents are two-sided
100% of fiche will be one sided

4.4.Varied typographic characteristics
60% of microfiche will be good scans
30% of microfiche will be fair scans
10% of microfiche will be hard to read
Same percentage for paper

4.5.
Compound documents
First set of documents does not contain multiple formats

4.2.Fixed Costs:

4.2.1.Equipment and software
Data Research Associates, Inc. is a turn-key vendor for Digital Equipment providing automated, integrated, multi-type library software packages.

4.3.Labor-based, variable cost components
4.3.1.Document preparation
4.3.1.1. Remove from storage locations
4.3.1.2. Transport to data entry area
Retrieval of the source documents at the Texas Tech site will be two-fold. The scanning location will be near the government document collection which contains 100% of the first document sets, 40% in paper and 60% in microform. The list of SuDoc numbers is already compiled as is the GPO, NTIS and NSA titles. Currently two graduate students are pulling microfilm and fiche titles that fit our selection criteria and those will be ready to scan when production begins.

Retrieval of the source documents at Amarillo College Library for the first document sets will be contained on CD (15%) and paper (85%). The paper collection is in same building as the scanning production center.

4.3.1.3. Check for completeness
The electronic data and the microfilm and fiche data will be assumed to be complete. The paper collections will be paged through to determine completeness prior to the scanning process.

4.3.1.4. Prepare for scanning
Unbinding
Photocopying

4.3.1.5.Disposition after conversion
The paper collection in the government document collection at Texas Tech is mostly stapled reports and it has been determined that an in-house tool can be used to remove and replace the staples before and after the scan.

The paper collection as Amarillo College is all in 3-ring binders which will accelerate the process. For this first subset of documents it estimated that only a very few titles will have to be photocopied. In later subsets, documents that are interlibrary loaned or borrowed will need to be photocopied if dismantling them would be disfiguring to the document.

The items would be returned to the shelves by the shelvers at Amarillo College. Restapling would be necessary at Texas Tech. Shelvers would refile The microforms and the ILL department would return items borrowed.

4.3.2.Image capture
4.3.2.1.Scanning
4.3.2.2.Inspection
4.3.2.3.Rescanning, as necessary

4.3.3.Data entry and verification
Two highspeed workstations will be used at TexasTech for the scanning of paper or film, with verification and inspection done from either workstation. One highspeed workstation and a dedicated stand alone fiche scanner will be in operation at Amarillo College with inspection, verification, and correction done from the highspeed workstation only.

4.3.4.Supervision
Full time supervisors will be employed at both scanning sitesto oversee the work in order to produce a high quality database.

4.4.Image capture methodologies
4.4.1.In-house scanning
Please reference the **Electronic Publishing Model**

5. Calculating implementation costs for image-based digital libraries: Worksheet and example.

Worksheet 2: Image-Based Digital Library Implementation
Part A: Start-up Costs --Computer Hardware and Software

A1.Purchase price of electronic document imaging hardware and software components used exclusively for digital library implementation.
$242,335

A2.System-related charges not included in line A1.
$ 16,245

Lease-to-purchase Microform scanner

A3.Cost of site preparation for system installation.(LAN drops)
$ 2,500

A4.Purchase price of imaging hardware and software components
N/A shared with other applications.

A5.Percentage of amount on line A4 attributable to digital library
N/A implementation.

A6.Amount on line A4 multiplied by decimal value on line A5.
N/A

A7.Total of amounts on lines A1, A2, A3, and A6; this is the
$261,080 startup cost for purchased hardware and software.

Part B: Annual Fixed Costs (calculated for first 3 years of project)

B1.Annual lease or rental payments for imaging hardware and software and software used exclusively for digital library implementation.
Depreciation costs
3 Years
$ 81,612

B2.Annual cost of maintenance contracts for imaging hardware and software used exclusively for digital library implementation.
First three years maintenance in purchase cost
$0

B3.Annual value of floor space occupied by imaging hardware used
N/A exclusively for digital library implementation.

B4.Annual lease or rental payments for imaging hardware and software shared with other applications.
N/A

B5.Annual cost of maintenance contracts for imaging hardware and software shared with other applications.
N/A

B6.Annual value of floor space occupied by imaging hardware shared with other applications.
N/A

B7.Total of amounts on lines B4, B5, and B6.
$81,612

B8.Percentage of amount on line B7 attributable to digital library
100% implementation.

B9.Amount on line B7 times decimal value on line B8.
$81,612

B10.Total of amounts on lines B1,B2,B3, and B9; this is the annual fixed cost for a digital library implementation.
$81,612

Part C: Start UP Costs --Document Preparation for Backfile Conversion

C1.Number of documents to be converted to electronic images.
1720 Benchmark figure

C2.Time, in minutes, to prepare one document for conversion.
5min.

C3.Time, in minutes, to return one document to original location following conversion.

5min.

C4.Total of amounts on line C2 and line C3.
10min.

C5.Amount on line C1 times amount on line C4.
17200

C6.Amount on line C5 divided by 60; this is the number of hours required for document preparation.
287hrs

C7.Hourly wage rate for employees performing document preparation
$ 7.00

C8.Amount on line C6 times amount on line C7.
$2,007

C9.Cost of equipment and supplies required for backfile preparation.
$9,800

C10.Total of amounts on lines C8 and C9.
$11,807

C11.Amount on line C10 times 0.1; this is the cost of supervision for backfile preparation.
$ 1,180

C12.Total of amounts on line C10 and line C11.
$12,987

C13.Enter contingency percentage as decimal value.
.05

C14 Amount on line C12 times decimal value online C13.
649

C15.Total of amounts on line C12 and line C14; this is the total cost of backfile preparation.

$13,636

Part D: Start-up Costs - Backfile Conversion by In-House Scanning

D1.Number of documents to be converted to electronic images, from line C1.
1720 Benchmark figure

D2.Average number of pages per document.
150

D3.Amount on line D1 times amount on line D2.
258,000

D4. Percent of backfile conversion to be performed by in-house scanning; f 100 percent enter 1.00, if zero, go to Part E.
1.00

D5.Decimal value on line D4 times amount on line D3; this is thenumber of pages to be converted by in-house scanning.
258,000

D6.Percent of pages to be photocopied for scanning; if 100 percent, enter 1.00, if no pages will be photocopied, enter zero and go to line D10.
.10

D7. Amount on line D5 times decimal value on line D6.
2580

D8. Photocopying cost, in cents, per page.
.10

D9. Amount on line D7 times decimal value on line D8.
258

D10. Average number of pages to be scanned per hour, including make-ready time, image inspection, and image recording.
60

D11.Number of scanning hours per day.
16

D12. Amount on line D10 times amount on line D11.
960

D13. Amount on line D5 divided by amount on line D12.
269

D14.Amount on line D13 divided by 250
1.1

D15.Desired time, in years, to complete backfile conversion.
1.3

D16. Amount on line D14 divided by amount on line D15; if decimal value, round up to next integer.
1

D17.Number of scanning workstations included in lines A1, A4, B1, and B4
4

D18. Amount on line D16 minus amount on line D17; if zero or negative value, go to line D21.
-3

D19.Cost per scanning workstation, including hardware and software.
0

D20. Amount on line D18 times amount on line D19.
0

D21.Amount on line D5 divided by amount on line D10.
4300

D22.Hourly wage rate for scanning workstation operator.
$7

D23.Amount on line D21 times amount on line D22.
$30,100

D24.otal of amounts on lines D9, D20, and D23.
$30,358

D25. Amount on line D24 times 0.1; this is the cost of supervision for backfile conversion by in-house scanning.
$ 3,035

D26.Total of amounts on line D24 and line D25.
$33,393

D27.Enter contingency percentage as decimal value.
.05

D28.Amount on line D26 times decimal value on line D27.
$ 1,670

D29.Total of amounts on line D26 and line D28; this is the total cost of backfile conversion by in-house scanning.
$35,063

Part E: Not Applicable

Part F: Start-Up Costs - Document Indexing, URL Assignment for Backfile Conversion.

F1.Number of documents to be converted to electronic images, form line C1
.1720 Benchmark figure

F2.Percentage of backfile for which indexing, cataloging, and URL assignment is required.
100%

F3.Amount on line F1 times decimal value on line F2.
1720

F4.Average indexing, URL assignmenttime per document, in minutes.
10 min

F5.Amount on line F3 times amount on line F4.
17,200

F6. Amount on line F5 divided by 60; this is the backfile I.C.U. time in hours
286hrs

F7. Hourly wage rate for indexing personnel.
$7.00

F8. Amount on line F6 times amount on line F7; this is the labor cost for document indexing.
$2,006

F9.Average number of characters per data base record.
300

F10.Amount on line F1 times amount on line F9.
516,000

F11.Key-entry rate, in characters per hour.
10,000

F12 Amount on line F10 divided by amount on line F11; this is the number of hours required for initial key-entry of data base records.
51.6hrs

F13. Multiply amount on line F12 by 2.15 if double-keying will be used or by 1.6 if sight verification will be used; if decimal value, roundup to next integer.
82.56

F14. Hourly wage rate for I,C,U personnel.
$10.00

F15.Amount on line F13 times amount on line F14; this is the labor cost of data entry.
$825.00

F16. Number of operating hours per data entry workstation per day
16

F17.Amount on line F16 times 250.
4,000

F18.Amount on line F13 divided by amount on line F17.
.02

F19.Desired time, in years, to complete backfile conversion.
1

F20.Amount on line F18 divided by amount on line F19; if decimalvalue, round up to next integer; this is the number of workstationsrequired for entry of data base records.
.02

F21.Number of key-entry workstations included in lines A1, A4, B1, B4, D18, and E24.
2

F22. Amount on line F20 minus amount on line F21; if zero or negative value, go to line F25.
-1.98

F23. Cost per data entry workstation, including hardware and software.
0

F24.Amount on line F22 times amount on line F23.
0

F25. Total of amount on lines F8, F15, and F24.
$2,831

F26. Amount on line F25 times 0.1; this is the cost of supervision for document indexing and key-entry of index data.
$283

F27.Total of amounts on line F25 and F26.
$3,114

F28. Enter contingency percentage as decimal value.
0.05

F29.Amount on line E27times decimal value on line F28.
$155.70

F30. Total of amounts on line F27 and F29. This is the total cost of indexing and data entry for backfile conversion.
3269

Part G: Start-up costs -- Backfile Storage Requirements

G1.Number of images in backfile, from line D3
258,000

G2. Number of document images per megabyte.
30

G3.Amount on line G1 divided by amount on line G2; this is the image storage requirements in megabytes.
8,600mg

G4. Unused online or nearline storage capacity in megabytes, included in lines A1, A4, B1, and B4.
18.4GIG

G5. Amount on line G3 minus amount on line G4; if zero or negative value, go to line G8.
No additional storage needed
-18,391,400

G6.Cost per megabyte for online or nearline storage.
0

G7. Amount on line G5 times amount on line G6.
0

G8. Cost per megabyte for offline storage of backfile security copies.
0.10

G9. Amount on line G3 times amount on line G8.
$ 860

G10. Number of security copies desired.
1

G11.Amount on line G9 times amount on lin G10.
$860

G12. Total of amounts on lines G7 and G11; this is the cost of backfile storage for document images.
$860

G13.Data entry workload, in characters, for document image backfilefrom line F10.
516,000

G14. Amount on line G13 divided by 1,000,000; this is the size of thebackfile of data base records in megabytes.
_.52

G15.Amount on line G14 times 2; this is the storage requirement for data base records in megabytes, including overhead.
_1.0

G16.Unused online storage capacity in megabytes, included in lines A1,A4, B1, and B4.
18.4GIG

G17. Amount on line G15 minus amount on line G16; if zero or negative value, go to line G20.
No additional storage needed

G18.Cost per megabyte for online storage of data base records.
_0

G19. Amount on line G17 times amount on line G18.
_0

G20. Cost per megabyte for offline storage of backfile security copies of dat base records.
$.65

G21 Amount on line G15 times amount on line G20; if decimal value, round up to next integer.
_$1

G22. .Number of security copies desired.
_1

G23. Amount on line G21 times amount on line G22.
$1

G24. Total of amounts on line G19 and line G23; this is the cost of backfile storage for data base records.
$1

G25 Total of amounts on line G19 and G24; this is the total cost of backfile storage for document images and data base records.
$861

Part H: Annual Variable Costs = Document Scanning

H1. Number of documents to be converted to electronic images per year.
4000

H2. Time, in minutes, to prepare one document for conversion.
10min

H3. Amount on line H1 times amount on line H2.
40,000

H4. Amount on line H3 divided by 60; if decimal value, round up to next integer.
667hrs

H5. Hourly wage rate for employees performing document preparation

$7.00

H6. Amount on line H4 times amount on line H5; this is the annual cost of document preparation.$4,666

H7. Average number of pages per document.
150

H8. Amount on line H1 times amount on line H7; this is the number of pages to be scanned annly
600,000

H9. Percent of pages to be photocopied for scanning; if 100 percent enter 1.00; if zero, got to line H13.
10%

H10.Amount on line H8 times decimal value on line H9.
6000

H11.Photocopying cost, in cents, per page.
.10

H12.Amount on line H10 times amount on line H11.
$600

H13.Percentage of annual documents to be converted by in-house scanning; if 100 percent, enter 1.00; if zero, go to line H 19
1.00

H14. Amount on line H8 times decimal value online H13; this is the total number of pages to be converted annually by in-house scanning.
600,000

H15.Average number of pages to be scanned per hour, including make- ready time, image inspection, and image recording.
60

H16. Amount on line H14 divided by amount online H15.
10,000

H17. Hourly wage rate for scanning workstation operator.
$7.00

H18. Amount on line H16 times amount on line H17; this is the annual labor cost for in-house scanning.
$70,000

H19. Percentage of annual documents to be converted by a scanning service bureau; if 100 percent, enter 1.00; if zero, go to line H32.
0

H20. Decimal value on line H19 times amount on line H8; this is the total number of pages to be converted by scanning service bureau
0

H21.Service bureau scanning charge per page.

0

H22.Amount on line H20 times amount on line H21.
0

H23.Other service bureau charges
0

H24. Packing and shipping costs for sending documents to service bureau.
0

H25. Percentage of service bureau work to be inspected by library if 100 percent, enter 1.00.
0

H26. Amount on line H20 times decimal value on line H25.
0

H27.Average time, in seconds, to inspect each image.
0

H28. 3,600 divided by amount on line H27: this is the number of images to be inspected per hour.
0

H29. Amount on line H26 divided by amount online H28; this is the number of hours required for image inspection.
0

H30. Hourly wage rate for employees performing image inspection.
0

H31. Amount on line H29 times amount on line H30.
0

H32. Total of amounts on lines H6, H12, H18, H24, and H31.
$75,266

H33. Amount online H32 times 0.1; this is the annual cost of supervision for document conversion. $ 7,526

H34. Amount on line H32 plus amount online H33.
$82,792

H35. Enter contingency percentage as decimal value.
0.05

H36. Amount on line H34 times decimal value online H35.
$ 4,139

H37. Total of amounts on lines H22,H23, H34, and H36; this is the total annual variable cost of document conversion.
$86,931

Part I: Annual Variable Costs - Document Indexing and Data Entry

I1. Number of documents to be converted to electronic images annually, from line H1.

4,000

I2. Percentage of annual documents for which indexing is required; if 100 percent enter 1.00; if indexing is not required, go to line 19.
_1.00

I3. Amount on line I1 times decimal value on line I2.
_4,000

I4. Average indexing, URL assignment time per document, in minutes.
_10min

I5. Amount on line I3 times amount on line I4.
40,000

I6. Amount on line I5 divided by 60; this is the annual document indexing time in hours.
_667hrs

I7. Hourly wage rate for indexing personnel.
_$7.00

I8. Amount on line 16 times amount on line I7; this is the annual labor cost for document indexing.
$4,667

I9. Average number of characters per data base record.
__300

I10._Amount on line I1 times amount on line I9; this is the annual data entry workload, in keystrokes.
1,200,000

I11 Key-entry rate, in characters per hour.

__10,000

I12.Amount online I10 divided by amount on line I11.
__120__

I13. Multiply amount on line I12 by 2.15 if double-keying will be used or by 1.6 if sight verification will be used; this is the number of hours required annually for key-entry, including verification and error correction.
__192 hr

I14. Hourly wage rate for data entry personnel.
_$7.00

I15. Multiply amount on line I13 by amount online I14; this is the annual labor cost of key-entry for data base records.
__$1,344

I16. Total of amounts on line I8 and line I15.
__$6,011

I17. Amount on line I16 times 0.1; if decimal value, round up to next integer; this is the annual cost of supervision for document indexing and key-entry of data base records.

_$601

I18. Amount on line I16 plus amount on line I17.
_$6621

I19. Enter contingency percentage as decimal value.
_0.05

I20. Amount on line I18 times decimal value on line I19.
_$30.00

I21. Total of amounts on line I18 and I20; this is the total annual cost of indexing and key entry for data base records.
_$6651

Part J: Additional Equipment Costs - Scanning, Inspection, and data Entry

J1. Number of hours required per year for document scanning, from line H16.
_10,000

J2. Number of scanning hours per workstation per day.
_16

J3. Amount on line J2 and 250.
_4,000

J4. Amount on line J1 divided by amount on line J3; if decimal value, round up to next integer.
_3_

J5. Number of unused scanning workstations included in lines A1, A4, B1, BH4, and D18.

_2_

J6. Amount on line J4 minus amount on line J5; if zero or negative value, go to line J9.
_1_

J7. Cost per scanning workstation, including hardware and software.
_$15,000

J8. Amount on line J6 times amount on line J7.
_$15,000

J9. Number of hours of image inspection per year, from line H29, if line H29 is blank, enter zero and go to line J17.
_0_

J10. Number of inspection hours per workstation per day.
_0_

J11. Amount on line J10 times 250.
_0_

J12. Amount on line J9 divided by amount on line J11; if decimal value, round up to next integer.
__0__

J13. Number of unused image inspection workstations included in lines A1, A4, B1, B4, D18, and E24.
__0__

J14. Amount on line J12 minus amount on line J13; if zero or negative value, go to line J17.
__0__

J15. Cost per image inspection workstation, including hardware &software
__0__

J16. Amount on line J14 times amount on line J15.
__0__

J17. Number of hours required per year for key-entry of data base records, from line I13.
__192__

J18.Number of data entry hours per workstation per day.
__8__

J19. Amount on line J18 times 250.
__2000__

J20. Amount on line J17 divided by amount on line J19; if decimal value, round up to next integer.
__.10__

J21. Number of unused data entry workstations included in lines A1,A4,B1,B4,D18,D24, and F22.
__-.13__

J22. Amount on line J20 minus amount on line J21; if zero or negative value, go to line J25.
__-.03__

J23.Cost per data entry workstation, including hardware and software.
__0__

J24. Amount on line J22 times amount on line J23.
__0__

J25. Total of amount on lines J8, J16, and J24; this is the cost of additional workstations for scanning, image inspection, and data entry.
__$15,000__

Part K -- Additional Storage Costs

K1. Number of images added to digital library implementation per year, from line H8.
__600,000__

K2. Number of images to be stored per megabyte.
__30__

K3. Amount on line K1 divided by amount on line K2; this is the annual additional image storage requirement in megabytes.

20.000mg

K4. Unused online or nearline storage capacity, in megabytes included in lines A1, A4, B1, B4, and G5.
18.391.400mg

K5. Amount on line K3 minus amount online K4; if zero or negative value , go to line K8.
-18.371.400mg

K6. Cost per megabyte for online or nearline storage.
0

K7. Amount online K5 times amount on line K6.
0

K8. Cost per megabyte for offline storage of security copies.
$0.12

K9. Amount online K8 times amount on line K3.
$2.400

K10. Number of security copies desired.
1

K11. ,Amount on line K9 times amount on line K10.
$2.400

K12. Total of amounts on lines K7 and K11; this is the additional annual storage cost for document images.
$2.400

K13. Quantity of data base records, in characters, to be added to digital library implementation annually, from line 110.
1.200.000

K14. Amount on line K13 times 2; this is the annual storage requirement, in bytes, for data base records, including overhead.
2.400.000

K15. Amount online K14 divided by 1,000,000.
2.4

K16. Unused online storage capacity in megabytes, included in lines A1,A4, B1, B4, and G17.
-18.371.400mg

K17.Amount online K15 minus amount on line K16; if zero or negative value, go to line K20.
No additional storage needed

K18.Cost per megabyte for online storage of data base records.
0

K19. Amount on line K17 times amount on line K18.
0

K20. Cost per megabyte for offline storage of security copies of data base records.

__$.65

K21. .Amount on line K15 times amount on line K20; if decimal valueround up to next integer.
__4__

K22. Number or security copies desired.
1

K23. Amount on line K21 times amount on line K22.
__4_

K24. Total of amounts on line K19 and line K23; this is additional annual storage cost for data base records.
__0_

K25. Total of amounts on line K12 and K24; this is the annual storage costs for document images and data base records.
_$2,400

Part L--Summary of Costs on Annualized Basis

L1.Start-up cost for purchased computer hardware and software, fromline A7
$261,080

L2.Cost of computer storage for backfile conversion, from line G25.
$ .861

L3.Cost of additional scanning, image inspection, and data entry equipment from line J25.
$ 15,000

L4. Total of amounts on lines L1, 12, and 13.
$276,941

L5. Useful life, in years, of computer hardware and software components, including storage.
__5yrs_

L6.Amount on line L4 divided by amount on line L5; this is theannualized cost of purchased computer hardware and software including storage for document backfile.
$ 55,388

L7. Total of amounts on lines C15, D29, E32, and F30; this is thetotal cost of backfile conversion.
$ 51,968

L8. Useful life, in years, of converted backfile.
__10_

L9. Amount on line L7 divided by amount on line L8; this is the annualized cost of backfile conversion.
$5,196_

L10. Annual fixed costs, form line B10.
$ 81,612

L11. Annual variable cost of document conversion, from line H37.
$ 86,931

L12. Annual variable cost of document indexing and data entry, from line I21.
$ 6,651

L13. Annual cost of additional computer storage, from line K25.
$ 2,400

L14. Total of amounts on line K7, K19, and L3.
$ 1,500

L15. Amount on L14 times 0.15.
$ 225

L16. Total of amounts on lines L6, L9, L10, L11, L12, L13, and L15, this is the annualized cost of a digital library implementation based on electronic document imaging technology.
$238,403

Appendix 3

Electronic Resource Library

DOE Reading Room Survey

Attachment B:
The DOE Reading Room Survey

Survey of DOE Reading Rooms and Services

May, 1996

Doe Reading Room	Estab.	# Titles	Cataloged	Locally?	OCLC	ILL	Montly Use	Acquisition Source	Full Text?	Manager	Collaborate
Alburq. Operations Office	1990	30 boxes	no	Written List	no	no	no entry	no entry	no	(19)	yes
Amarillo College	1990	1150	yes	yes	OCLC (8)	OCLC (8)	50-100	All (11)	Biblio. (15)	Karen MacIntosh	yes
University of Chicago, Opr. Office	1992	5,500	no	no(4)	no	no	3	(9)	Bibliographic	Shelly Hankins	yes
Los Alamos National Lab	1990	300+	yes	WP list	no	no	150-200	All	no	Carmon Rodriques	yes
Nevada Operations Office	1995*	300,364	yes	yes(5)	Opennet(7)	no	no stats	All (10)	Some (16)	Janet Fogg	yes
Panhandle, TX, Public Lib.	1990	300	yes	by Amar.Coll.	OCLC (8)	OCLC (8)	30	All(11)	Biblio. (15)	Carrie Keith (Pantex)	yes
Oak Ridge Operations Off.	1994	13,000	no(2)	WP list	no	Xerox	10-15	All(11)	no,but (17)	Jane Greenwalt	yes
Richland, WA - (Hanford)	1984	27,000	yes(3)	yes	no	Xerox	200-300	locally	no(18)	Terri Taub	yes
Rocky Flats, Frt Rang CC	1989	1758	yes	FilemakerPro	no	no	20	all(12)	no	no name	yes
Sandia NL,Livermore PL	1992	no entry	Word Pro	no	no	no	10	local (13)	no	no name	no entry
Savannah River Op.Off.	1984	Shelflist	yes	no(6)	no	no	20	All(14)	See (14)	Paul Lewis	yes

* CIC (Coordination & Information Center) est. 1981, merged with DOE/NV, 1995.
2. Except 2,000 titles in Human Radiation Experiment. Internet data base HREX.
3. Data stored in tab-delimited ASCII text file, author, or keyword in title, no subject search.
4. In-house classification system, librarians use shelf list. No public access catalog. D-base inventory at Chicago Operations Office.
5. PC-based indices available in Reading Room.
6. Access currently available via PC in Reading Room, developing proposal to mount the database on the WNW with full search/report capabilities.
7. Index available on Internet, Microfiche, or PC.
8. Bibliographic entry in OCLC so record shows in catalog and interlibrary loan databases. Currently available through http"//www.actx.edu/hlc/h (Harrington Library Consoritum)
9. Most docs shipped from Chicago Operations Office.
10. Collect from multiple US locations.
11. DOE Washington office, laboratory, and others.
12. Washington Office, local plant, other.
13. Local lab and local DOE.
14. Local USDOE office of External Affairs is informed of documents received and coordinates/approves items to be added to the collection.
15. Catalog available on Internet and local HLC system, Jan., 1997 full text & visuals via Internet & Z39.50 library interfaces.
16. One of the CIC collections is full text on the Internet "Human Radiation Experiments" http://www.ohre.doe.gov.
17. 2,000 full text "Human Radiation Experiment database HREX, http://www.ohre.gov
18. Other site organizations putting full text reports on Internet, they hope to put catalog on this year.
19. Moving collection from Kirtland AFB to Alburqurque Technical/Vocational Institute

COMMENTS: The survey revealed that the DOE Reading Room materials at Amarillo College and Panhandle Public Library are accessible to the world through the OCLC cataloging/interlibrary loan network. Library materials that are not cataloged or classified using a system the information-seeker is familiar with, renders the collection relatively unaccessible. The full text of these materials will be accessible to the information-seeker through the ERL archive of scanned resources.

Appendix 4

Electronic Resource Library

Linda Hall Library Brief

Attachment C:
The Linda Hall Library Brief

Briefing
Linda Hall Library of Science, Engineering and Technology.
May 26, 1996

Linda Hall Library Collections include:

- More than 40,000 Journal and Serial titles
- Strong Conference and Symposium Proceedings Collection
- In excess of 1.5 million Government Contracted Technical Reports
- Over 150,000 Standards and Specifications
- U.S. Patent and Trademark Depository Library Collection
- U.S. Government Documents
- More than 300,000 Monographs
- Strong History of Science Collection dating from the 15th Century

Leonardo is the library's state-of-the-art information system. It is a cooperative project with the Spencer Art Reference Library of the Nelson-Atkins Museum of Art. In a joint venture with the United Engineering Trustees, Inc., the library opened the **Linda Hall Library-East/Engineering Societies Information Center** located at the United Nations Plaza in New York City. It is designed to provide reference service and current reference materials in engineering, especially those published by the five largest engineering societies in the United States.

The library opened to the public in 1946 and was created from trust funds established by Herbert F. and Linda S. Hall. Acquisition of the library of the American Academy of Arts and Science in 1947, and the transfer of the Engineering Societies Library in 1995, have significantly increased holdings and added depth to the research collection.

Linda Hall Library is on the same campus as the University of Missouri/Kansas City. Federal documents received by the UMKC libraries as a selective depository but housed at the Linda Hall Library begin with the Item Number 0001 and the SUDOC number A1.47: through Item Number 1089-E and SUDOC number Y3.N88. As of 29 May 1992 (most current printout available) 958 currently selected items sent to Linda Hall.

The *List of Classes of United States Government Publications Available for Selection by Depository Libraries* November, 1995 edition lists the following sections as housed in the Linda Hall library. The selections are in microfiche or paper.

Government Departments and Agencies Documents Shelved at the Linda Hall Library from the Government Document Collection at University of Missouri/Kansas City.

<u>Commerce Department</u>

National Institute of Standards and Technology (NIST)
Patent and Trademark Office
Civil Aeronautics Board
National Technical Information Service
Arms Control and Disarmament Agency
National Archives and Records Administration
Federal Register Office
Science and Education
Technical Information Systems

<u>Defense Department</u>

Defense Technical Information Center
Defense Nuclear Agency
Army Department
Engineers Corps (Army)
Energy Department
Federal Energy Regulatory Commission
Energy Information Administration
Economic Regulatory Administration
Bonneville Power Administration
Western Area Power Administration
Alaska Power Administration
Southeastern Power Administration
Education Department
National Center for Educational Statistics
Educational Research and Improvement Office
Elementary and Secondary Education Office
Presidential Scholars Commission
Environmental Protection Agency
Water Programs Operations Office
Air Quality Planning and Standards Office
Pesticide and Toxic Substance Office
Radiation Programs Office
Technology Transfer
Water Regulations and Standards Office
Government Printing Office
Superintendent of Documents
Department of Interior
Minerals Management Service
Interstate Commerce Commission
Interior Department
Geological Survey
Library of Congress
General Reference and Bibliography Division
Copyright Office
Serial and Government Publication Division Research Service
Descriptive Cataloging Division
Science and Technology Division
Law Library
European Division
National Aeronautics and Space Administration
Transportation Department
Nuclear Regulatory Commission
Nuclear Waste Technical Review Board
Occupational Safety and Health Review Commission Center

Of Test sample of citations brought to the Linda Hall Library compiled by the United Kingdom Atomic Energy Authority Research Group *Bibliography of Unclassified Report and Published Literature on the Transplutonium Elements (1957-1964) compiled in 1964 by R W. Clarke* Linda Hall Library had 61 citations in her collections and filled all but three of them. The following were Xeroxed:

4 from Russian journals in Russian
1 from a Scandianavian country in English
4 from the Elsevier Publishing Company in Amsterdam in French

11 from American journals in English
1 from Amsterdam in English

Sample of Journal Titles

1 *Academie Des Sciences* (Paris) (French)
1 *ACTA Chemica Scandinavica* (English)
3 *Analytical Chemistry* (American Chemical Society)
3 *Inorganic Chemistry* (American Chemical Society)
2 *Journal of Chemical* Physics(The American Institute of Physics)
4 *Journal of Inorganic & Nuclear Chemistry,* Pergamon Press, NY, London, Paris, LA
2 *Journal of Chromatography: International Journal on Chromatography, Electrophoresis and Related Methods,* Elsiver Publishing Company; Amsterdam, (French)
1 *Journal of the American Chemical Society*
1 *Nuclear Physics* (Journal devoted to the experimental and theoretical study of the fundamental constituents of matter and their interactions.) Amsterdam
3 *Physical Review: A journal of experimental and theoretical physics* established by E. L.Nichals in 1893.(American Physical Society published by American Institute of Physics.
1 *Proceedings:* International Conference on the Neutron Interactions with the Nucleus (Columbia University, New York)
1 *Soviet Physics JETP* (translated to English)
1 *Talanta; An International Journal of Analytical Chemistry*(English)

Sample of Journal Articles

"Decay of Am241" by S.,A. Varanov, V.M. Kulakov, A.G. Zelenkov and V.M. Shatinsky, (I.V. Kurchatov Atomic Energy Institute of the USSR Academy of Sciences, Moscow USSR. *Nuclear Physics,* Vol.43, pp.547-552, May-June 1963.

"Determination of Americium-243 in 'Curium-244" by C.J. Banick, G.A. Carothers, and W. T. Donaldson, (Savannah River Laboratory S.C.), *Analytical Chemistry,* Vol.35, No.9, p1312-1313,August, 1963.

"Determination of Americium in Plutonium by Gamma Counting" by Joseph Bubernak, Marion S. Lew, and George M. Matlack, ASL, *Analytical Chemistry,*Vol. 20, No11, pp. 1759-1762, November, 1958.

"First Observation of Queous Tetravalent Americium" by L.B. Asprey and R. A. Penneman, *Journal of the American Chemical Society,* Vol. 83, p.2200, April, June, 1961.

"Isomers of Am242" by F. Asaro, I. Perlman, J.O. Rasmussen, and S. G. Thompson, (Lawrence Radiation Lab, Berkeley) *Physical Review,* Vol. 120, No. 3, pp. 934-943, November 1, 1996.

"New Data on Alpha Decay of Americium Isotopes" by s.A. Baranov, V.M. Kulakov, and V.M. Shatinskii, *Soviet Physics JETP,* Vol. 18, No.3, pp. 1241-1245, April, 1964.

"Point Source Technique for Gamma Ray Absorption Studies" by Joseph Bubernak, Marion s. Lew, Matlack of Los Alamos Scientific Laboratory, under auspices of the U.S. Atomic Energy Commission, *Analytical Chemistry,* Vol. 34, No.4, pp. 585-586, April, 1962.

"Preparation and Crystal Data for Lanthanide and Actinide Triiodides" by L.B. Asprey, T.K. Keenan, and F.H. Kruse, *Inorganic Chemistry,*Vol. 3, No. 7, pp,. 1137-1140, June 29, 1964.

"Preparation and Properties of Aqueous Tetravalent Americium" by L.B. Asprey and R. A. Penneman, *Inorganic Chemistry,* Vol,.1, No.1, pp. 134-136, February, 1962.

Attachment D:
Citation Analysis, Texas Tech Library

NOTE: This is a scanned document and could not be altered in order to make corrections.

Date: 03/25/96
From: Charles David
Stoune

To: M. Karen Ruddy
Subject: Plutonium
Citation Study

INTRODUCTION

Our grant proposal to identify and digitize the literature on Plutonium published by the U.S. government is too broadly drawn to be useful. In 1965 the Atomic Energy Commission [AEC] reported that there were already 500,000 unclassified documents in their libraries. Given the increasing pace of publication since then, it is not at all unreasonable to think that this total now well exceeds 1 million documents. A substantial percentage of these will have something to do with Plutonium. Work by Saffady (1996) indicates that the cost to digitize such a backfire would be in the range of several tens of millions f dollars, and would exceed the GNP of most countries. Therefore we must find a way to identify the useful portion of the backfire, and restrict our digitization efforts to these items.

In an attempt to identify this more useful material, we decided to look at the citation patterns in recent literature. First, we identified all the Government reports listed in the 1994 annual issue of Government Reports Announcement Index [GRAI]. We restricted our search to only those reports that identified Plutonium in the index. This resulted in a set of 160 reports. Had the universe been larger, I might have used only a 10% random sample, but instead I used a 25% interval sample.

RESULTS

Of the 40 articles chosen, one (1) was a published bibliographical search, and four (4) were foreign government reports or these not identifiably available in any library accessible by WorldCat. The remaining thirty-five (35) were of various kinds (see chart below). Texas Tech University owns thirty-four (34), and the other is being requested through Interlibrary Loan

Conference reports	15
Technical reports	13
Foreign trip reports	1
Histories	1
Thesis	1

The thirty-four (34) articles to which we have access [by way of DOE fiche depository program] cite a total of 408 articles. Fifty-three point nine percent (53.9%) of the cited articles are themselves reports, with journals and books making presentations, letters (personal communication items) and thesis. Table one (1) shows the distribution of categories in five-year blocks from 1945 through the present. Government report citations for years before 1965 are virtually non-existent. In the interval from 1965 until 1980 the combined cited reports make up less than five percent (5%) of the total universe of citations. Beginning in 1980, citations climb, reaching a peak with the recent 1990 to 1995 interval. Does this represent real need, or does it rather reflect the increasing ease of accessibility? In this case the pattern is probably real, as nuclear government reports have been well indexed for some time. Another problem is whether the citations to reports are biased in any of the types of articles. With technical reports accounting for thirteen (13) of the thirty-four (34) we have access to, one could expect that about thirty-eight point two percent (38.2%) of the 220 reports or eighty-four (84) reports would be cited there. In fact, only fifty-nine (59) reports or twenty-six point eight percent (26.8%) are cited. Thought this discrepancy is valid, it probably does not alter our strategy.

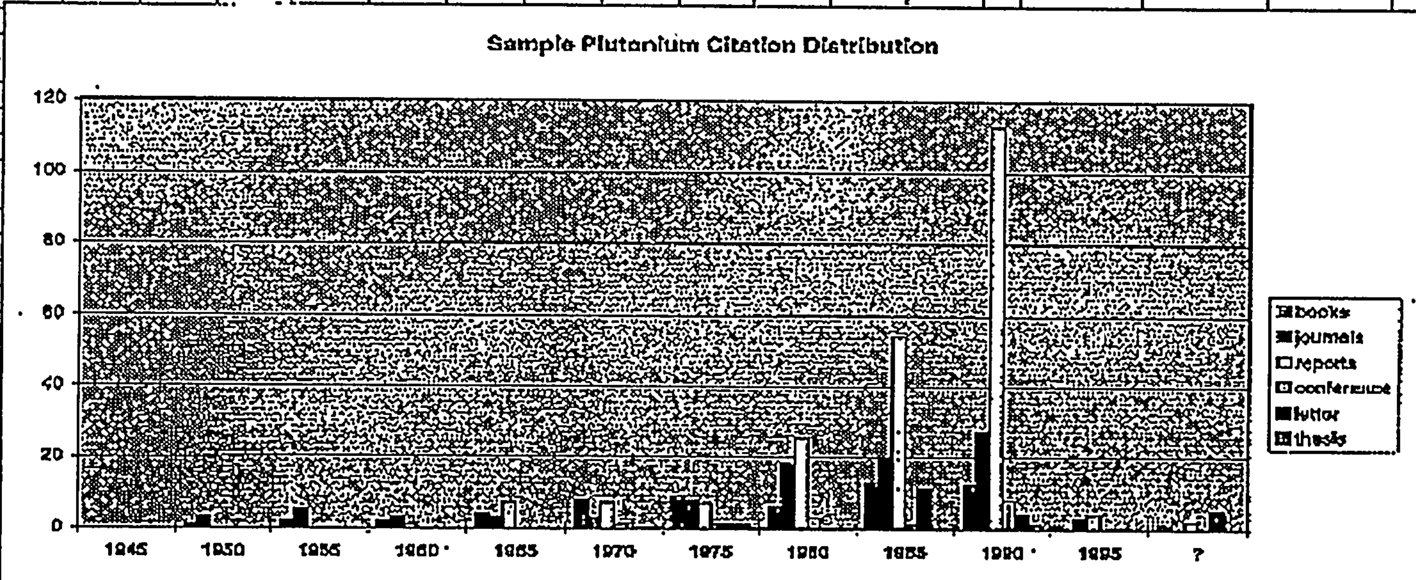
CONCLUSIONS

I would recommend that we restrict our digitizing efforts to government reports published in 1980 or later. For many of these we may still be able to find a digital copy of the original which would further reduce our costs.

There remains the problem of what to do with the articles that were written before 1980. Some percentage of these would be useful, but how do we identify the relevant subset. My only suggestion would be a further citation analysis. It might be possible to structure an expensive Science Citation Search to search only government reports published before 1980 that were cited more than a threshold value [perhaps 5 times] in other government reports. Since the final set ought to be relatively small, costs might be manageable.

Citation Distribution in 25% Sample of 1994 Citations in Government Reports Announcements Index

Types	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	?
books		1	2	2	4	8	9	6	13	12		1
journals		3	5	3	9	3	8	18	20	27	3	
reports				1	7	7	7	25	54	113	4	2
conference						1	1	3	1	8		
letter							1		11	4		5
thesis							1			1		



Appendix 6

Electronic Resource Library

Internal Report to Principal Investigators

Attachment E:
Internal Report to ERL Principle Investigators

DATABASE POPULATION PLAN

I.
SCANNING SETS

1. DOE Reading Room - Amarillo College Lynn Library, Pantex Plant collection.
· Documents are unclassified, non-sensitive, English language materials. A current survey revealed they currently exists as:

a. Paper collection, 4th floor Amarillo College; cataloged through HLC with DRA automated library system, entered in OCLC database (catalog and interlibrary loan access)

b. Scanned, non-PDF files, CD-ROM collection begun by Pantex and is being continued by Amarillo College Lynn Library.

STRATEGY:
Exchange electronically the CD-ROM files by loading them onto the ERL server, or workstation hard drive, produce PDF and text files, apply quality control procedure, index the data, create http links to the records, and make them available on the WWW by producing URL, URN, or PURLs, imbed that code in the 856 field of the MARC record in order to also make the data accessible through the Z39.50 research library catalog network.

2. Sandia National Laboratory Collection of seminal documents collected from bibliography citations and acquired through ILL, DIALOG, and NTIS sources. Assume at least 50% or more are copyright protected and the remaining are federally published non-copyright documents that can be legally scanned and disseminated. Currently exists as:

a. Paper documents in 3 file cabinets at SNL.

STRATEGY:
Travel to SNL, determine value of seminal documents, determine how many are copyright material, transport to Amarillo College scanning site. Scan the paper documents using the Adobe Acrobat suite of software products enhanced by the VerZions network based software program designed to automate and manage the Adobe Acrobat family of products, (Capture, Distiller and Exchange) in order to create PDF (portable document format) files. Exchange electronically the CD-ROM files by loading them onto the ERL server, or workstation hard drive, produce PDF and text files, apply quality control procedure, index the data, create http links to the records, and make them available on the WWW by producing URL, URN, or PURLs, imbed that code in the 856 field of the MARC record in order to also make the data accessible through the Z39.50 research library catalog network. Catalog the title on OCLC which makes it available on the HLC regional library network and completing the Z30.50 requirement. Both access networks are now in place for retrieving the needed bibliographic citation, abstract or full text document from the ERL server.

3. Texas Tech University Government Document Collection
Following the suggestions from the Citation Analysis the TTU collection of paper government documents will be scanned using the Adobe Acrobat suite of software products enhanced by the VerZions network based software program designed to automate and manage the Adobe Acrobat family of products, (Capture, Distiller and Exchange) in order to create PDF (portable document format) files. Exchange electronically the CD-ROM files by loading them onto the ERL server, or workstation hard drive, produce PDF and text files, apply quality

control procedure, index the data, create http links to the records, and make them available on the WWW by producing URL, URN, or PURLs, imbed that code in the 856 field of the MARC record in order to also make the data accessible through the Z39.50 research library catalog network. Catalog the title on OCLC which makes it available on the HLC regional library network and completing the Z30.50 requirement. Both access networks are now in place for retrieving the needed bibliographic citation, abstract or full text document from the ERL server.

STRATEGY

Two part-time graduate students are locating titles and preparing scanning sets using the paper document collection in TTU government documents. They are also sorting through the microfiche and microcard collections pulling from title anaysis. A second scanning site at Texas Tech will allow compilation of digital images from two sites which will be fetched to the HLC computer center where the ERL server and workstation will complete the processes required to prepare the titles for the ERL archive.

4. MOXDAR collection compiled by Dr. Abdurrahman of UT Austin assisted by Edward Reott at UT Austin. Negotiations are under way to convert their documents to PDF files for retrieval using the conversion model the ERL is developing. It is estimated that 75% of this collection is copyright material so an innovative design to deliver for-fee documents subsidized by the ERL. is also under consideration. Future budgets will include a new product put out by Minolta, called DPCS 3000, a Digital Publication Copying System that includes a tracking system for recording copyright fees and reimbursement to handle the copyright question.

STRATEGY

Collection is paper so will follow the same procedure as Sandia National Laboratory collection.

5. A&M nuclear group Marvin Adams collaborating with Dr. Abdurrahman on MOXDAR project as well as providing COMMENT entries in bibliographic citations from this groups research projects.

6. (xxx.lanl.gov-like) **E archive**Texas Tech researchers Richard Wigmans and Mark Frautsch are interested in working on this project. Will coordinate through Phil Nash at Texas Tech

7. Publication of Nuclear Group Proceedings working with Dr. Paul Nelson, coordinator of the Nuclear Group to publish proceeding papers through the ERL and make them available through the ERL.

8. The Glenn T. Seaborg Collection

One "set" of sequential sets of information is the development of the Seaborg literature. Applying Citation Analysis using his body of work and positioning it in the middle of an X going up from him is the literature that cites his work and going down from him is the scientific research that he cited in his work. Collecting this "set" of literature is my goal.

Seaborg published over 900 articles. A list of works from the OCLC database cites 91 books, 11 visuals, 1 mixed media, 25 sound records, and 2 music scores with text by Seaborg.

Texas Tech is developing a bibliography of all his publications using the Science Citation Index. Request for permission to publish his works through the ERL Electronic Publishing service is being investigated.

If copyright override is not possible, the Minolta system can be used. It allows the crisp, clear, non-distorted copying of bound publications, even thick reference books. It allows this to be done without damage to fragile bindings or brittle pages. (One of the 4inch Seaborg books Interlibrary loaned and published in the 60s is "eating" itself up - three pages "broke off " corners of pages as a Seaborg article was scanned on the Xerox machine).

An account management software product will allow customized information to be entered into a profile for each title as to how the information will be accessed, i.e. request a charge card number for any that we cannot obtain copyright permission, and reimburse intellectual property owner etc.

Appendix 7

Electronic Resource Library

Project Checkoff List

Attachment F
ERL Timeline/Checkoff

Checkoff LIST for Electronic Resource Library

Project Year One

Staff Development

_X_ Hire Information Scientist, 7/95.

Collection Development

_X_ Determine size and location of collections, 10/95.
_X_ Determine document types, 10/95.
_X_ Determine which documents have no MARC catalog records, 1/96.
_X_ Collaborate with DOE Public Information Office and researchers to determine which documents will be digitized, 4/96.
_X_ Develop forms for recording document titles to be digitized and linked, 4/96.
_X_ Compile titles and annotations of documents that are candidates for scanning, 3/96 and ongoing.
_X_ Compile URL's for linking sites, 3/96 and ongoing.
_____ Contact remote sites for permission to link, 5/96.

User Assessment

_X_ Analyze scientific and researcher information interface needs, 1/96.
_____ **Analyze k-12 information interface needs, 5/96.**
_X_ Determine access needs of the ANRCP/DOE community, 9/95.
_____ **Determine access needs of general public, state and local governments, and elected officials, 5/96.**

System Feasibility

_X_ Investigate/collaborate with current projects at Texas A&M (Nuclear group), 7/95.
_X_ Investigate/collaborate with current projects at ORNL, 7/95.
_X_ Investigate/collaborate with current projects at DOE/OSTI, 7/95.
_X_ Investigate/collaborate with current projects at Los Alamos Laboratory, 7/95.
_____ **Determine connectivity requirements to meet user need, 5/96.**
_____ **Plan for establishing T-1 service to *Electronic Resource Library* Web Server, 5/96.**
_____ **Determine user/interface/access methodology, 5/96.**
_X_ Determine server/storage requirements, 5/96.
_X_ Confirm that Adobe Software will meet requirements, 5/96.
_X_ Resolve problems connected with receiving and processing three main categories of materials: a) electronic, b) print, and c) film.
_X_ Specify scanning technology to digitize historical archives, 5/96.
_X_ Specify software to import machine readable documents, 5/96.

System & Software Procurement

_X_ Produce preliminary report for consultant review, 1/96
_X_ Produce final report, 4/96.
_X_ Produce RFP for system and software, 5/96.

Cataloging and Classifying Documents

_X_ Create MARC bibliographic records for documents through OCLC, 8/95.
_X_ Transfer bibliographic records to the Harrington Library Consortium public access catalog, Ongoing.
_X_ Provide bibliographic records to DOE OSTI for documents not accessible through the Government Information Locator Service, Ongoing.

PROJECT YEAR TWO

System Procurement and Installation

__X__Issue RFP to hardware and software vendors, 6/96.

_____Receive and install system, 9/96.

Establishing Connectivity

_____Install sufficient INTERNET bandwidth for information access, 9/96.

_____Obtain class C licence for LAN access to server, 6/96.

Staff Development

_____Hire quality control specialist and operators, 9/96.

_____Train staff on server operating system, application software, and user interfaces, 9/96.

_____Train scanning workstation operators, 9/96.

_____Establish quality control procedures, 9/96.

_____Contract for server management, 9/96.

_____Contract for Web site development, 9/96.

_____Contract with other sister sites for remote access and permission to link, 9/96.

System Testing/Production

_____Create test database of 100 documents or 10,000 pages, 11/96.

_____Test system indexing for full text access, 12/96.

_____Test user interfaces/security, 1/97.

_____Begin full production of historical archives, 2/97.

User Training/Public Access Implementation

_____Conduct workshop for public school teachers involved with science & engineering curricula, 2/97.

_____Conduct workshop for Panhandle Area Librarians, 3/97.

_____Produce video tutorial for information access, 6/97.

PROJECT YEAR THREE

Document Production/Utilization

_____Produce reports for document production, Quarterly.

_____Produce quarterly reports of system utilization, Quarterly.

Document Procurement

_____Collaborate with ANRCP Center staff and DOE Information office to add current scientific information, Ongoing.

Evaluate User Satisfaction

_____Conduct online survey of user needs/satisfaction, 10/97.

_____Interview public school teachers and students, 5/98.

Investigate Additional Information Types

_____Report on need for calendar information for Center Activities, 11/97.

_____Report on need for multi-media tour of Pantex Plant, 5/98.

_____Report on other needs of ANRCP for information, 5/98.

PROJECT YEAR FOUR

Document Production/Utilization

_____Produce reports for document production, Quarterly.

_____Produce quarterly reports of system utilization, Quarterly.

Document Procurement

_____Collaborate with ANRCP Center staff and DOE Information office to add current scientific information, Ongoing.

Evaluate User Satisfaction

_____Conduct online survey of user needs/satisfaction, 10/98.
_____Interview public school teachers and students, 5/99.

Investigate Additional Information Types

PROJECT YEAR FIVE
Document Production/Utilization
_____Produce reports for document production, Quarterly.
_____Produce quarterly reports of system utilization, Quarterly.

Document Procurement
_____Collaborate with ANRCP Center staff and DOE Information office to add current scientific information, Ongoing.

Evaluate User Satisfaction
_____Conduct online survey of user needs/satisfaction, Annually.
_____Interview public school teachers and students, Annually.

Investigate Additional Information Types, Ongoing.

ADDITIONAL TASKS DEVELOPED FOR FY2
DURING PLANNING YEAR FOR PROJECT and INTO FY2.
_X_Produce electronic bibliography for DOE Reading Room Collection at Amarillo College, 1/96
_X_Establish interim procedure for obtain full text of DOE Reading Room Collection at Amarillo College for researchers and scientist, 1/96.
_X_Study scanning project contracted by Amarillo College Library and Pantex Plant for possible inclusion in final RFP for *Electronic Resource Library.1/96.*
_X_Contact vendors to determine participation and cooperation for software, hardware, and networking possibilities. 2/96
_X_Analyze *National Digital Library Federation* (NDLF), the joint venture of major research libraries and archives coordinated by the Commission on Preservation and Access to explore questions of transition from traditional library service to the new digital environment. 3/96.
_X_Pursue establishment of *a DOE Digital Library Federation* (DDLF), a proposed joint venture of DOE laboratory and resource sites for creation of a coordinated distributed digital library of archives containing full text, indexed DOE documents unique to the site, recorded in a central bibliographic database scanned and produced for full text archive only at designated site, thus avoiding duplication of scanned titles and compatibility of technology.
_X_Survey DOE Reading Rooms and determine quality of access, 3/96. REPORT ATTACHED.
_X_Incorporate Dr. William Saffady suggestions into final ERL plan after receiving consultant report. 4/96.
_____Investigate/collaborate with current projects at Sandia Laboratory, 5/96.
_____Pursue establishment of Glenn Seaborg collection development, 5/96.

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March 14, 1996

Dr. Bill Harris
Deputy Director, ANRCP
600 South Tyler - Suite 800
Amarillo, Texas 79105

Dear Dr. Harris:

Enclosed please find a copy of the paper that Dr. Dyer is presenting at the *International Meeting on Military Conversion and Science "Utilization of the Excess Weapon Plutonium: Scientific, Technological and Socio-Economic Aspects"* in Como, Italy on March 20, 1996.

Sincerely,

Jaimy S. Rand
Administrator
MAUA Team

A PROPOSED METHODOLOGY FOR THE ANALYSIS AND SELECTION OF ALTERNATIVES FOR THE DISPOSITION OF SURPLUS PLUTONIUM

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Submitted by the

Amarillo National Resource Center for Plutonium

March 1996

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Abstract

A Proposed Methodology for the Analysis and Selection of Alternatives for the Disposition of Surplus Plutonium

The nuclear states are currently involved in the development of comprehensive approaches to the long-term storage and management of fissile materials. A major objective of this effort is to provide a framework for prevention of the proliferation of nuclear weapons. The evaluation should include non-proliferation, economic, technical, institutional, schedule, environmental, and health and safety issues.

The ANRCP has proposed that an evaluation of alternatives be guided by the principles of decision analysis, a logical and formal approach to the solution of complicated problems that are too complex to solve informally. This approach would consist of four steps:

1) identification of alternatives and objectives,
2) estimation of the performance of the alternatives with respect to the objectives,
3) development of values and weights for the objectives, and
4) evaluation of the alternatives and sensitivity analysis.

In order to facilitate the evaluation process, the ANRCP proposes the use of nine objectives grouped into the following categories:

1) Non-proliferation objectives (which includes resistance to theft and diversion by unauthorized parties, resistance to retrieval and reuse by the host notion, schedule, and fostering progress and cooperation with other nations and Russia)
2) Operational effectiveness (which includes cost, technical viability, and other benefits)
3) Environmental, safety, and health considerations

In order to evaluate alternatives on the basis of these objectives, they have been clarified through the definition of secondary objectives in some cases. Once the objectives were defined, the next step is to develop measures of performance associated with these objectives. Some of these measures of performance use natural scales, such as cost (dollars), time (months), and environmental impacts (cubic meters of secondary waste). Other measures require specially constructed verbal scales and the performance of each alternative is assessed based on expert judgment.

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A Methodology for the Analysis and Selection of Alternatives for the Disposition of Surplus Plutonium

1. Background

The end of the Cold War and subsequent arms limitation and reduction agreements have led to a surplus of weapons-usable plutonium in the United States and Russia. In order to prevent the proliferation of nuclear weapons, steps must be taken to manage this plutonium in a manner which takes into account non-proliferation, economic, technical, institutional, schedule, environmental, and health and safety issues.

The purpose of this paper is to define a model and the methodology that could be used to support the selection of alternatives for the disposition of surplus plutonium. There are a number of methods that have been proposed to model preferences and support decisions, and each of them may be used constructively in some contexts. However, we believe that the significance of decisions regarding the disposition of plutonium requires the use of a methodology that can evaluate alternatives involving risk and multiple performance measures, and that is practical, theoretically sound, and transparent to external reviewers and interest groups. The one methodology that meets these requirements is multi-attribute utility theory (MAU), which has been supported for use in similar situations by the National Research Council, an agency of the United States National Academy of Sciences. [1]

MAU (Keeney and Raiffa, 1976) is one of the major analytical tools associated with the field of decision analysis (Clemen, 1991; Holloway, 1979; McNamee and Celona, 1990; Raiffa, 1968; von Winterfeldt and Edwards, 1986). Simply, decision analysis is a logical and formal approach to the solution of problems that are too complex to solve informally. In the past, decision analysis has been applied to problems such as siting

[1]National Research Council, letter to Ben Rusche, DOE/OCRWM, dated October 10, 1985.

electricity generation facilities (Keeney, 1980), choosing among vendors for the evaluation of alternatives for the commercial generation of electricity by nuclear fusion (Dyer and Lorber, 1982), and selecting a nuclear waste clean up strategy (Keeney and von Winterfeldt, 1994).

The MAU methodology for the evaluation of alternatives for the disposition of plutonium consists of the following steps:

1. Identification of alternatives and objectives
2. Estimation of the performance of the alternatives with respect to the objectives
3. Development of values and weights for the objectives
4. Evaluation of the alternatives and sensitivity analysis

As a first step, reasonable alternatives for the disposition of plutonium must be identified along with the objectives that are used in the analysis. The alternatives and the objectives form a matrix in which each row corresponds to an alternative and each column represents an objective. The cells of the matrix contain estimates of the performance of each alternative on each of the objectives. When these estimates are uncertain, it is often appropriate to quantify them with ranges or with probability distributions determined using risk analysis methods (e.g., Clemen, 1991; Keeney and von Winterfeldt, 1991).

Typically, it is possible to gain a number of insights regarding the alternatives simply through a careful inspection of this matrix. For example, one or more alternatives may be "dominated" by another alternative, meaning that the dominating alternative performs as well or better on every objective than the dominated alternative. Alternatives that are dominated can often be eliminated from further consideration in the decision process, which may significantly simplify the remaining steps in the analysis.

Step three creates a value model based on the objectives by defining value functions, if necessary, on the measures of the performance of the alternatives, and by assigning weights to the objectives. This process is carried out with decision makers or their designated representatives, and allows the measures of performance on each objective to be aggregated into a single figure of merit. Finally, this value model can be used to determine a ranking of each of the alternatives, and a sensitivity analysis is typically conducted to determine if this ranking is robust relative to reasonable changes in the weights or the other parameters that determine the value model. This sensitivity analysis may include changes in the value model that are suggested by interactions with representatives of other interest groups or stakeholders.

This process should summarize the critical information needed for an evaluation of alternatives, and provide the insights that both support and explain the basis for this evaluation. However, it is important to emphasize that the decision analysis process does not lead to a computerized model that actually determines the decision for a complex problem. Rather, this process highlights the strengths and weaknesses of alternatives, the implications of tradeoffs among these strengths and weaknesses, and the sensitivity of the evaluation to the underlying assumptions so that better informed choices can be made.

Any model of a physical process or of subjective preferences will omit some details in the abstraction from the real-world in order to crystallize the essence of the problem. Some of these omitted details may be relevant in the final selection of alternatives by a decision maker or decision makers, particularly when the alternatives are determined to be "very close" in the formal analysis. Further, the appropriate value model for use as a guide to public policy is, in general, not sharply defined. As a result, the decision analysis process will emphasize the support of the decision makers charged with the responsibility for the selection of alternatives, and will attempt to clarify the consequences of each choice. We subscribe to the philosophy that the result of using models should be insights, not numbers.

Sections 2-5 of this report will describe these four steps of the MAU methodology in more detail. Section 6 will summarize the discussion.

2. Identification of Alternatives and Objectives

2.1 Alternatives

The evaluation process begins with the identification of the set of reasonable alternatives that are appropriate for serious consideration. This screening process may be aided by reference to a set of criteria that identify the most important considerations guiding this preliminary selection process. Examples of the use of screening processes to determine reasonable alternatives for the disposition of surplus plutonium are provided by the studies conducted by the National Academy of Sciences (1994) and by Office of Fissile Materials Disposition of the United States Department of Energy (OFMD, 1995).

The reasonable alternatives for plutonium disposition determined in these studies fall into three categories: reactor alternatives, immobilization alternatives, and borehole alternatives. The reactor alternatives would use surplus plutonium to fabricate mixed oxide (MOX) fuel for nuclear reactors that generate electrical power. The spent fuel from these reactors would ultimately be transferred to a national waste management system for ultimate disposition. The immobilization alternatives combine the surplus plutonium materials in borosilicate glass or ceramics; additional radionuclides may be added to provide a radiation barrier to inhibit recovery and reuse. This material would also be transferred to a national waste management system for ultimate disposition. The borehole alternatives involve the placement of the plutonium in a deep borehole, possibly after the material is immobilized in an inert matrix.

Other alternatives may eventually be considered by the United States and Russia. However, the general methodology for the evaluation of these alternatives should be flexible enough to evaluate and compare any reasonable approach to the disposition of the surplus plutonium.

2.2 Objectives and Measures

The first step in the application of MAU is the development of a "hierarchy" of objectives, criteria, and measures. Objectives are often broad statements of goals. Typically two or more criteria are associated with objectives at the next level of the hierarchy to provide more specific statements of desirable characteristics of alternatives, and to help define the objectives in more detail. In complex decision problems, these criteria may be decomposed further into sub-criteria, and so on, until a sufficient level of detail is reached to allow measures to be identified.

In some cases, these measures may be quantified as estimates on a natural scale, for example, net present value of cost, time, travel miles, etc. In other cases, it may be necessary to construct scales that are more descriptive in nature, and that may require estimates for the alternatives based on expert judgment. In many cases, these measures are surrogates for higher-level issues.

Useful reference points for the identification of measures for evaluating plutonium disposition alternatives include measures proposed for previous studies involving technology choices (e.g., Keeney, Lathrop, and Sicherman, 1986; Keeney and von Winterfeldt, 1994; Merkhofer and Keeney, 1987), for previous studies concerned with the management and disposition of surplus plutonium (National Academy of Sciences, 1994), and for evaluations of technologies and sites for tritium supply and recycling.

Objectives. The objectives for any decision provide the basis for evaluating the relative desirability of available alternatives. For the purpose of illustrating the methodology, we present the objectives recommended by the National Academy of Sciences (1994) and used by the Office of Fissile Materials Disposition (OFMD, 1995) for the purpose of a preliminary screening. The objectives used by the OFMD for screening the alternatives for the disposition of plutonium were the following:

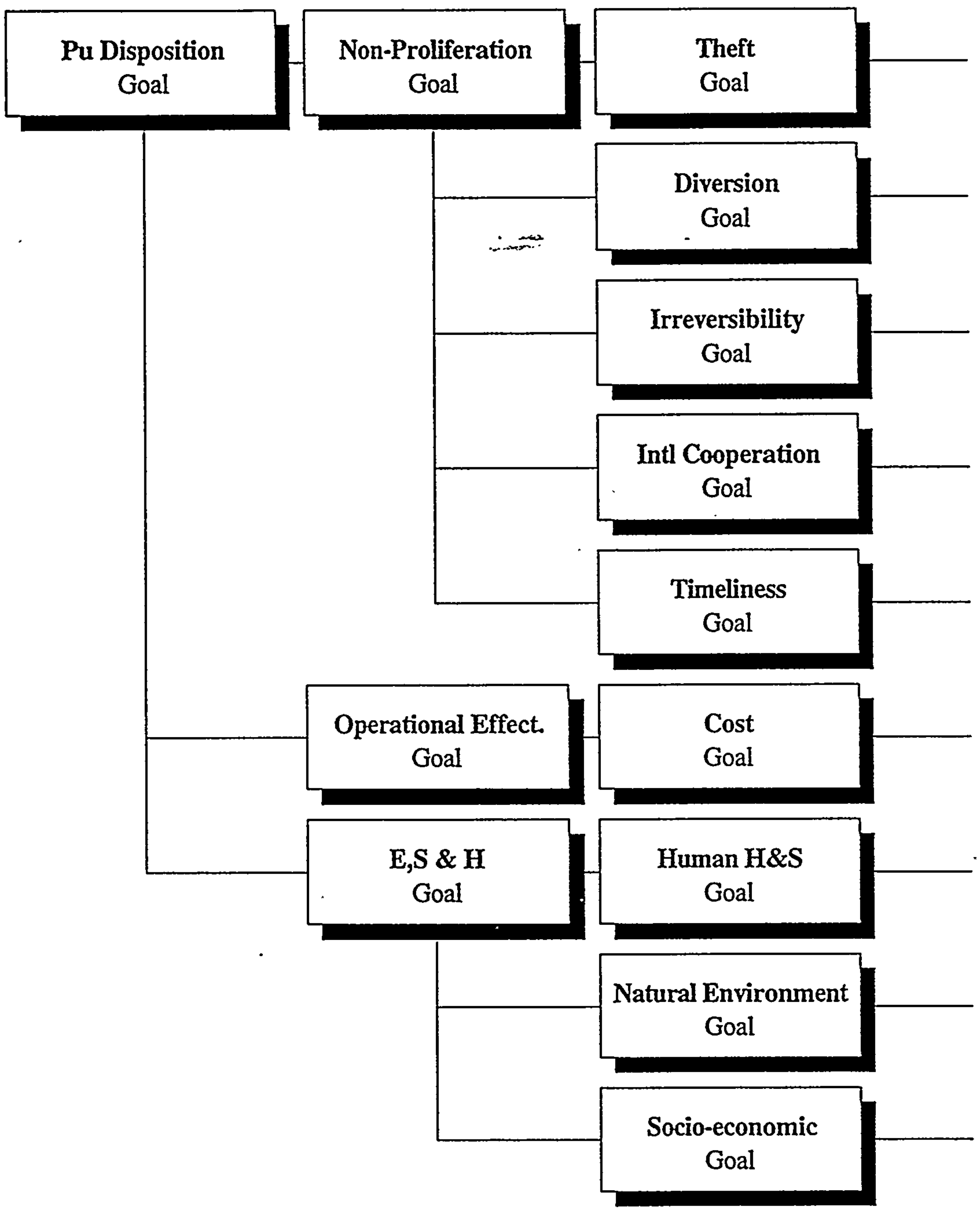
1. Resistance to theft and diversion by unauthorized parties
2. Resistance to retrieval, extraction, and reuse by the host nation
3. Technical viability
4. Environmental, safety, and health
5. Cost effectiveness
6. Timeliness
7. Fostering progress and cooperation with Russia and other nations
8. Public and institutional acceptance
9. Additional benefits

For this illustration of the methodology, these nine objectives have been reorganized to emphasize the commonality among some of them, and to provide additional detail regarding others. This reorganization is shown in the form of a hierarchy of objectives in Figure 1.

At the highest level of this hierarchy, we have identified three major categories of objectives:

1. Non-proliferation which includes resistance to theft, resistance to reuse, international cooperation, and timeliness (objectives 1, 2, 6 and 7 from the original list of nine)
2. Operational effectiveness which includes and cost effectiveness (objectives 1 and 5 from the original list of nine)
3. Environmental, safety, and health (objective 4 from the original list of nine) which has been decomposed into human health and safety, environmental protection, and socio-economic effects at the next level in the hierarchy

FIGURE 1 -- HIGH LEVEL OBJECTIVES FOR PLUTONIUM DISPOSITION



Such a reorganization of the nine objectives would simplify the task of creating a value model, and particularly the assessments of weights on the objectives, as we discuss in Section 4. In addition, this simplified structure would provide a natural means for transferring the insights from the model to the decision maker.

It should also be noted that objectives 3, 8 and 9 from the original list, technical viability, public and institutional acceptance, and additional benefits, have been dropped from the proposed hierarchy. Technical viability refers to the level of technological development associated with the alternative, and is essentially a surrogate for the risk of possible delays and cost overruns. These concerns can be captured in an evaluation through the use of probability distributions on measures of time and cost, if necessary.

Public and institutional acceptance is a major concern in any screening process, and the basis for the elimination of many of the alternatives that may originally be considered. However, the other objectives that have been selected for this illustration are based on meeting public concerns. Therefore, we believe that an alternative selected based on the other eight objectives will be one that would also be ranked highly on the objective of public acceptability. In addition, the economic impacts of the alternatives on local communities have been included in the proposed measures of the Environmental, Safety, and Health objective, as we shall discuss.

Also, we have deleted the objective of "additional benefits" from this hierarchy. Some of the alternatives may offer the possibility of producing useful by-products, such as the production of electric power by nuclear reactors or the possibility of sharing costs with other programs. However, the most significant examples of these "other benefits" can be captured as offsetting costs, and will be effectively measured by the cost effectiveness objective.

As previously mentioned, Figure 1 represents the highest level of the objectives for selecting a plutonium disposition alternative. Figures 1a, 1b and 1c provide the details for the three main objectives of the analysis: Non-proliferation, Operational Effectiveness and Environment, Health and Safety respectively.

Two comments are in order regarding Figures 1, 1a, 1b and 1c. First, the major purpose of these diagrams, particularly Figure 1, is to assist the decision makers in "making sense" of an evaluation of alternatives based on thirty eight detailed performance measures. The reorganization of the objectives as shown in this hierarchy is neither unique nor fixed. It could be altered based on feedback from those involved in determining policy toward plutonium disposition. Second, the fact that one objective or sub-objective appears at a "lower level" in the hierarchy than another does not imply that it is less important, or that it should receive a smaller "weight" in the analysis than another objective.

The objectives categorized as providing assurance against non-proliferation (Figures 1 and 1a) indicate five distinctly different areas of concern. The first objective is to minimize the opportunities for theft of the materials by unauthorized parties. Generally, an alternative will be more resistant to theft during the processing steps required to transform the material from weapons-usable plutonium into its final form for permanent disposition if these steps are relatively simple and transparent, if the form of the material is not "attractive" to potential thieves because of size, radioactivity, or other concerns, and if effective safeguards and security can be applied.

The second objective is to maximize the resistance of the disposition alternative to the diversion of the plutonium by the host nation during processing, and to provide an internationally verifiable and acceptable process. Providing adequate accessibility safeguards, and measurement capability will allow an alternative to satisfy international inspection standards and provide assurance that diversion by the host nation is not taking place. Many of the factors considered in the theft subobjective can also apply here.

FIGURE 1A -- DETAIL FOR NON-PROLIFERATION OBJECTIVE

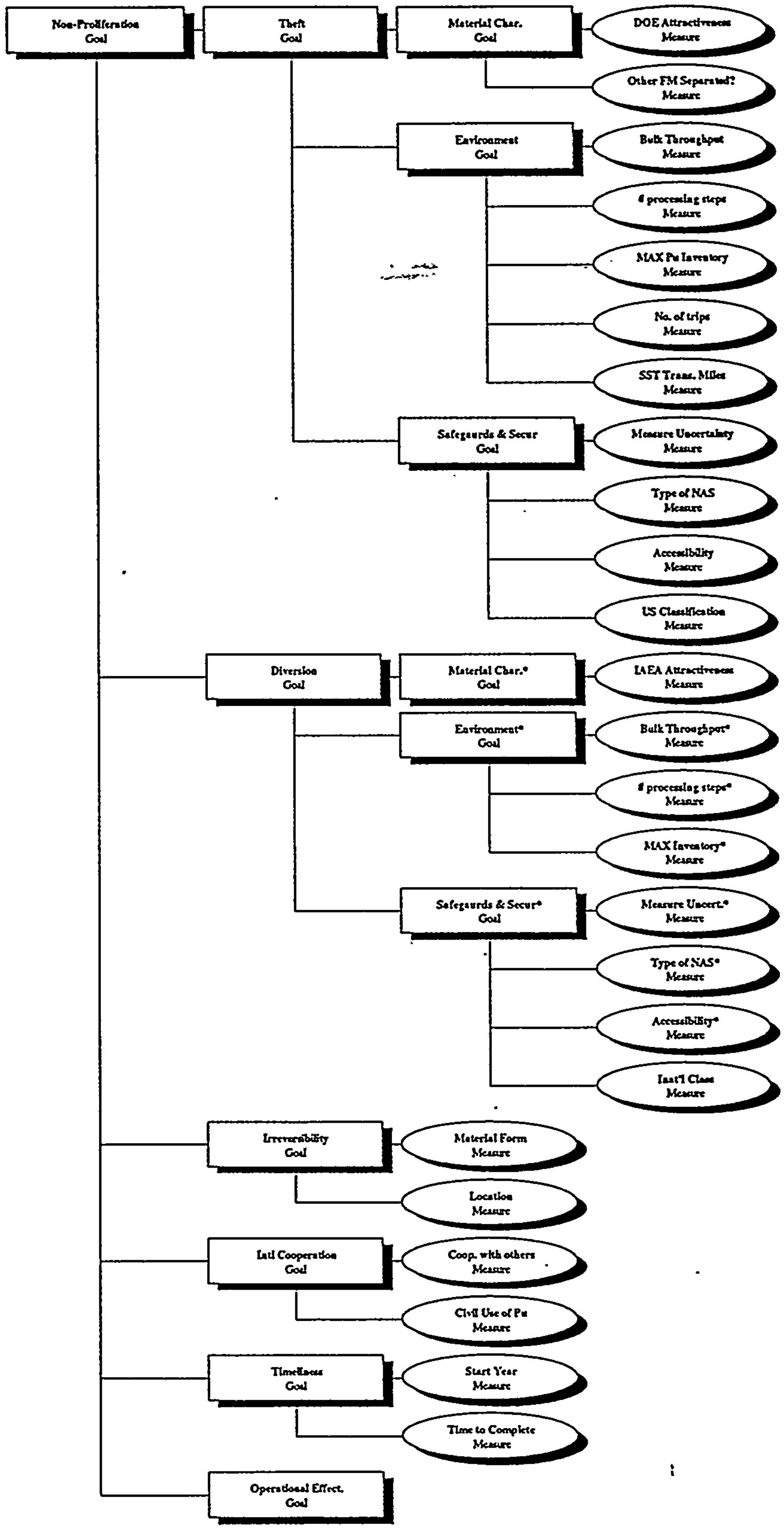


FIGURE 1B -- DETAIL FOR OPERATIONAL EFFECTIVENESS OBJECTIVE

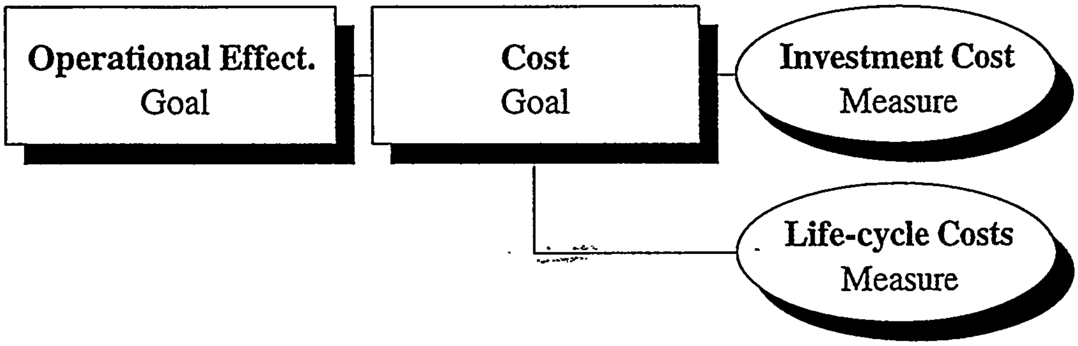
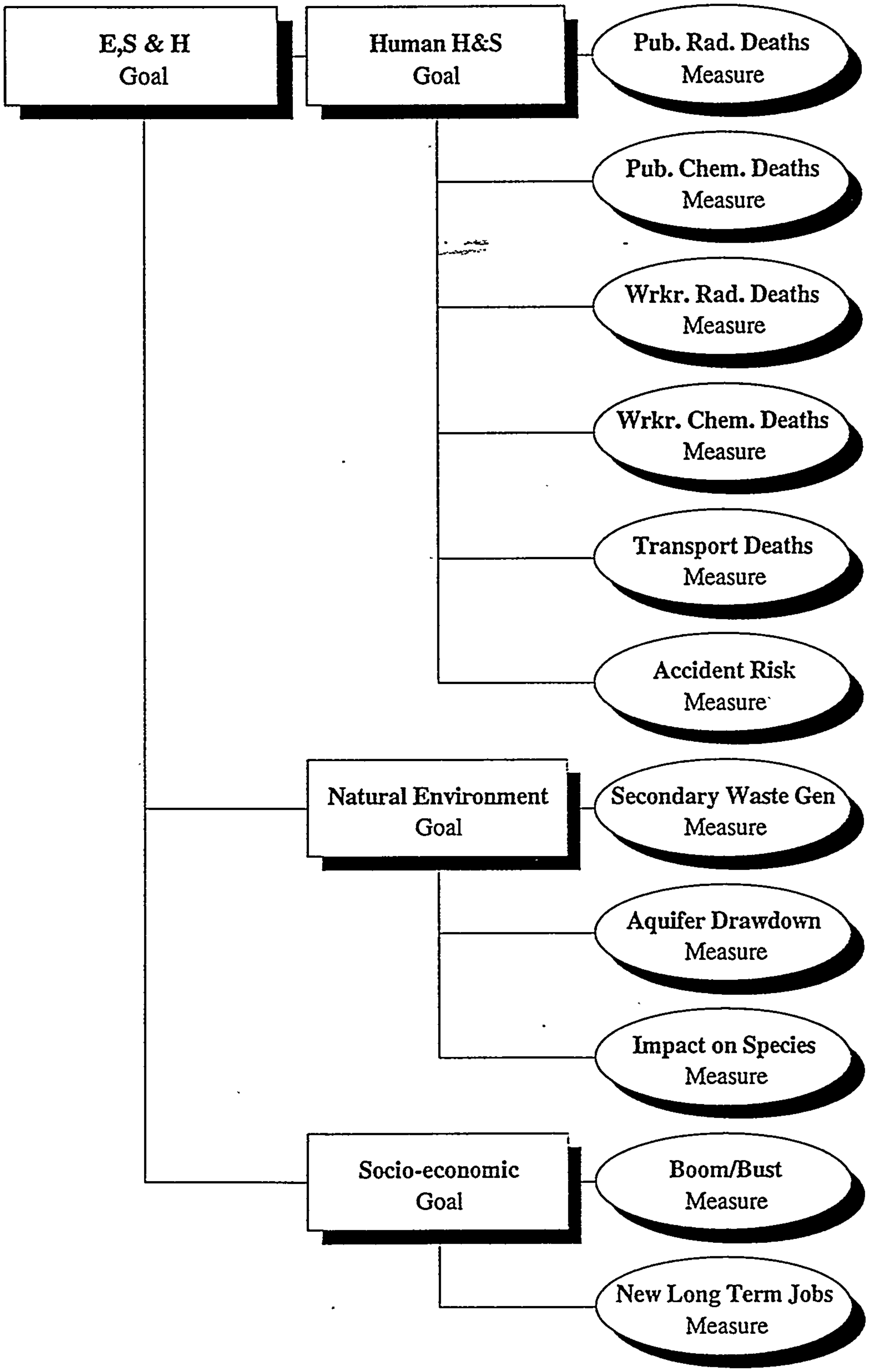


FIGURE 1C -- DETAIL FOR ENVIRONMENTAL SAFETY AND HEALTH OBJECTIVE



The third objective is to maximize the difficulty of recovering the disposed material after processing has been completed. The disposed material will be less attractive for reuse by the host nation if it meets the "spent fuel standard", or would be as costly, detectable, and time consuming to retrieve and fabricate into weapons as the recovery of plutonium from spent commercial reactor fuel. The final form and location of the disposed material will determine its long-term resistance to reuse.

The fourth non-proliferation objective is concerned with fostering international cooperation with the disarmament and nuclear non-proliferation goals. This objective may be related to international relationships, and to issues concerning the civil use of plutonium.

The fifth objective, Timeliness, is based on an estimate of the time required for the disposition effort to begin, and on the time required for the completion of the effort once it has begun. These time estimates may be highly uncertain for some of the alternatives, and can be represented as probability distributions when necessary. The assessment of the uncertainty associated with the time to begin an alternative's disposition process may be influenced by its technical maturity and by its regulatory history. Timeliness influences both international cooperation and the "window of vulnerability" of the material.

An alternative will be considered operationally effective (Figures 1 and 1b) if it has low cost. The cost may consider both life-cycle costs and the initial investment costs, and estimates of both may be uncertain. If so, these estimates should be represented by probability distributions. Revenues resulting from by-products such as electric power may offset some of the costs. The potential for cost sharing with other related projects may also be considered to offset costs.

The objective of protecting the environment, safety, and health has three sub-objectives. The first is minimizing human health and safety risks, which requires minimizing risks to the public from normal operations, minimizing risks to workers from normal operations, and minimizing risks to both from accidents that could result from operations or inter-site transportation activities.

The second sub-objective is maximizing environmental protection. This objective requires the minimization of direct impacts on animal species, the minimization of impacts on local water supply, and the minimization of secondary wastes.

The third sub-objective is related to the socio-economic impacts of the alternatives. The short-term socio-economic disruptions by the alternatives should be minimized, while any long-term economic and social benefits should be maximized. These socio-economic impacts also relate to the screening objective of encouraging public acceptance of the alternative, particularly in the local communities that would be affected by construction and operation.

Measures. In order to evaluate the alternatives, a measure or a set of measures is needed for each of the objectives, as shown in Figures 1a, 1b and 1c. These measures should be selected so that each alternative can be evaluated on each of them, and so that each measure is then logically linked to one or more of the objectives.

The measure or set of measures associated with an objective should cover all aspects of the objective. In some cases the selection of an appropriate measure may be clear. For example, it is customary to measure the life-cycle cost of an alternative in terms of discounted net present value dollars. Similarly, concerns regarding the timeliness of the disposition activities associated with an alternative may be captured by measures of the "time to start the disposition activities" and the "time to complete the disposition activities". However, when no relevant and/or natural scales are closely linked to an objective, such as maximizing the likelihood of international cooperation, it may be necessary to work with experts to construct a measure to indicate different levels of achievement.

3. Estimation of the Performance of the Alternatives on the Objectives

Given the identification of the alternatives and the definitions of the measures, the next step is to obtain estimates of the performance of each alternative on each measure. This step defines the alternative-by-objective (and measure) matrix that summarizes the overall performance of each alternative on the relevant measures. An example of such a matrix is provided in Figure 3, where performances of three hypothetical alternatives are evaluated on five measures used for illustration purposes only. The entries in the cells in this matrix may be in the form of point estimates, ranges, or in the form of probability distributions. For example, a probability distribution might be represented by a simple three point distribution of the form (0.05 fractile, median, 0.95 fractile), that reflects the uncertainty associated with the estimates of performance. Probability distributions are included for the life cycle and investment costs of an alternative in Figure 2.

FIGURE 2 -- EXAMPLE OF ALTERNATIVES BY OBJECTIVES MATRIX

	Measures				
	Life Cycle Costs ($B)	Investment Cost ($B)	Expected Worker Fatalities	Impacts on Species (# species)	Completion Time (yr.)
Alternative A	(1, 2, 5)	(2, 2.5, 3)	.001	1	2010
Alternative B	(2, 4, 10)	(2, 3, 5)	.002	0	2025
Alternative C	(-1, 0, 5)	(2, 3, 5)	.001	3	2025

A careful inspection of this simple matrix may provide some rich insights regarding the alternatives. For example, one or more alternatives may be identified as clearly inferior because of their poor performance on most if not all of the relevant objectives. Others may obviously "rise to the top" because of superior performance on many of the objectives.

In order to obtain the performance estimates with respect to these measures, a series of assessment meetings may be necessary to focus on the major objectives. For example, experts in the area of safeguards and security (S&S) may be asked to evaluate the performance of the alternatives on the non-proliferation objectives. Other teams may be involved to develop estimates of cost and time, while still other groups may focus on the analysis necessary to develop the measures of environment and health impacts.

4. Development of Value Functions and Weights

Once the performance of each alternative on each measure in the alternatives-by-objectives matrix has been obtained, the next step in the analysis involves assembling the measures into a "super-measure" of the desirability of each alternative. The aggregation procedure is complicated by the diversity of the types and scales of the individual measures. As evident in Figure 2, some measures may be represented by probability distributions while some are expressed as point estimates. Some measures units are dollars and some are cubic meters of secondary waste, while others are defined over constructed scales, further complicating the aggregation procedure.

Utility theory provides the basis for the appropriate approach to aggregate the seemingly disparate measures. It is a logically consistent and tractable means of representing the degree to which each alternative fulfills the objectives shown in Figure 1. The use of utility theory ensures that any recommendation reflects:

- the relative attractiveness of a specific level on a measure
- the relative attractiveness of performance on different measures and objectives
- the interactions, if any, between objectives.

These three issues will be addressed in the following sections. For a more detailed presentation of these topics see Keeney and Raiffa (1976) and von Winterfeldt and Edwards (1986).

4.1 Single Attribute Value Functions

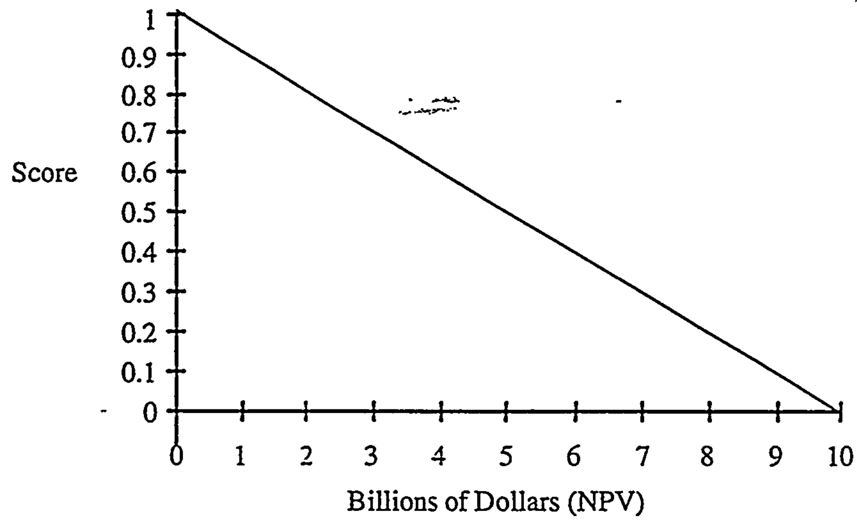
The relative attractiveness of performance outcomes on a measure is captured by a single attribute value function. A value function is constructed or assessed so that it incorporates a decision maker's preferences for performance on a measure in a utility value or score; a superior objective measure will score higher on the value scale. Value functions can be linear or non-linear as dictated by both normative concerns and the nature of the decision maker's preferences. Once constructed, value functions can be combined with probability distributions to ensure that the risk associated with an alternative is properly evaluated.

Figure 3 illustrates two *hypothetical* value functions. It is particularly important to emphasize that these value functions are used here only for the sake of exposition. The first value function represents the value associated with different levels of the Life Cycle Cost of an alternative. The function is decreasing because lower cost is preferred to higher cost; hence, lower costs receive higher value scores. The function is linear because the range of dollar amounts being considered may be small in comparison to the national budget, so the marginal value of each incremental dollar over this range is assumed to be equal.

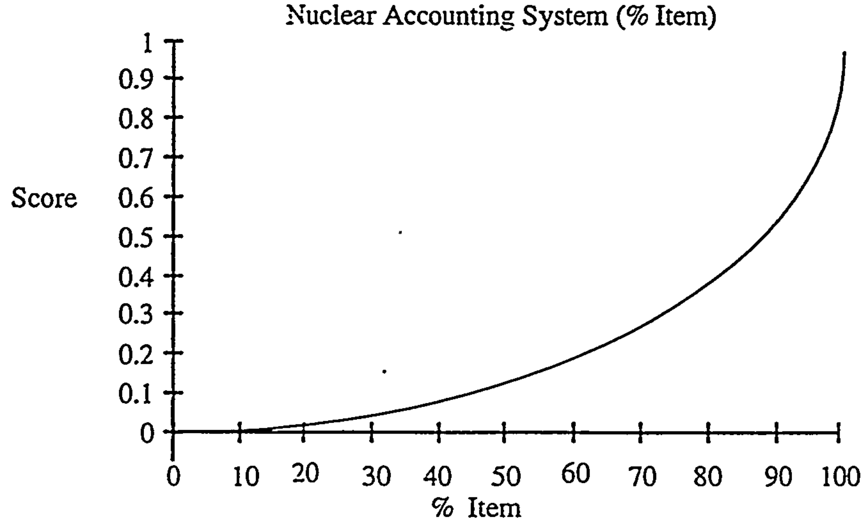
The second value function representing "Type of Nuclear Accounting System" (defined per facility as the percentage of time in the facility that "item" accounting is used) is a bit more complicated. Intuitively, the ideal facility would utilize 100% item accounting and receive the highest value. Due to the comparative ease of measuring material that is classified as item, even a small decrease from 100% item accounting receives a stiff penalty. Looking at the scores for facilities that use very little item

FIGURE 3 -- TWO EXAMPLE VALUE FUNCTIONS

Decreasing. Linear Value Function for Life Cycle Cost



Nonlinear Value Function for Type of Nuclear Accounting System (% Item)



accounting (these facilities rely heavily on "bulk" accounting), it is also clear that moving from 0% item to 10% does not receive a substantial increase in score relative to moving from 90% to 100%. The scale for Type of Nuclear Accounting System is "exponentially biased toward item accounting".

4.2 Weights

Each objective, sub-objective, and measure in the attribute hierarchy is given a weight. These weights reflect the value tradeoffs among objectives (or sub-objectives and measures within objectives), and are dependent on the ranges of the outcomes considered in the analysis.

As a simple example, consider the problem of choosing among disposition alternatives based on the objectives of cost, ES&H, and non-proliferation. Suppose that three alternatives are under consideration with costs of $2.2, $2.4, and $2.5 billion, respectively, and with representative values on the other two objectives. Now, suppose that a fourth alternative is added to the list with a cost of $3.0 billion, and with values on the other two measures that lie within the ranges of values determined by the original three alternatives. Utility theory prescribes that the weight on cost in choosing among the original three alternatives (where costs range from $2.2 to $2.5 billion) should be *smaller* than the weight on cost in choosing among the four alternatives (where costs range from $2.2 to $3.0 billion). Intuitively, this is because a wider range of costs is considered in choosing among the four alternatives; i.e., cost is more of a discriminating factor in choosing among the four alternatives than in choosing among the original three.

As a result of this insight, it should be clear that weights on objectives are not simply measures of the "relative importance" of each objective. Loosely speaking, they are measures of the importance of the *increase* from the worst to the best level of performance on one objective compared to the *increase* from the worst to the best level of performance on another objective. Therefore, weights must be assessed carefully to ensure that the results of the evaluation are consistent with the preferences of the decision maker or decision makers.

This assessment procedure can be based on a dialogue with a decision maker (or a group of stakeholders) that can take the following form. First, we assume that we have specified the ranges over which the performances of the alternatives can vary on each objective; that is, we have identified the "worst" and "best" feasible levels of performance on each objective. Next, we assume that an alternative achieves only the worst levels of performance on each of two objectives, say objective A and objective B. Holding its levels of performance constant on all of the other objectives, we ask the decision maker if it would be appropriate to pay more to increase the performance of this alternative from the worst to the best level on objective A, or to increase its performance from the worst to the best level on objective B?

Suppose that the decision maker responds, "I would pay more to increase objective A from its worst to its best level of performance." Next, we would ask her to identify a level of performance on objective A so that she believes it would be appropriate to pay the same amount to increase objective A from its worst level to this level of performance as to increase objective B from its worst to its best level of performance. The response to this question determines the ratio of the weights on objectives A and B, and additional questions comparing the other objectives provide sufficient information to specify the numerical values of these weights.

In some cases, it may appear that responses to questions of this type would be extremely difficult to make. However, the assessment process can be aided by the skills of a trained analyst, and a variety of "consistency checks" can be used to ensure that the responses are meaningful. These assessment protocols are also scripted to minimize biases in the responses, systematic errors that are known to occur as a result of the limitations of human information processing capabilities. For additional details and examples of assessment dialogues, see Keeney and Raiffa (1976) or von Winterfeldt and Edwards (1986).

Weights can be used to combine objectives and measures at different levels of the hierarchy, and the individuals who provide the judgments required to develop these weights may be different, depending on the level. For example, the judgments required to combine the measures for the sub-objectives "minimize number of processing steps" and "minimize attractiveness of material" for the objective Maximize Resistance to Theft may be more appropriately obtained from S&S experts who help evaluate alternatives as described in Section 3.

At the highest level of the hierarchy of objectives, the weights are less related to expert judgment, and much more to questions of policy. These higher level weights should be obtained in interviews with persons representing national policy makers.

4.3 Aggregation Methods

In order to obtain an overall evaluation for each disposition alternative on a higher level objective, we may use an aggregation model that can combine different measures into a single value. The model also must show the results of "sub-aggregation" at lower levels of the objectives hierarchy so that decision makers can better compare the attractiveness of alternatives. Since the decision for plutonium disposition involves both multiple criteria and risk, it is appropriate to use multi-attribute utility models for this study (Keeney and Raiffa, 1976) .

If stakeholder preferences are consistent with some special independence conditions, then a multi-attribute utility model $u(x_1, x_2, \ldots, x_n)$, where x_i represents the level of performance on measure *i*, can be decomposed into an additive, multiplicative, or other well-structured form that simplifies assessment. An additive multi-attribute utility model can be represented as follows:

$$u(x_1, x_2,\ldots, x_n) = \sum_{i=1}^{n} w_i u_i(x_i) \qquad (1)$$

where $u_i(\cdot)$ is a single-attribute value function over measure i that is scaled from 0 to 1, w_i is the weight for measure i and $\sum_{i=1}^{n} w_i = 1$. If the decision maker's preference structure is not consistent with the additive model (1), then the following multiplicative model may be used, which is based on a weaker independence condition:

$$1 + ku(x_1, x_2,\ldots, x_n) = \prod_{i=1}^{n}[1 + kk_i u_i(x_i)] \qquad (2)$$

where $u_i(\cdot)$ is also a single-attribute value function scaled from 0 to 1, the k_i's are positive scaling constants satisfying $0 \le k_i \le 1$, and k is an additional scaling constant that characterizes the interaction effect of different measures on preference. The value of k can be determined from one additional question similar to the questions used to determine the objective weights. As a special case when $\sum_{i=1}^{n} k_i = 1$, the multiplicative model (2) reduces to the additive model (1).

The choice of the appropriate model for aggregation will be based on information collected from interviews with policy makers. For approaches to the assessment of an additive utility model and a multiplicative utility model, see Keeney and Raiffa (1976).

5. Evaluation of the Alternatives and Sensitivity Analysis

5.1 Evaluation and Ranking

Once the single measure value functions have been completely defined, the data from the alternatives-by-objectives matrix (see Figure 2) are converted to component utilities. For measures that are known with a high degree of certainty, this process amounts to supplying the measure as an argument to the value function to obtain a score for each alternative on each measure. If a measure has been defined with a probability distribution, the appropriate value function is applied to the distribution to provide an expected utility value for the measure.

The component value function scores are aggregated, using the correct multi-attribute utility function, within each of the major objectives, and within each of the categories of objectives identified by the decision maker as illustrated in Figure 1. During this aggregation, the weights are used to reflect the tradeoffs between measures, and are multiplied by the corresponding scores. This stage of the evaluation process is important and useful for decision makers as it provides scores for each alternative for the major objectives of the plutonium disposition problem, and on the three categories of objectives identified in Figure 1. At this stage it is possible to examine the relative strengths and weaknesses of the alternatives. A hypothetical example of the results of this phase of the analysis is provided in Figure 4.

It is often possible to obtain important insights from an inspection of this table of scores. In addition to highlighting the relative strengths of the alternatives on the major objectives or the objective categories, alternatives that are dominated may also be identified. For example, these hypothetical scores indicate that Alternative A dominates the No Action alternative since its scores are as good or better on every major category. Note that this table could be created at a "lower level" in the hierarchy as well, highlighting the nine objectives used in the screening process. Comparisons among objectives and sub-objectives at different levels in the hierarchy may also be used to provide additional insights.

FIGURE 4 -- EXAMPLE OF PHASE I AGGREGATION			
	MAJOR CATEGORIES		
	Non-Proliferation	Operational Effectiveness	Environmental Safety and Health
Alternative A	0.7	0.3	0.7
Alternative B	0.5	0.8	0.1
Alternative C	0.4	0.4	0.4

Note: Scores are from 0 (least preferred) to 1 (most preferred). Scores are purely hypothetical.

Weights may be assessed to represent tradeoffs between the major objectives. This will allow another level of aggregation to provide a measure of the overall utility of each alternative. This step will allow for quick comparisons regarding the relative desirability of the alternatives, and should provide an excellent means of ranking the field of contending disposition alternatives.

5.2 Sensitivity Analysis

Before final disposition recommendations are made, the analysis must be tested to see if the evaluation of alternatives is robust. This sensitivity analysis basically amounts to making changes in the performance on the measures and/or weights and observing changes in the resulting evaluations and rankings.

It is impossible to predict exactly what sensitivity analyses would be performed as the evaluation process is problem specific and iterative. The following types of analyses have been useful when examining similar problems:

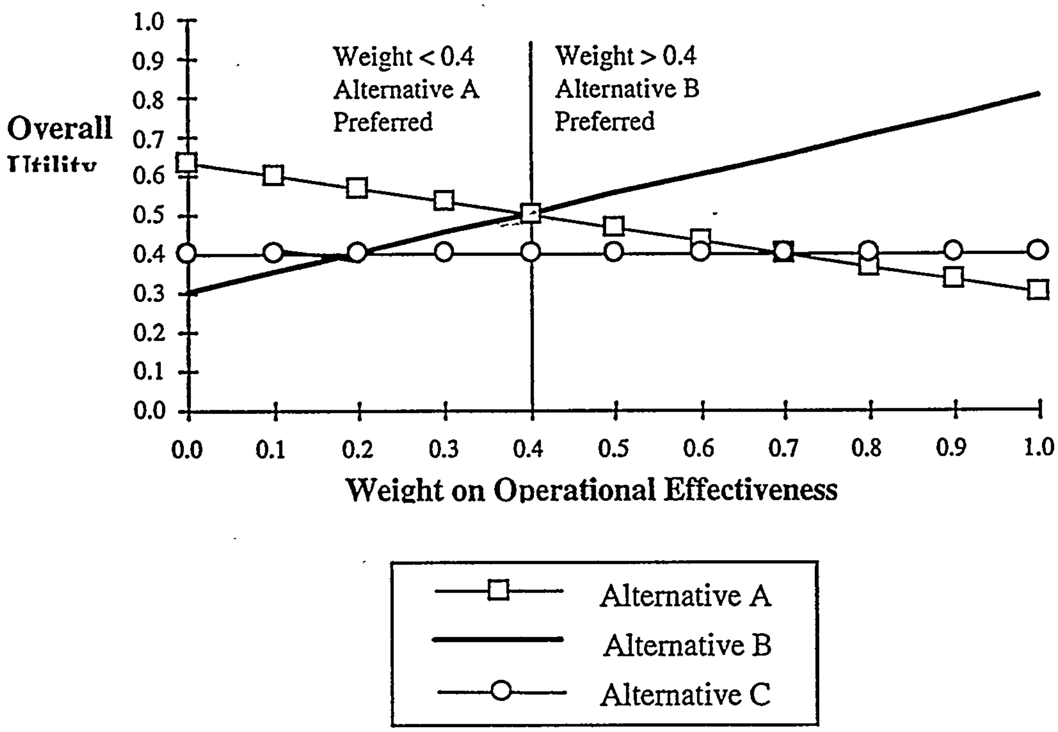
- Change the weight of an important objective while leaving the ratios between weights on other objectives unchanged. This will highlight the effect of changing the emphasis placed on an objective.

- Investigate specific entries in the alternatives-by-objectives matrix (over a reasonable range). In cases where ranges of values or probability distributions are provided as estimates, values other than the mean (average) may be selected for the sensitivity analyses (e.g. the 10th and/or 90th percentile levels). This process helps test the robustness of the ranking to the assumptions and facts that form the basis of the analysis.
- Manipulate the measures and/or probability distributions to reflect specific viewpoints. For example, it may be appropriate to investigate the implications of an optimistic perspective about the life cycle costs of an alternative. This analysis will demonstrate the effect of different perspectives about the alternatives.

Any sensitivity analyses performed will be summarized in several formats. Numerical results are presented and, where appropriate, graphical representations are also provided. These results should also be explained intuitively to ensure that all participants understand the implications and are able to contribute to discussions.

Figure 5 provides an example of the first type of sensitivity analysis based on the hypothetical scores in Figure 4. The weight placed on Operational Effectiveness is varied from 0 to 1 holding the ratio of all other weights unchanged. This analysis indicates that if the weight on Operational Effectiveness is less than 0.4 (holding the ratios of other weights constant), then Alternative A will be preferred; if it is greater than 0.4, then Alternative B is preferred. Similar analyses could be performed on all other objectives and sub-objectives.

FIGURE 5 -- EXAMPLE OF SENSITIVITY ANALYSIS ON "WEIGHTS"



6. Summary and Conclusions

This presentation presents a proposed methodology for the analysis and selection of alternatives for the disposition of surplus plutonium. The approach is intended to be general, and could easily be modified to address specific issues and concerns unique to a country or a stakeholder group.

This approach to the evaluation of alternatives has several advantages over the presentation of a great deal of technical information in the form of discussion and tables, and then a verbal argument regarding the selection of the preferred alternative. First, the approach brings some order and structure to the evaluation process. It helps to focus the different teams of personnel who are responsible for generating information regarding one or more aspects of the complex alternatives required for plutonium disposition. Second, it provides a "scorecard" that can be used by policy makers and stakeholders to understand, relatively easily, the strengths and weaknesses of the various alternatives. Third, the evaluation and sensitivity analysis can easily reduce the set of "reasonable alternatives" to a smaller subset that may be viable candidates for the final choice, depending on the implied "weights" that are assigned to the objectives.

The selection of alternatives for the disposition of plutonium is a critical issue that requires simultaneous consideration of many conflicting objectives. We believe that this approach can help countries to make these decisions in a logical and informed manner, and to communicate with each other more effectively regarding the rationale behind these choices.

7. References

Clemen, R. T. (1991). *Making Hard Decisions.* Boston: PWS Kent Publishing.

Dyer, J. S. and Lorber, H. W. (1982). The Multi-attribute Evaluation of Program-Planning Contractors. *OMEGA, 6,* 673-678.

Hertz, D. B., and Thomas, H. (1983). *Risk Analysis and its Applications.* New York: John Wiley.

Holloway, C. A. (1979). *Decision Making Under Uncertainty: Models and Choices.* Englewood Cliffs, N.J.: Prentice-Hall.

Keeney, R. L. (1980). *Siting Energy Facilities.* New York: Wiley.

Keeney, R. L., Lathrop, J., and Sicherman, A. (1986). An Analysis of Baltimore Gas and Electric Company's Technology Choice. *Operations Research, 34,* 18-49.

Keeney, R. L. and Raiffa, H. (1976). *Decisions with Multiple Objectives.* New York: Wiley.

Keeney, R. L. and von Winterfeldt, D. (1991). Eliciting Probabilities from Experts in Complex Technical Problems. *IEEE Transactions on Engineering Management, 38,* 191-201.

Keeney, R. L. and von Winterfeldt, D. (1994). Managing Nuclear Waste from Power Plants. *Risk Analysis, 14* , 107-130.

Krantz, D. H., Luce, R. D., Suppes, P., and Tversky, A. (1971). *Foundations of Measurement.* New York: Academic Press.

McNamee, P. and Celona, J. (1990). *Decision Analysis with Supertree.* 2nd edition. San Francisco: Scientific Press.

Merkhofer, M. L. and Keeney, R. L. (1987). A Multi-attribute Utility Analysis of Alternative Sites for the Disposal of Nuclear Waste. *Risk Analysis, 7,* 173-194.

OFMD (1995). Summary Report of the Screening Process to Determine Reasonable Alternatives for Storage and Disposition of Weapons-usable Fissile Materials. March 17, 1995.

National Academy of Sciences (1994). *Management and Disposition of Excess Weapons.* Washington D.C.: National Academy Press.

Raiffa, H. (1968). *Decision Analysis.* Reading, MA: Addison Wesley.

von Winterfeldt, D. and Edwards, W. (1986). *Decisional Analysis and Behavioral Research.* New York: Cambridge University Press.

AMARILLO NATIONAL RESOURCE CENTER FOR PLUTONIUM

WORK PLAN PROGRESS REPORT

Institution: University of Texas at Austin

Principal Investigator (P.I.): Dr. Randall Charbeneau

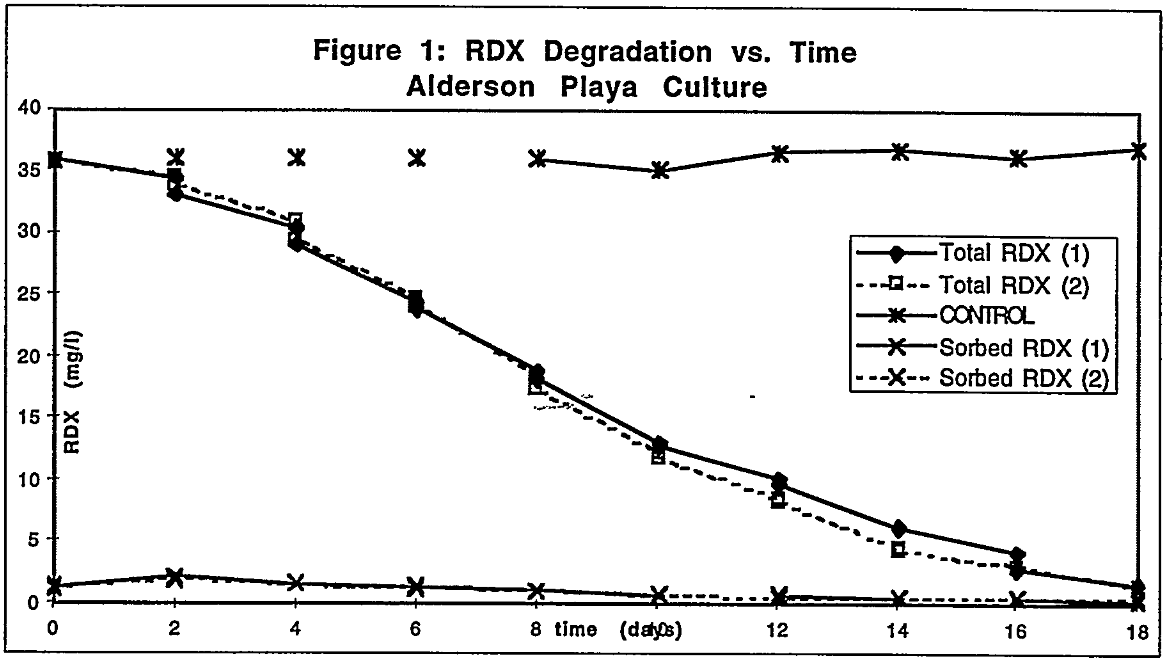
Sub-Contract Number: UTA95-0176, UTA95-0177, UTA95-0275

Award Period: January 15, 1996 to January 16, 1997

Report Period: February 1, 1996 to April 30, 1996

1.3.3 Bioremediation of HE

The characterization of the microbial degradation kinetics of RDX is nearing completion. Using the mixed culture derived from Alderson Playa (AP) soils, RDX concentrations of 36 mg/liter were reduced to approximately 1.5 mg/liter in 18 days. Figure 1 shows that the degradation of RDX over time in a set of duplicate reactors was nearly identical. The reactors were supplied nutrients and carbon sources periodically to maintain the culture throughout the duration of the experiment. Both reactors demonstrate a slight inhibition in degradation at concentrations above 30 mg/liter. However, from 4 to 12 days, the degradation rate is essentially constant as RDX concentrations are reduced from 30 mg/liter to 10 mg/liter. From 12 to 18 days, the rate decreases presumably because of a decrease in available substrate or a preference of the culture to further break down metabolites instead of the parent compound. Figure 2 shows a magnification of the plot to better reveal the trend of RDX sorption by the biomass. Once again, the duplicate reactors behave quite similarly.



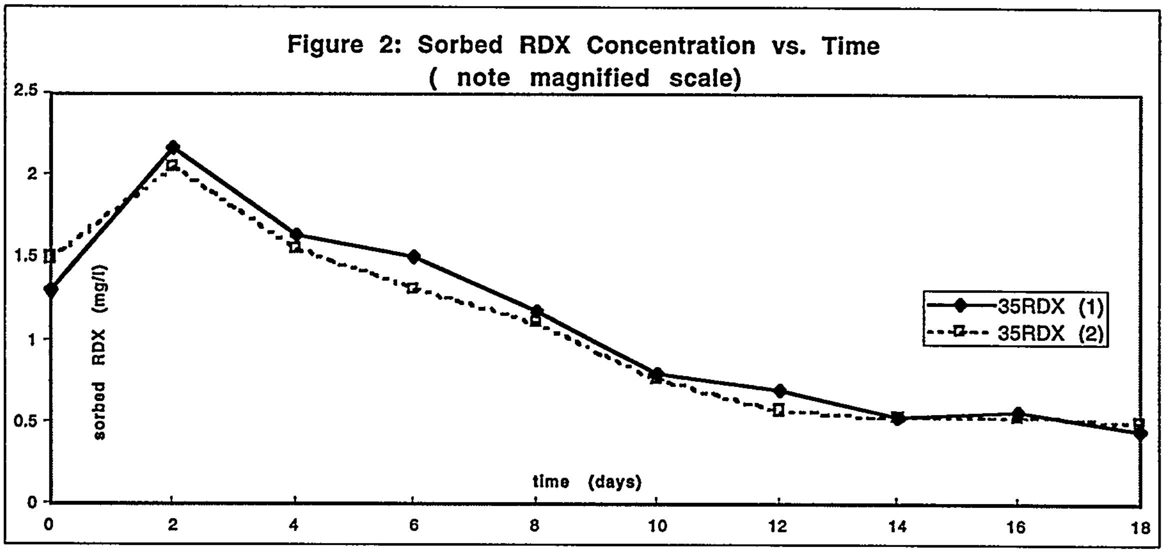
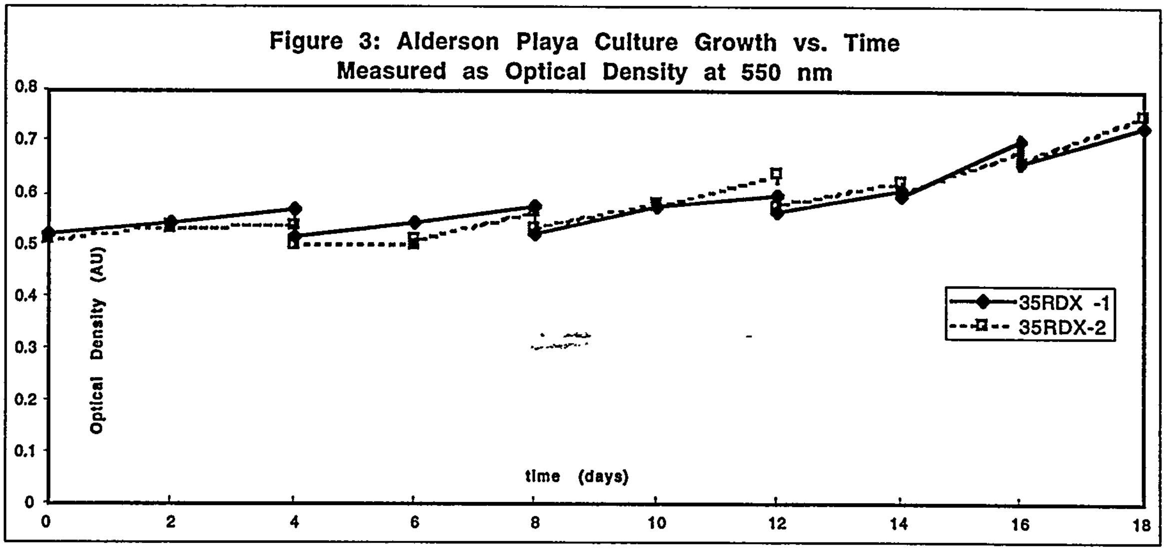
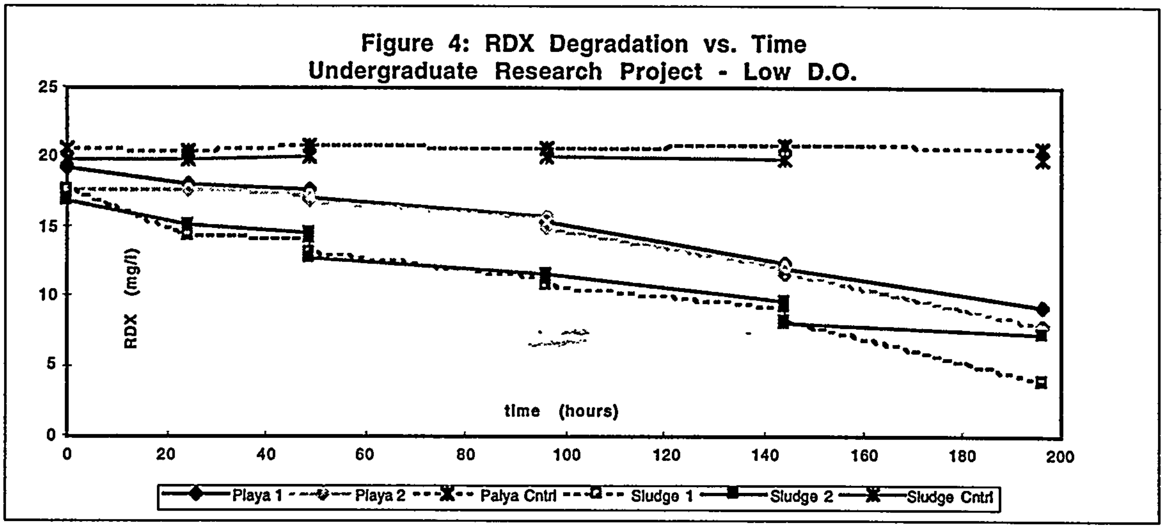


Figure 3 shows the changes in culture growth over time in terms of optical density at a wavelength of 550 nm. It demonstrates that the utilization of RDX as a nitrogen source is so rigorous that very little culture growth is possible despite exceedingly high carbon to nitrogen ratios. Moreover, the highest recorded optical densities occurred at the end of the experiment. This result might reflect either the toxicity of the initial high levels of RDX or the susceptibility of RDX metabolites to further degradation. Once again, the results from the two duplicate reactors were very similar.



In an effort to characterize the kinetic coefficients for the degradation of RDX by the Alderson Playa culture, 4 sets of rate kinetics experiments were performed each at a different RDX concentration. The RDX concentrations used for these experiments were 10, 25, 35, and 45 mg/liter and the experiments were run over a 24 hour period following each nutrient or carbon addition. Currently, analysis of the acquired data proceeds toward the development of kinetic coefficients that will characterize the degradation process. However, at concentrations greater than 10 ppm, RDX does appear to be kinetically inhibitory.

In a joint project with an honors-level undergraduate civil engineering major, the degradation of RDX is presently being examined at low dissolved oxygen (D.O.) levels using both the Alderson Playa culture and a culture derived from Pantex sludge. We term this condition microaerophyllic because the D.O. concentration can be less than 2 mg/l but not yet anaerobic by definition. This condition is being explored as a closer approximation of field conditions and as a possible enhancement of the biodegradation kinetics. As seen in Figure 4, the cultures performed similarly over a span of 8 days. The removal efficiency of roughly 50% is comparable to previous degradation results over that time frame.



The first major experiment involving duplicate reactors parallel to the RDX degradation experiment is to be run on HMX starting later this week using biomass from the RDX experiment. Biomass from the RDX degradation experiment is being enriched for this purpose. The initial biomass level may be raised to a level higher than that used in the RDX experiments for the purpose of shortening the degradation time span.

1.3.3. TCE Treatability Study

Batch TCE Degradation Assays. Batch TCE biodegradation assays, using sediments that had been stimulated in headspace bottles, were started on February 25 and completed on April 7. Results from the headspace bottles had shown that stimulation with phenol or methane resulted in generation of carbon dioxide, indicating that indigenous methanotrophs and phenol degraders could be stimulated. However, results from the headspace bottles indicated that supplemental nutrients were required.

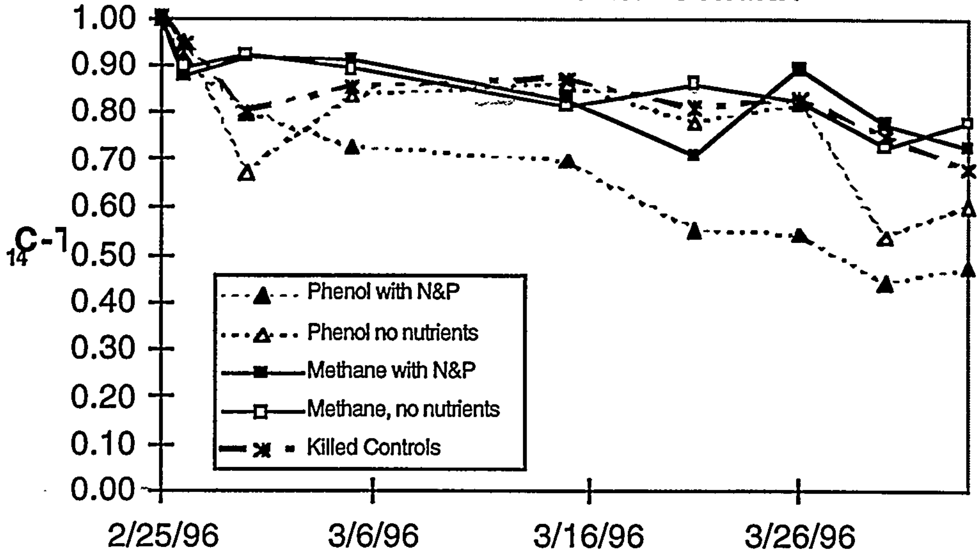
Sediments from the headspace bottles were transferred to vials for a batch TCE degradation study. A total of seven vial series were prepared, each of which corresponded to a different substrate and nutrient condition from the headspace bottle experiment. In addition to four vial series prepared with biologically-active sediments, three different "killed" control series were prepared to determine losses due to non-biological mechanisms.

Approximately 2 to 3 g of stimulated aquifer material was placed in a 6-mL hypovial, along with enough groundwater to provide saturated conditions. Groundwater was then spiked with ^{14}C-TCE to provide an initial concentration of 100 to 200 μg TCE/L. Each vial was then sealed with a septum and an aluminum crimp top seal. Vials were then incubated underwater (to reduce diffusion of ^{14}C-TCE from the vials) at 16 to 18°C.

Vials were sampled over time to determine losses of ^{14}C-TCE and generation of $^{14}CO_2$ and ^{14}C-nonvolatiles. A modified purge and trap device was used to separate ^{14}C-TCE and $^{14}CO_2$, and samples were analyzed by liquid scintillation counting. Results from the TCE biodegradation assays are presented in Figure 1.

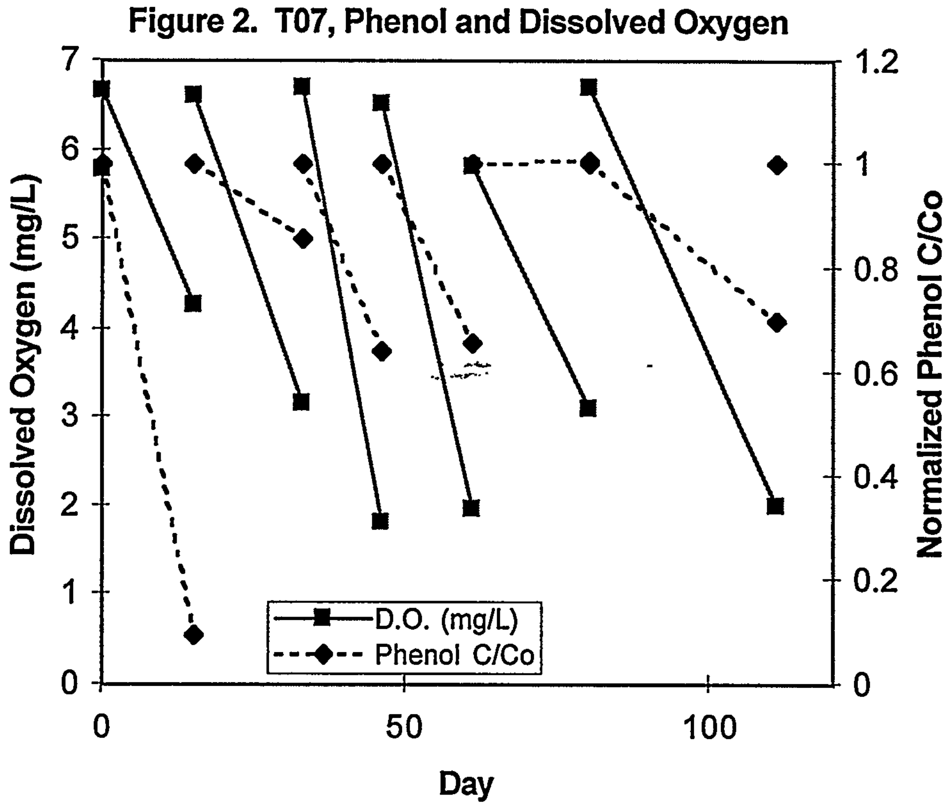
These results show TCE losses for all vials under consideration. However, the only vial series with significant losses as compared to the killed controls was the series containing sediments that were stimulated with phenol and supplemental nutrients (added as 20 mg/L $(NH_4)_2HPO_4$). Methane-stimulated sediments resulted in no losses of TCE beyond the losses from killed controls. The phenol-stimulated sediments without additional nutrients may have resulted in ^{14}C-TCE losses, but these data sets must be statistically compared.

Figure 1. ^{14}C-TCE Over Tim Different Substrate Conditic



Test Tube Biostimulation and TCE Degradation Assays. Stimulation of sediments in test tubes started on December 19, 1995 and continued until April 12. In general, column fluids were exchanged once every 2 to 3 weeks. Fluid that were injected into the columns was sterilized Pantex groundwater amended with dissolved oxygen, dissolved substrates (methane or phenol), and supplemental nutrients (20 mg/L $(NH_4)_2HPO_4$). During incubation, dissolved oxygen and substrates were utilized as shown in Figure 2. This figure is an example of oxygen and phenol utilization in one of the test tubes over time.

TCE degradation assays were started on April 12. Rather than injecting groundwater with substrates and nutrients, groundwater spiked with about 100 µg ^{14}C-TCE/L was injected.



Ongoing and Future Work. TCE degradation assays using the sediments in test tubes must be completed. Initial results (as of April 29) show some TCE losses, but conclusions cannot yet be made.

Plate counts will be completed to quantify the bacterial populations in the stimulated aquifer sediments. Methanotrophic and phenol-degrader populations will be estimated in the sediments that were stimulated in the test tubes.

After completion of the current degradation assay and plate counts, results from the different methods will be compared. Major comparisons will include:

- Methane and phenol as primary substrates;
- Nutrient requirements;
- Headspace bottles and test tube microcosms as methods for studying biostimulation; and

Batch vial studies and test tube microcosms as methods for studying TCE biodegradation.

1.3.5 Chromium Remediation at the Pantex Plant

Introduction

Chromium has been found at concentrations above background levels in several wells in the perched aquifer below the Pantex Plant, particularly in those beneath Zone 12. In some wells, the concentrations of total chromium exceed levels used to define hazardous wastes by the toxicity characteristic and approach being two orders of magnitude higher than drinking water standards. Concentrations in at least one of these wells (PM-20) shows marked increases in total chromium concentrations from 1991 through 1994. Chromium in the perched aquifer is assumed to result from release at the surface, therefore there may be significant amounts of chromium in the vadose zone moving towards the perched aquifer. However, zones of high chromium concentrations have yet to be located in any soils.

A research program has been initiated under the Amarillo National Resource Center for Plutonium to obtain information to support the remediation of chromium at the Pantex Plant. It is being carried out by research teams at Texas A&M University (TAMU), Texas Tech University (TTU) and the University of Texas at Austin (UT). This is the report on activities of these research teams during the time period between February 1, 1996 through April 30, 1996. It is organized according to the following six work tasks:

1. Develop and validate analytical procedures and quality control programs
2. Develop chemical models for chromium in the vadose zone and perched aquifer
3. Conduct ion exchange studies
4. Evaluate redox chemistry of chromium
5. Identify sources and speciation of chromium
6. Evaluate sorption of chromium on soils

Progress in Task 1 (Develop and validate analytical procedures and quality control programs) Internal quality control procedures continued to be applied to each laboratory. A quality control/quality assurance evaluation of analytical procedures at each university was delayed due to problems at TAMU in developing an analytical procedure based on inductively coupled plasma/mass spectrometry (ICP/MS). This procedure has been developed for total chromium using a Hewlett Packard ICP-MS 4500 with Cetac standard sample introduction system with a Direct Injection Nebulizer. Chromium is monitored at atomic masses of 50, 52, and 53. Detection limits for this analysis are at or below 1 μg/l. The quality control/quality assurance evaluation was conducted at the end of the quarter and the report will be submitted early in the next quarter.

Progress in Task 2 (Develop chemical models for chromium in the vadose zone and perched aquifer) Work continued during the quarter in applying equilibrium models to evaluate aspects of chromium remediation in the perched aquifer. First, the mixed chromium-iron solid phase reported in the literature (Saas, B.M., and Rai, D.M., "Solubility of Amorphous Chromium(III)-Iron(III) Hydroxide Solid Solutions", *Inorg. Chem.* 26:2228, 1987.) was included in the model data base. This solid has variable stoichiometry between chromium and iron as represented by the formula $Cr_xFe_{(1-x)}(OH)_3$. The solubility of iron(III) and chromium(III) as a function of pe at various values of pH when the chromium/iron ratio equals 0.25 is shown in Figure 1. Conditions for this simulation are given in Table 1.

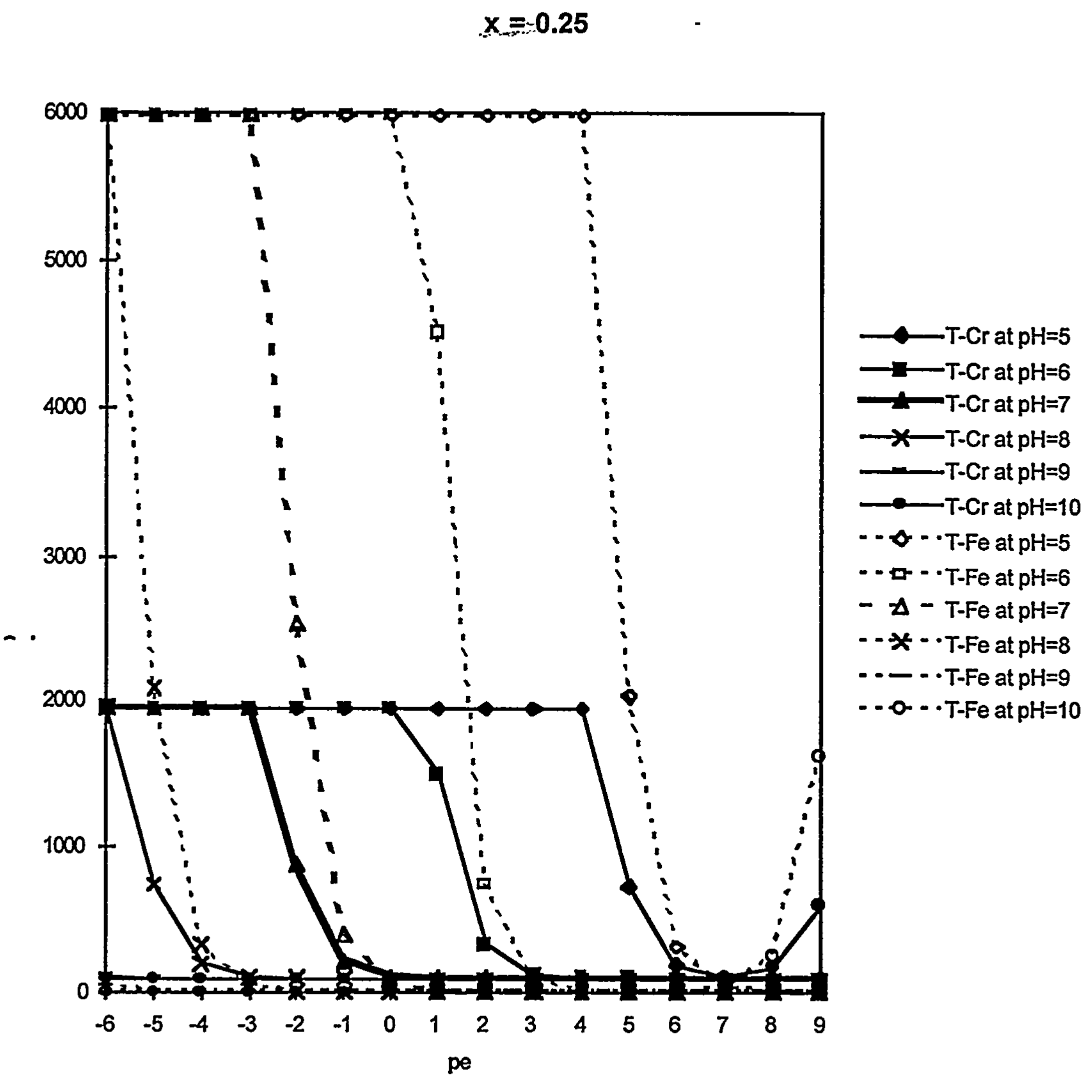


Figure 1. Total Cr and Total Fe Solubilities at Different pH and pe in Equilibrium with $Cr_x Fe_{(1-x)} (OH)_3$ at x = 0.25.

Table 1. Input Concentrations of Components for the MINTEQA2 Runs for Controlling Solids

Component	Cr	Fe	Ba	Mg	Na	K	SO_4
Concentration (µg/l)	1,950	6,000	230	51,900	20,200	9,100	40,000

The effect of different iron solid phases on the redox condition of the aquifer was evaluated with the chemical equilibrium model. Figure 2 shows that very reducing conditions (low values of pe) can be obtained. The most reducing conditions are obtained when magnetite controls the solution phase concentrations of iron. For comparison with Figure 2, the highly reducing conditions resulting from equilibrium with hydrogen gas at 1 atm would result in a pe of -7.0 at pH 7.

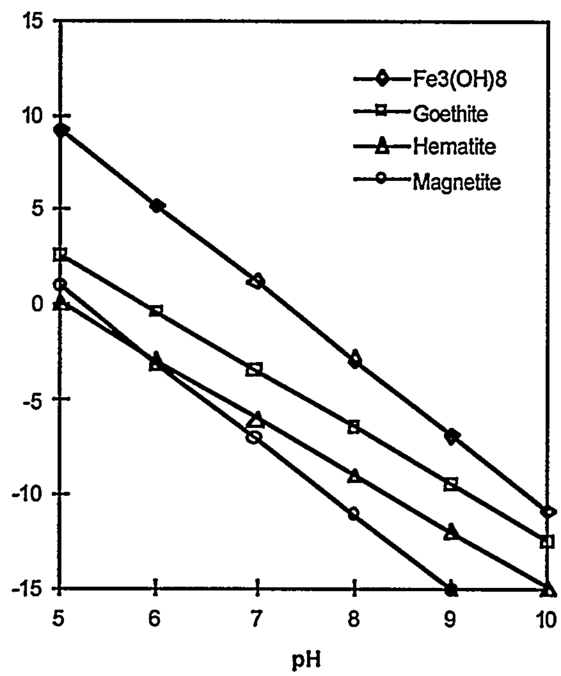


Figure 2. pe-pH diagram for Different Fe Solid Phases With the Activity of Ferrous Iron (Fe^{+2}) Fixed at 10^{-4} M.

Progress in Task 3 (Conduct ion exchange studies) Ion exchange has been studied for Cr(VI) removal from Pantex groundwater. Cr(VI) is believed to exist primarily as chromate, CrO_4^{-2}, at the normal groundwater pH (7.5 - 8) and Cr(VI) concentrations (0.6 - 2.5 mg/L). Six column tests using a strong base anion resin (SBA) and Pantex groundwater have been performed. Breakthrough curves for each test were very gradual, spreading over thousands of pore volumes of throughput. Theories for gradual breakthrough including anion competition and kinetics limitations have been explored.

Anion competition was mentioned previously in the 1996 First Quarter Report. Further studies have revealed no competitive relationship between other anions and CrO_4^{-2}. Figure 3 shows the breakthrough curves for the anions of interest. The CrO_4^{-2} breakthrough curve is independent of the breakthrough curve for any other anion.

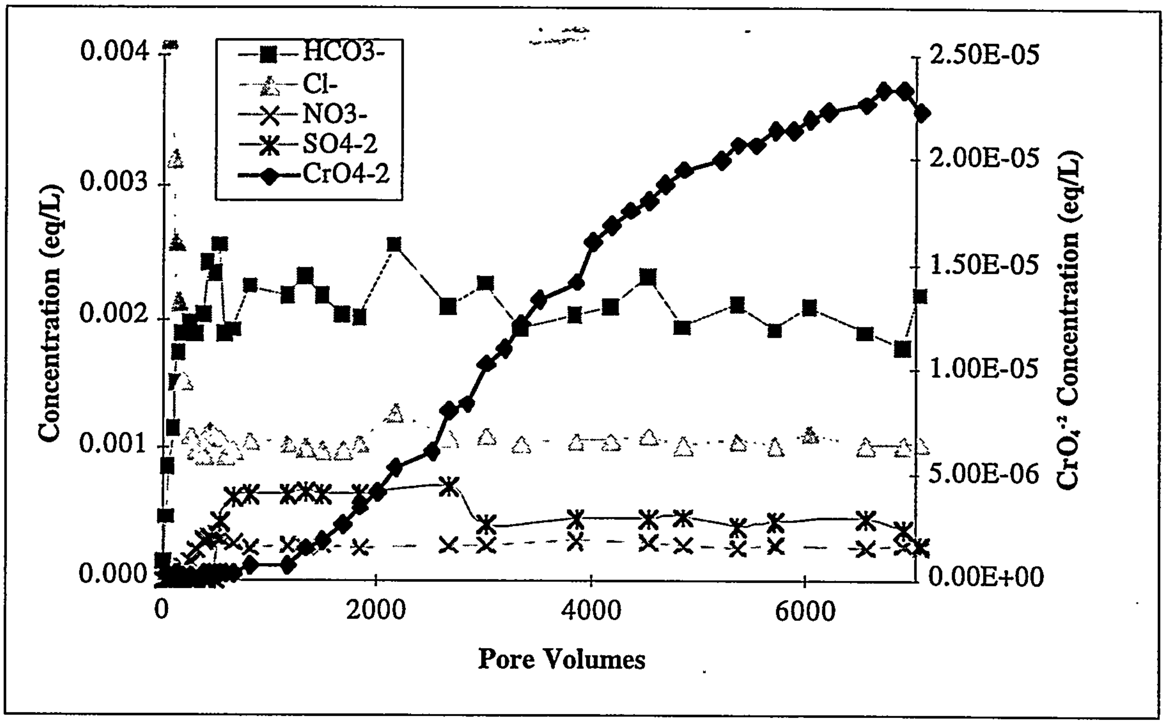


Figure 3. Anion Breakthrough Curves for Column Test 5

A competitive equilibrium model was compared to the experimental results. The Equilibrium Multicomponent Chromatography Theory with Constant Separation Factors (EMCT/CSF) developed by Helfferich and Klein was programmed for use on Macintosh™. The initial anion concentrations in groundwater shown in Table 2 were used as input for the model.

Table 2. Anion Concentrations Used in the EMCT/CSF Model

Anion	Concentration (mg/L)	Concentration (eq/L)
CrO_4^{-2}	0.6	2.2×10^{-5}
F^-	1.2	7.0×10^{-5}
Cl^-	33	1.0×10^{-3}
NO_3^-	15	2.4×10^{-4}
SO_4^{-2}	21	4.0×10^{-4}

The EMCT/CSF produced a sharp breakthrough curve for CrO_4^{-2}. The program does not take into account previous ion exchange research at the University of Houston which pointed out the irregular characteristics of Cr(VI) ion exchange at acidic pH. Arup Sengupta and Dennis Clifford found the same gradual breakthrough when ion exchange resins were used for a waste stream at pH 4 and Cr(VI) concentrations of 5-20 mg/L. They proposed that $HCrO_4^-$, the predominant Cr(VI) specie under these conditions, becomes concentrated in the resin phase. As the concentration increases, equilibrium with $Cr_2O_7^{2-}$ is approached as shown in Figure 4. The combination of Cr(VI) species complicates the ion exchange equilibrium and causes the gradual breakthrough.

The normal Pantex groundwater conditions mentioned previously preclude the mechanism proposed by Sengupta and Clifford. However, a similar mechanism which has not been identified may take place under the normal groundwater conditions, and this possibility will be studied further during the next quarter.

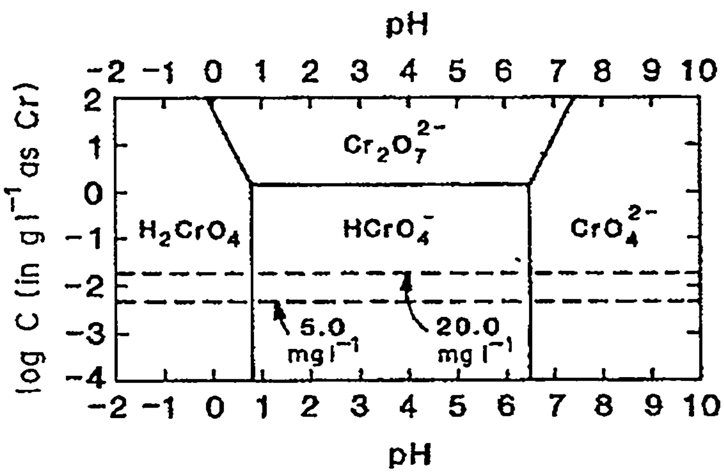


Figure 4. Predominance Diagram for Cr(VI) Species

Progress in Task 4 (Evaluate Redox chemistry of chromium) Experiments were initiated during this quarter to evaluate the ability of iron to reduce hexavalent chromium under conditions found in the perched aquifer beneath the Pantex Plant. Two types of experiments have been conducted – solution experiments and slurry experiments that contain aquifer material. All experiments were conducted using the media described in Table 3 and were deoxygenated by purging with nitrogen gas. Samples were taken and filtered before analysis for total chromium.

Table 3. Composition of the Artificial Groundwater Used in Redox Experiments.

Ion	Ca^{2+}	K^+	Mg^{2+}	Na^+	Cl^-	CrO_4^{2-}
Concentration (mg/L)	45.5	9.1	51.9	75.9[a]	232.2[b]	2.0

a: Higher than concentrations found in well PM-20 due to alkalinity addition as $NaHCO_3$
b: Higher than concentrations found in well PM-20 because it was added as the anionic component of the cation reagents.

The solution experiments showed rapid and complete reduction of hexavalent chromium when ferrous iron was added at 1.5 times the stoichiometric amount at pH 7.6. The concentration of total chromium in solution was less than 20 µg/l for all samples analyzed. The earliest sample was taken at 10 seconds after addition of iron. A second solution experiment was conducted to insure that the addition of a concentrated ferrous iron stock solution with low pH was not biasing reduction kinetics due to the low pH values that occur in the vicinity of the iron solution before complete mixing. Similar results to the first solution experiment were observed and are shown in Table 4.

Table 4. Total Dissolved Chromium as Function of Time in Solution Experiment.

Time (min)	1.5	4.4	10.6	25	30
Total Dissolved Chromium (µg/l)	13.2	10.8	2.7	1.1	0.9

The rapid kinetics observed in the solution tests indicate that kinetics will not limit reduction of hexavalent chromium in solution. Therefore, the main factor determining the efficiency of chromium reduction by ferrous iron is the amount of ferrous iron required to effectively reduce chromium. This may be in excess of the stoichiometric amount, due to other reactions that could consume ferrous iron such as adsorption on soil surfaces or redox reaction with other oxidants in the soil. A series of slurry experiments was conducted to evaluate the required iron doses. These experiments were conducted by adding aquifer material to the same media that was used in the solution experiments. Iron was added first and allowed to react with aquifer material for 22 hours before addition of hexavalent chromium. The aquifer material was taken from well PTX06-1012, which is located approximately 2700 ft southwest of Zone 12. Elevated chromium concentrations have not been observed in the vicinity of this well. This material was air dried and screened to particle sizes below 0.25 mm before being added at a soil/solution ratio of 0.10 by weight to the artificial groundwater. Results of these experiments are shown in Figure 5.

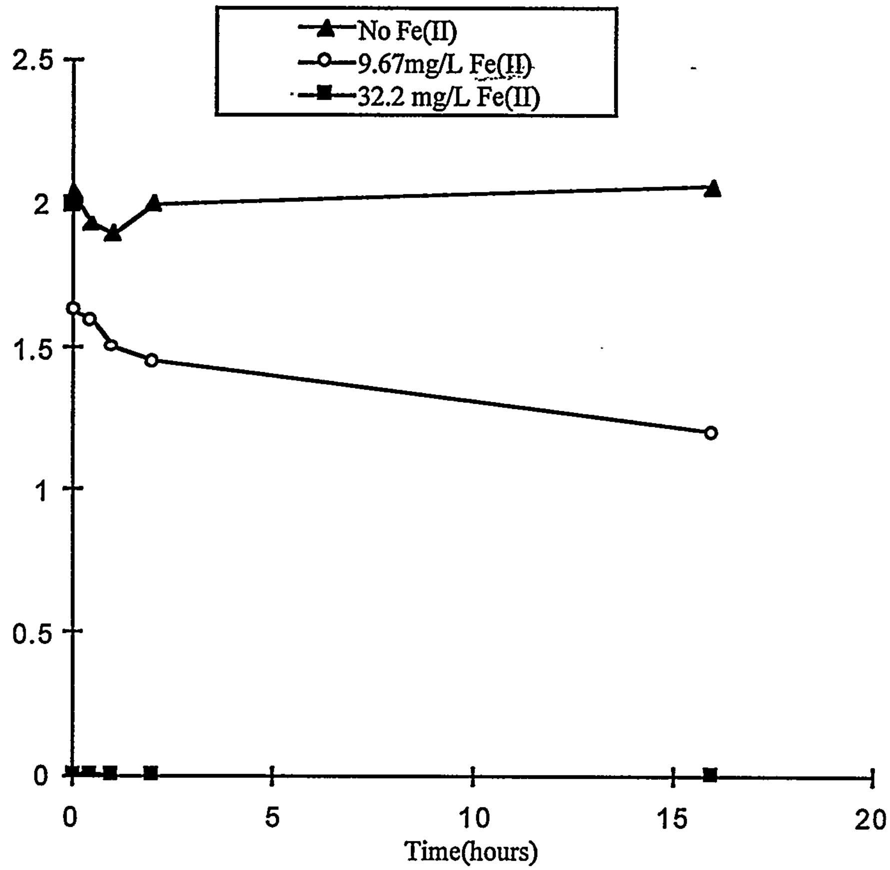


Figure 5. Changes in Total Dissolved Chromium Concentration With Time For Different Amounts Of Fe(II).

These results demonstrate that the aquifer material exerts a substantial short-term demand for iron. This demand could be caused by adsorption or oxidation reactions. The results for the experiment with iron added at 1.5 times the stoichiometric amount (i.e. 9.67 mg/l) are very interesting. It appears that some of the ferrous iron remains in solution to rapidly reduce chromium. However, a substantial amount of chromium remains in solution at the first sampling time (1.5 minutes) and it is removed at a slower rate over the next 16 hours. This indicates that some of the ferrous iron may be removed from solution, but continue to retain its ability to reduce chromium at a slower rate. Adsorption and surface reaction could be a mechanism to describe this observation.

Experiments will continue during the next quarter to further document this effect and a milestone report will be prepared.

Progress in Task 5 (Identify sources and speciation of chromium) Dr. Heyward Ramsey has investigated existing information and has calculated estimates for the range of flows and concentrations in the blowdown water emitted from the former cooling tower during its operational life. This cooling tower is a likely source of the Cr contamination in the Zone 12 area. A milestone report will be generated from this effort early in the next quarter.

The field sampling for speciation of Cr by well location and depth has been postponed to take place this summer. TTU researchers will be on site for several purposes this summer, so it should be simple to coordinate with the Battelle Environmental Monitoring group. The sampling should take place during the next quarter.

During the next quarter, the field sampling planning will be completed, the first sampling round should take place, and the former cooling tower Cr generation report will be completed.

Progress in Task 6 (Evaluate Sorption of Chromium on Soils) The Cr sorption isotherms for eight subsurface soil samples were completed in the previous quarter. The next step is to perform one-dimensional soil column sorption tests. These tests were delayed until the next quarter due to a request to perform isotherm tests on the same soils for HMX and RDX. Those tests are near completion, so the 1-D column tests for Cr should begin in May. During the next quarter, one-dimensional column tests for Cr sorption will be performed.

Appendix 9

K-16 Math & Science Education

Needs Assessment
Survey Information

DATA ELEMENTARY SCIENCE AND/OR MATHEMATICS TEACHERS SURVEY

There were 479 elementary teachers responding to the survey. The following is a question by question summary of percent answering each question.

A. General Information:

1. Age: (a) 20-29 *{19.2%}* (b) 30-39 *{26.1%}* (c) 40-49 {34.9%} (d) 50-59 {17.7%} (e) 60 and over {2.1%}.

2. Sex: (a) female {96.7%} (b) male {3.3%}

3. Ethnic background: (a) African American {0.6%} (b) Asian {0.6%} (c) Caucasian {94.6%} (d) Hispanic {3.1%} (e) Native American {0.6%} (f) Other {0.4%}

4. Degree Status: (a) bachelor's {34.6%} (b) bachelor's plus hours {47.3%} (c) master's {10.0%} (d) master's plus hours {7.5%} (e) doctorate {0.6%}

5. Number of years teaching experience, including this year: (a) 1- {22.8%} (b) 5-9 {23.0%} (c) 10-14 {17.4%} (d) 15-19 {16.2%} (e) 20 or more {20.5%}

6. Number of schools where you held full-time teaching positions: (a) 1 {39.2%} (b) 2 {27.3% } (c) 3 {16.5%} (d) 4 {8.3%} (e) 5 or more {8.8%}

7. Number of years in your present school, including this year: (a) 1 {16.5%} (b) 2 {9.0%} (c) 3-5 {24.2%} (d) 6-10 {21.9%} (e) 11 or more {28.5%}

8. Present school district: ______________________

9. Usual number of classes (sections) for each grade level in your school: (a) 1 {10.4%} (b) 2 {6.6%} (c) 3 {26.0%} (d) 4 {20.3%} (e) more than 4 {36.7%}

10. Classification of high school your students will eventually attend: (a) A {3.4%} (b) AA {6.8%} (c) AAA {28.8%} (d) AAAA {54.4%} (e) AAAAA {6.6%}

11. Current school: (a) public school {98.1%} (b) private school {1.9%}

12. Current grade-level teaching assignment: (a) PK {1.3%} (b) K {12.3%} (c) 1 {17.5%} (d) 2 {15.6%} (e) 3 {17.7%} (f) 4 {14.6%} (g) 5 {9.8%} (h) 6 {3.3%} (i) combination of grade levels {7.9%}

13. Certification concentration area: (a) science {8.4%} (b) mathematics }10.8%} (c) reading {24.9%} (d) social studies {4.1%} (e) language arts {17.3%} (f) other {34.4%}

14. Currently teaching science: (a) yes {86.2%} (b) no {13.8%}

15. Currently teaching mathematics: (a) yes {91.5%} (b) no {8.5%}

16. Number of college science content (not education) classes completed (approximately): (a) 2 or fewer {44.9%} (b) 3 {26.8%} (c) 4 {10.3%} (d) more than 4 {17.9%}

17. Number of college mathematics content (not education) classes completed (approximately): (a) 0 {9.7%} (b) 1 {11.2%} (c) 2 {34.3%} (d) 3-4 {30.3%} (e) more than 4 {14.4%}

18. Number of years since your last college science content class (approximately): (a) 0-2 {10.8%} (b) 3-5 {20.5%} (c) 6-8 {11.2%} (d) 9-11 {13.5%} (e) 12 or more {44.0%}

19. Number of years since your last college mathematics content class (approximately): (a) 0-2 {11.9%} (b) 3-5 {18.6%} (c) 6-8 {10.6%} (d) 9-11 {14.2%} (e) 12 or more {44.7%}

20. Frequency that you personally use computers: (a) less than once a month {17.5%} (b) once a month {8.5%} (c) every 2 weeks {7.3%} (d) weekly {34.4%} (e) daily {32.3%}

21. If you use computers for schoolwork, primary purpose: (a) word processing {38.2%} (b) record management {18.3%} (c) instruction {28.0%} (d) other {3.6%} ______________________________

22. If you don't use computers for schoolwork, primary reason: (a) lack of access to computers {30.4%} (b) lack of training {33.5%} (c) lack of time {22.5%} (d) lack of software {8.4%} (e) other {5.2%} ______________________________

23. Computers available for class use: (a) daily {57.3%} (b) weekly {36.0%} (c) monthly {1.7%} (d) never {5.0%}

24. Computer available for class demonstrations: (a) daily {45.1%} (b) weekly {25.5%} (c) monthly {1.3%} (d) never {28.1%}

25. Internet access available: (a) in my classroom {4.5%} (b) in my school {28.4%} (c) in my district {33.1%} (d) none of these {34.0%}

26. Classroom sets of calculators available: (a) yes {58.8%} (b) no {41.2%}

How important do you consider the following when deciding whether or not to attend professional development:

27. **where** it will be held: (a) very important {49.4%} (b) somewhat important {44.6%} (c) not important {6.0%}

28. **when** it will be held: (a) very important {68.2%} (b) somewhat important {29.3%} (c) not important {2.5%}

29. **how long** it will last: (a) very important {40.9%} (b) somewhat important {53.5%} (c) not important {5.6%}

30. **cost** to attend: (a) very important {75.1%} (b) somewhat important {23.4%} (c) not important 1.5%}

31. **topic** addressed: (a) very important {93.1%} (b) somewhat important {6.7%} (c) not important {0.2%}

32. **who** is presenting it: (a) very important {42.2%} (b) somewhat important {52.0%} (c) not important {5.8%}

33. **how much time** you will be out of the classroom: (a) very important {70.7%} (b) somewhat important {27.2%} (c) not important {2.1%}

Would you attend non-required professional development <u>relating directly to what you teach</u> if it is offered

34. in your school district: (a) definitely yes {49.7%} (b) probably yes {47.6%} (c) probably no {2.5%} (d) definitely no {0.2%}

35. at cluster sites near your district: (a) definitely yes {24.7%} (b) probably yes {65.7%} (c) probably no {9.2%} (d) definitely no {0.4%}

36. at an Education Service Center: (a) definitely yes {21.1%} (b) probably yes {66.1%} (c) probably no {12.3%} (d) definitely no {0.4%}

37. at a university (graduate credit): (a) definitely yes {15.8%} (b) probably yes {55.6%} (c) probably no {24.2%} (d) definitely no {4.4%}

38. at a community college (undergraduate credit): (a) definitely yes {10.5%} (b) probably yes {48.2%} (c) probably no {33.1%} (d) definitely no {8.2%}

39. at a museum or science center: (a) definitely yes {13.5%} (b) probably yes {67.5%} (c) probably no {17.7%} (d) definitely no {1.3%}

40. after school: (a) definitely yes {5.8%} (b) probably yes {58.2%} (c) probably no {32.8%} (d) definitely no {3.1%}

41. at night: (a) definitely yes {2.9%} (b) probably yes {32.3%} (c) probably no {51.5%} (d) definitely no {13.3%}

42. on Saturdays: (a) definitely yes {5.0%} (b) probably yes {37.9%} (c) probably no {42.5%} (d) definitely no {14.6%}

43. for one or two days: (a) definitely yes {7.9%} (b) probably yes {77.0%} (c) probably no {13.0%} (d) definitely no {2.1%}

44. once a month (week-days) during the school year: (a) definitely yes {8.6%} (b) probably yes {61.5%} (c) probably no {26.6%} (d) definitely no {3.3%}

45. once a month (Saturdays) during the school year: (a)definitely yes{4.0%}(b) probably yes {28.2%} (c) probably no {51.7 %} (d) definitely no {16.1%}

46. on one week-day in the summer: (a) definitely yes {19.3%} (b) probably yes {67.3%} (c) probably no {9.9%} (d) definitely no {3.6%}

47. for one week in the summer: (a) definitely yes {9.2%} (b) probably yes {47.5%} (c) probably no {33.3%} (d) definitely no {10.0%}

48. for 1 week in the summer and follow-up during the school year: (a) definitely yes {8.2%} (b) probably yes {46.4%} (c) probably no {36.4%} (d) definitely no {9.0%}

49. for 3 weeks in the summer and follow-up during the school year: (a) definitely yes {2.9%} (b) probably yes {15.2%} (c) probably no {49.5%} (d) definitely no 32.4%}

50. Average distance you usually travel to attend **non-required** professional development: (a) less than 5 miles {8.5%} (b) 5-30 miles {28.2%} (c) 31-60 miles {33.8%} (d) 61-120 miles {24.1%} (e) more than 120 miles {5.3%}

51. Does your district provide funds for individuals or groups of teachers to attend **non-required** professional development for math and/or science teachers? (a) yes {77.0%} (b) no {23.0%}

52. Which of the following best describes your knowledge about the Amarillo National Resource Center for Plutonium:
(a) I have never heard of it before this survey. {63.6%} (b) I have heard of it before this survey but have no idea about its purpose. {28.9%} (c) I have general ideas about its purpose. {7.5%} (d) I understand its purpose. {0%}

B. If you teach science, please answer questions 53 through 104. If you only teach mathematics, skip to section C beginning with question 105.

Have you completed a college class (not education/methods) primarily devoted to:

53. general biology: (a) yes {77.1%} (b) no {22.9}
54. zoology: (a) yes {33.0%} (b) no {67.0%}
55. botany: (a) yes {28.3%} (b) no {71.7%}
56. physics: (a) yes {14.8%} (b) no {85.2%}
57. chemistry: (a) yes {26.0%} (b) no {74.0%}
58. geology: (a) yes {41.8%} (b) no {58.2%}
59. astronomy: (a) yes {9.6%} (b) no {90.4%}
60. environmental science: (a) yes {20.7%} (b) no {79.3%}
61. integrated general science: (a) yes {57.2%} (b) no {42.8%}

How many **SCIENCE** teacher organizations do you have membership in at the

62. local/state level (STAT, etc.): (a) 0 {95.4%} (b) 1 {3.8%} (c) 2 or more {0.8%}

63. national level (NSTA, NABT, etc.): (a) 0 {96.7%} (b) 1 {3.3%} (c) 2 or more {0%}

Have you attended a convention or conference for **SCIENCE** teachers in the last 3 years

64. in the Panhandle: (a) yes {28.2%} (b) no {71.8%}
65. in Texas but not in the Panhandle: (a) yes {6.0%} (b) no {94.0%}
66. in another state: (a) yes {0.8%} (b) no {99.2%}

67. In the last 3 years have you attended **district-required** professional development addressing methodology used to teach science? (a) yes {20.4%} (b) no {79.6%}

68. In the last 3 years have you attended **district-required** professional development addressing knowledge of science concepts? (a) yes {20.4%} (b) no {79.6%}

69. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach science: (a) every year {10.7%} (b) every other year {16.7%} (c) every 3-5 years {33.2%} (d) never {39.4%}

70. Frequency you **choose** to attend **non-required** professional development addressing knowledge of science concepts: (a) every year {11.0%} (b) every other year {14.5%} (c) every 3-5 years {32.9%} (d) never {41.6%}

71. Which of the following best describes your knowledge about the publication National Science Education Standards: (a) I have not heard of it. {47.8%} (b) I have heard of it but have no idea what it says. {29.8%} (c) I have general ideas about what it says. {20.5%} (d) I have begun implementation of ideas it presents. {2.0%}

How often do you use the following activities for science instruction:

72. Activities involving students in manipulating objects and/or equipment: (a) daily {6.1%} (b) weekly {38.7%} (c) monthly {39.2%} (d) once a semester {11.5%} (e) never {4.4%}

73. Field trips to off-campus sites for science objectives: (a) weekly {0.2%} (b) monthly{3.4%} (c) every semester{13.5%} (d) every year{44.1%} (e) never {38.7%}

74. Collaborative or cooperative learning: (a) daily {12.6%} (b) weekly {40.3%} (c) monthly {29.0%} (d) once a semester {9.9%} (e) never {8.2%}

75. Computer activities in science class or lab: (a) daily {2.0%} (b) weekly {7.4%} (c) monthly {8.9%} (d) once a semester {8.4%} (e) never {73.3%}

76. Teacher demonstrations in science: (a) daily {4.0%} (b) weekly {35.1%} (c) monthly {44.0%} (d) once a semester {12.1%} (e) never {4.9%}

77. Teacher lecture in science class: (a) daily {17.1%} (b) weekly {47.1%} (c) monthly {19.4%} (d) once a semester {2.3%} (e) never {14.1%}

78. Discovery/Inquiry learning: (a) daily {8.1%} (b) weekly {41.3%} (c) monthly {34.5%} (d) once a semester {8.8%} (e) never {7.3%}

79. Computers for tutorials: (a) daily {4.2%} (b) weekly {9.7%} (c) monthly {5.2%} (d) once a semester {2.7%} (e) never {78.1%}

80. Alternative assessment: (a) daily {3.6%} (b) weekly {21.0%} (c) monthly {28.0} (d) once a semester {8.8%} (e) never {38.6%}

Indicate the extent you need assistance with each of the following in your science teaching:

81. New teaching methods: (a) definitely yes {34.6%} (b) probably yes {53.5%} (c) probably no {10.6%} (d) definitely no {0.3%)

82. Instructional materials: (a) definitely yes {43.7%} (b) probably yes {43.0%} (c) probably no {12.3%} (d) definitely no {1.0%}

83. Resources available in our region: (a) definitely yes {49.2%} (b) probably yes {41.7%} (c) probably no {8.3%} (d) definitely no {0.8%}

84. Programs available in our region: (a) definitely yes {47.6%} (b) probably yes {44.6%} (c) probably no {6.8%} (d) definitely no {1.0%}

85. Speakers available in our region: (a) definitely yes {43.5%} (b) probably yes {44.7%} (c) probably no {10.6%} (d) definitely no {1.3%}

86. Field trips available in our region: (a) definitely yes {54.3%} (b) probably yes {36.8%} (c) probably no {7.3%} (d) definitely no {1.8%}

87. Uses of Internet in science classes: (a) definitely yes {32.0%} (b) probably yes {33.5%} (c) probably no {25.9%} (d) definitely no {8.6%}

88. Maintaining plants and animals: (a) definitely yes {24.3%} (b) probably yes {44.9%} (c) probably no {27.6%} (d) definitely no {3.3%}

89. Discovery/Inquiry learning: (a) definitely yes {29.9%} (b) probably yes {55.7%} (c) probably no {13.2%} (d) definitely no {1.3%}

90. Collaborative or cooperative learning: (a) definitely yes {25.2%} (b) probably yes {47.1%} (c) probably no {25.4%} (d) definitely no {2.3%}

91. Hands-on activities: (a) definitely yes {46.1%} (b) probably yes {37.8%} (c) probably no {14.0%} (d) definitely no {2.0%}

92. Classroom demonstrations: (a) definitely yes {40.9%} (b) probably yes {44.1%} (c) probably no {13.5%} (d) definitely no {1.5%}

93. Alternative assessment: (a) definitely yes {22.6%} (b) probably yes {49.7%} (c) probably no {23.9%} (d) definitely no {3.8%}

94. Technology in science classrooms: (a) definitely yes {36.6%} (b) probably yes {48.5%} (c) probably no {13.1%} (d) definitely no {1.8%}

95. Process skills: (a) definitely yes {24.2%} (b) probably yes {50.3%} (c) probably no {23.0%} (d) definitely no {2.5%}

96. Life science: (a) definitely yes {23.0%} (b) probably yes {53.8%} (c) probably no {21.3%} (d) definitely no {2.0%}

97. Physical science: (a) definitely yes {23.8%} (b) probably yes {54.0%} (c) probably no {19.3%} (d) definitely no {3.0%}

98. Earth science: (a) definitely yes {24.8%} (b) probably yes {55.3%) (c) probably no {18.8%} (d) definitely no {1.3%}

99. Environmental science: (a) definitely yes {25.5%} (b) probably yes {54.0%} (c) probably no {18.8%} (d) definitely no {1.8%}

100. Astronomy: (a) definitely yes {24.8%} (b) probably yes {47.4%} (c) probably no {22.8%} (d) definitely no {5.0%}

101. Integration of mathematics and science: (a) definitely yes {34.3%} (b) probably yes {51.0%} (c) probably no 13.3%} (d) definitely no {1.5%}

102. Applications of science concepts in society: (a) definitely yes {29.3%} (b) probably yes {52.9%} (c) probably no {16.5%} (d) definitely no {1.3%}

103. Science related societal issues: (a) definitely yes {22.8%} (b) probably yes{49.9%} (c) probably no {24.6%} (d) definitely no{2.8%}

104. Science related career opportunities for students: (a) definitely yes {31.2%} (b) probably yes{44.5%} (c) probably no{21.9%} (d) definitely no{2.5%}

C. If you teach mathematics, please answer questions 105 through 157. If you teach only science, please skip to section D and question 158.

How many **MATHEMATICS** teacher organizations do you have membership in at the

105. local/state level (PACTM, TCTM, etc.): (a) 0 {89.9%} (b) 1{9.0%} (c) 2 or more{1.2%}

106. national level (NCTM, etc.): (a) 0{94.4%} (b) 1{5.6%} (c) 2 or more{0%}

Have you attended a convention or conference for **MATHEMATICS** teachers in the last 3 years

107. in the Panhandle: (a) yes{49.5%} (b) no{50.5%}

108. in Texas but not in the Panhandle: (a) yes{13.4%} (b) no{86.6%}

109. in another state: (a) yes{2.7%} (b) no{97.3%}

110. In the last three years have you attended **district-required** professional development addressing methodology used to teach mathematics concepts? (a) yes{53.2%} (b) no{46.8%}

111. In the last three years have you attended **district-required** professional development addressing knowledge of mathematics concepts? (a) yes{48.5%} (b) no {51.5%}

112. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach mathematics concepts: (a) every year{26.3%} (b) every other year{19.4%} (c) every 3-5 years{37.1%} (d) never{17.3%}

113. Frequency you **choose** to attend **non-required** professional development addressing knowledge of mathematics concepts: (a) every year{26.0%} (b) every other year{18.7%} (c) every 3-5 years {35.3%} (d) never{20.0%}

114. Have you participated in training addressing the use of manipulatives? (a) yes {87.8%} (b) no{12.2%}

115. Which of the following best describes your knowledge about the publication <u>Curriculum and Evaluation Standards for School Mathematics</u>: (a) I have not heard of it. {49.1%} (b) I have heard of it but have no idea what it says. 20.6%} (c) I have general ideas about what it says.{20.0%} (d) I have begun implementation of ideas it presents.{10.3%}

116. Which of the following best describes your knowledge about the publication <u>Professional Standards for Teaching Mathematics</u>: (a) I have not heard of it. {47.7%} (b) I have heard of it but have no idea what it says. {22.0%} (c) I have general ideas about what it says. {21.1%} (d) I have begun implementation of ideas it presents.{9.2%}

117. Which of the following best describes your knowledge about the publication <u>Assessment Standards for School Mathematics</u>: (a) I have not heard of it. {53.1%} (b) I have heard of it but have no idea what it says. {18.5%} (c) I have general ideas about what it says. {24.0%} (d) I have begun implementation of ideas it presents.{4.4%}

How often do you use the following in mathematics instruction:

118. Hands-on activities in which students use manipulatives: (a) daily{43.8%} (b) weekly {42.2%} (c) monthly {11.9%} (d) once a semester {1.1%} (e) never{0.9%}

119. Teacher demonstrations using manipulatives: (a) daily{43.1%} (b) weekly{44.2%} (c) monthly {11.2%} (d) once a semester {0.9%} (e) never{0.7%}

120. Collaborative or cooperative learning: (a) daily {30.8%} (b) weekly{50.9%} (c) monthly{12.3%} (d) once a semester {2.3%}(e) never{3.7%}

121. Computers for tutorials: (a) daily{16.9%} (b) weekly{47.8%} (c) monthly{6.2%} (d) once a semester {1.4%} (e) never{27.7%}

122. Computers for drill and practice: (a) daily{18.5%} (b) weekly{54.3%} (c) monthly{8.0%} (d) once a semester{1.6%} (e) never{17.6%}

123. Computers for instructional activities: (a) daily{11.2%} (b) weekly {34.9%} (c) monthly{8.0%} (d) once a semester {4.1%} (e) never{41.7%}

124. Calculators for computation: (a) daily{3.0%} (b) weekly{11.7%} (c) monthly{24.8%} (d) once a semester{16.1%} (e) never{44.4%}

125. Calculators for instructional activities: (a) daily{3.9%} (b) weekly{9.2%} (c) monthly{25.9%} (d) once a semester {17.2%} (e) never{43.9%}

126. Problem-solving activities: (a) daily{58.3%} (b) weekly{30.5%} (c) monthly{7.5%} (d) once a semester {0.9%} (e) never{2.7%}

127. Teacher lecture: (a) daily{60.3%} (b) weekly{20.3%} (c) monthly{5.5%} (d) once a semester{1.2%} (e) never{12.7%}

128. Discovery/Inquiry learning: (a) daily{33.5%} (b) weekly{42.5%} (c) monthly{13.4%} (d) once a semester{4.2%} (e) never{6.5%}

129. Alternative assessment: (a) daily{14.8%} (b) weekly{35.4%} (c) monthly{23.9%} (d) once a semester {4.4%} (e) never{21.5%}

Indicate the extent you need assistance with each of the following in your mathematics teaching:

130. New teaching methods: (a) definitely yes{30.7%} (b) probably yes{47.8%} (c) probably no{20.6%} (d) definitely no{0.9%}

131. Instructional materials: (a) definitely yes{32.3%} (b) probably yes {42.7%} (c) probably no {22.9%} (d) definitely no{2.1%}

132. Resources available in our region: (a) definitely yes{39.1%} (b) probably yes {43.7%} (c) probably no {16.2%} (d) definitely no{0.9%}

133. Programs available in our region: (a) definitely yes{38.6%} (b) probably yes {46.6%}(c) probably no {13.7%} (d) definitely no{1.1%}

134. Speakers available in our region: (a) definitely yes{33.6%} (b) probably yes{46.0%} (c) probably no{17.4%} (d) definitely no{3.0%}

135. Field trips available in our region: (a) definitely yes{39.7%} (b) probably yes{42.5%} (c) probably no {14.4%}(d) definitely no{3.4%}

136. Uses of Internet in mathematics classes: (a) definitely yes{31.2%} (b) probably yes{30.2%} (c) probably no{25.6%} (d) definitely no{13.0%}

137. Discovery/Inquiry learning: (a) definitely yes {28.6%} (b) probably yes{52.1%} (c) probably no {17.5%} (d) definitely no{1.8%}

138. Collaborative or cooperative learning: (a) definitely yes {22.1%} (b) probably yes{48.6%} (c) probably no{25.8%} (d) definitely no{3.5%}

139. Manipulatives to model mathematics concepts: (a) definitely yes{34.0%} (b) probably yes{37.5%} (c) probably no{24.6%} (d) definitely no{3.9%}

140. Computers in mathematics classrooms: (a) definitely yes{36.2%} (b) probably yes{41.5%} (c) probably no{18.9%} (d) definitely no{3.5%}

141. Calculators in mathematics classrooms: (a) definitely yes{27.5%} (b) probably yes {38.4%} (c) probably no{26.2%} (d) definitely no{7.9%}

142. Problem-solving: (a) definitely yes{38.9%} (b) probably yes{44.4%} (c) probably no{14.9%} (d) definitely no{1.8%}

143. Alternative assessment: (a) definitely yes{25.3%} (b) probably yes{46.3%} (c) probably no{23.3%} (d) definitely no{5.1%}

144. Patterns, relations and functions: (a) definitely yes{30.6%} (b) probably yes{47.8%} (c) probably no{19.8%} (d) definitely no{1.8%}

145. Number sense (not the competition but the comfort with and ability to use numbers): (a) definitely yes{37.1%} (b) probably yes 40.1%}(c) probably no{18.8%} (d) definitely no{3.9%}

146. Geometry: (a) definitely yes{23.0%} (b) probably yes{42.4%} (c) probably no{30.0%} (d) definitely no{4.6%}
147. Proportions: (a) definitely yes{21.1%} (b) probably yes{38.1%} (c) probably no{34.4%} (d) definitely no{6.4%}

148. Statistics: (a) definitely yes{22.2%} (b) probably yes{32.8%} (c) probably no{35.1%} (d) definitely no{9.9%}

149. Probability: (a) definitely yes{24.4%} (b) probably yes{38.9%} (c) probably no{30.1%} (d) definitely no{6.7%}

150. Reasonableness: (a) definitely yes{30.1%} (b) probably yes{43.7%} (c) probably no{21.4%} (d) definitely no{4.8%}

151. Estimation: (a) definitely yes{30.3%} (b) probably yes{42.4%} (c) probably no{22.5%} (d) definitely no{4.8%}

152. Measurement: (a) definitely yes{27.8%} (b) probably yes{41.8%} (c) probably no{26.7%} (d) definitely no{3.7%}

153. Fractions: (a) definitely yes{26.6%} (b) probably yes{38.1%} (c) probably no{30.3%} (d) definitely no{5.0%}

154. Decimals: (a) definitely yes{22.0%} (b) probably yes{35.3%} (c) probably no{32.3%} (d) definitely no{10.3%}

155. Integration of mathematics and science: (a) definitely yes {37.0%} (b) probably yes{44.7%} (c) probably no{14.6%} (d) definitely no{3.7%}

156. Applications of mathematics in today's world: (a) definitely yes{38.8%} (b) probably yes{46.5%} (c) probably no {12.6%} (d) definitely no{2.1%}

157. Mathematics related career opportunities for students: (a) definitely yes{35.4%} (b) probably yes{40.1%} (c) probably no{19.7%} (d) definitely no{4.7%}

DATA FROM SECONDARY MATHEMATICS TEACHERS SURVEY

There were 151 secondary teachers responding to the survey. The following is a question by question summary of numbers and percent answering each question.

1. Age: (a) 20-29 *{22--14.6%}* (b) 30-39 *{51--33.8%}* (c) 40-49 *{52--34.4%}* (d) 50-59 *{23--15.2%}* (e) 60 and over *{3--2%}*

2. Sex: (a) female *{114--74.5%}* (b) male *{39--25.5%}*

3. Ethnic background: (a) African American *{0--0%}* (b) Asian *[1--.7%}* (c) Caucasian *{147--96.1%}* (d) Hispanic *{3--2%}* (e) Native American *{2--1.3%}*

4. Degree Status: (a) bachelor's *{42--27.5%}* (b) bachelor's plus hours *{72--47.1%}* (c) master's *{19--12.4%}* (d) master's plus hours *{20--13.1}* (e) doctorate *{0--0%}*

5. Number of years teaching experience, including this year: (a) 1-4 *{29--19.1%}* (b) 5-9 *{36--23.7%}* (c) 10-14 *{28--18.4}* (d) 15-19 *{17--11.2%}* (e) 20 or more *{42--27.6%}*

6. Number of schools where you held full-time teaching positions: (a) 1*{40--26.1%}* (b) 2 *{49--32.0%}* (c) 3 *{31--20.3%}* (d) 4 *{18--11.8%}* (e) 5 or more *{15--9.8}*

7. Number of years in your present school, including this year: (a) 1 *{35--22.9%}* (b) 2 *{11--7.2%}* (c) 3-5 *{33--21.6%}* (d) 6-10 *{37--24.2%}* (e) 11 or more *{37--24.2%}*

8. Present school district ______________________

9. Classification of high school your students will or do attend: (a) A *{7--4.7%}* (b) AA *{10--6.7%}* (c) AAA *{44--29.3%}* (d) AAAA *{77--51.3%}* (e) AAAAA *{12--8%}*

10. Current school: (a) public school *{151--98.7%}* (b) private school *{2--1.3%}*

11. Current assignment: (a) junior high *{40--26.5%}* (b) middle school *{33--21.9%}* (c) high school *{68--45%}* (d) combination of junior high/high school *{10--6.6%}*

12. Teaching certificate: (a) elementary with math concentration *{25--16.3%}* (b) elementary with non-math concentration *{10--6.5%}* (c) secondary with math as 1st teaching field *{62--40.5%}* (d) secondary with math as 2nd teaching field *{18--11.8%}* (e) secondary with math as only teaching field *{9--5.9%}* (f) other (please describe) *{29--19%}* ______________________

13. Number of years since your last college mathematics class (approximately): (a) 0-2 *{24--15.7%}* (b) 3-5 *{32--20.9%}* (c) 6-8 *{25--16.3%}* (d) 9-11 *{21--13.7%}* (e) 12 or more *{51--33.3%)*

14. Frequency that you personally use computers: (a) less than once a month *{27--17.9%}* (b) once a month *{13--8.6%}* (c) every 2 weeks *{13--8.6%}* (d) weekly *{44--29.1%}* (e) daily *{54--35.8%}*

15. If you use computers for schoolwork, primary purpose: (a) word processing *{36--27.9%}* (b) record management *{55--42.6%}* (c) instruction *{25--19.4%}* (d) other *{13--10.1}*______________________

16. If you don't use computers for schoolwork, primary reason: (a) lack of access to computers *{22-28.6%}* (b) lack of training *{20--26%}* (c) lack of time *{16--20.8%}* (d) lack of software *{12--15.6%}* (e) other *{7--9.1%}*______________________

17. Computers available for class use: (a) every period {49--34%} (b) once a day *{7--4.9%}* (c) once a week *{29.20.1%}* (d) once a month *{13--9%}* (e) less than once a month *{46--31.9%}*

18. Computer available for class demonstrations: (a) every period *{57--38.8%}* (b) once a day *{7—4.8%}* (c) once a week *{17--11.6%}* d) once a month *{9--6.1%}* (e) less than once a month *{57--38.8%}*

19. Internet access available: (a) in my classroom *{2--1.5%}* (b) in my school *{68--50%}* (c) in my district *{21--15.4%}* (d) none of these *{45--33.1%}*

20. Kinds of class sets of calculators available: (a) 4-function *{18--12%}* (b) fraction *{32--21.3%}* (c) scientific *{13--8.7%}* (d) graphing *{80--53.3%}* (e) none available *{7--4.7%}*

21. Approximate percentage of students in your high school that complete 3 years of mathematics: (a) 0-10% *{1--1%}* (b) 11-25% *{5--5.1%}* (c) 26-50% *{16--16.2%}* (d) 51-75% *{11-11.1%}* (e) over 75% *{66-66.7%}*

22. Approximate percentage of students in your high school that complete 4 years of mathematics: (a) 0-10% *[28--28%}* (b) 11-25% *{43--43%}* (c) 26-50% *{19--19%}* (d) 51-75% *{6--6%}* (e) over 75% *{4--4%}*

How important do you consider the following when decidi{ng whether or not to attend professional development:

23. **where it will be held:** (a) very important *{63--41.7%}* (b) somewhat important *{74--49%}* (c) not important *{14--9.3%|*

24. **when it will be held:** (a) very important *{97--64.2}* (b) somewhat important *{46--30.5%}* (c) not important *{8--5.3%}*

25. **how long it will last:** (a) very important *{57--37.7%}* (b) somewhat important *{77--51%}* (c) not important *{17--11.3%}*

26. **cost** to attend: (a) very important *{95--62.9%}* (b) somewhat important *{52--34.4%}* (c) not important *{4--2.6%}*

27. **topic** addressed: (a) very important *{142--94%}* (b) somewhat important *{8--5.3%}* (c) not important *{1--.7%}*

28. **who is presenting it:** (a) very important *{59--39.3%}* (b) somewhat important *{86--57.3%}* (c) not important *{5--3.3%}*

29. **how much time** you will be out of classroom: (a) very important *{106--70.2%}* (b) somewhat important *{43--28.5%}* (c) not important *{2--1.3%}*

Would you attend non-required professional development <u>relating directly to what you teach</u> if it is offered

30. in your school district: (a) definitely yes *{78--51.3%}* (b) probably yes *{71--46.7%}* (c) probably no *{2--1.3%}* (d) definitely no *{1--.7%}*

31. at cluster sites near your district: (a) definitely yes *{38--25%)* (b) probably yes *{99--65.1%}* (c) probably no *{14--9.2%}* (d) definitely no *{1--.7%}*

32. at an Education Service Center: (a) definitely yes *{32--21.2%}* (b) probably yes *{94--62.3%}* (c) probably no *{23--15.2}* (d) definitely no *{2--1.3%}*

33. at a university (graduate credit): (a) definitely yes *{28--18.4%}* (b) probably yes *{87--57.2%}* (c) probably no *{34--22.4%}* (d) definitely no *{3--2%}*

34. at a community college (undergraduate credit): (a) definitely yes *{17--11.2%}* (b) probably yes *{76--50%}* (c) probably no *{54--35.5%}* (d) definitely no *{5--3.3%}*

35. after school: (a) definitely yes *{10--6.6%}* (b) probably yes *{81--53.3%}* (c) probably no *{51--33.6%}* (d) definitely no *{10--6.6%}*

36. at night: (a) definitely yes *{5--3.3%}* (b) probably yes *{66--43.4%}* (c) probably no*{72--47.4%}* (d) definitely no *{9--5.9%}*

37. on Saturdays: (a) definitely yes *{4--2.6%}* (b) probably yes *{63--41.4%}* (c) probably no *{70---46.1%}* (d) definitely no *{15--9.9%}*

38. for one or two days: (a) definitely yes *{15--9.9%}* (b) probably yes *{113--74.8%}* (c) probably no *{22--14.6%}* (d) definitely no *{1--.7%}*

39. once a month (week-days) during the school year: (a) definitely yes *{15--9.9%}* (b) probably yes *{91--60.3%}* (c) probably no *{43--28.5%}* (d) definitely no *{2--1.3%}*

40. once a month (Saturdays) during the school year: (a) definitely yes *{3--2%}* (b) probably yes *{51--33.6%}* (c) probably no *{79--52%}* (d) definitely no *{19--12.5%}*

41. on one week-day in the summer: (a) definitely yes *{27--17.8%}* (b) probably yes *{98--64.5%}* (c) probably no *{20--13.2%}* (d) definitely no *{7--4.6%}*

42. for one week in the summer: (a) definitely yes *{12--7.9%}* (b) probably yes *{86--56.6%}* (c) probably no *{40--26.3%}* (d) definitely no *{14--9.2%}*

43. for 1 week in the summer and follow-up during the school year: (a) definitely yes *{12--7.9%}* (b) probably yes *{84--55.5%}* (c) probably no *{46--30.5%}* (d) definitely no *{9--6%}*

44. for 3 weeks in the summer and follow-up during the school year: (a) definitely yes *{4--2.6%}* (b) probably yes *{27--17.8%}* (c) probably no *{84--55.3%}* (d) definitely no *{37--24.3%}*

How many **MATHEMATICS** teacher organizations do you have membership in at the

45. local/state level (PACTM, TCTM, etc.): (a) 0 *{93--61.6%}* (b) 1*{45--29.8%}* (c) 2 or more *{13--8.6%}*

46. national level (NCTM, etc.): (a) 0 *{107--72.8%}* (b) 1 *{37--25.2%}* (c) 2 or more *{3--2%}*

Have you attended a convention or conference for **MATHEMATICS** teachers in the last 3 years

47. in the Panhandle: (a) yes *{96--64.4%}* (b) no *{53--35.6%}*

48. in Texas but not in the Panhandle: (a) yes *{41--29.1%}* (b) no *{100--70.9%}*

49. in another state: (a) yes *{10--7.2%}* (b) no *{128--92.8%}*

50. Does your district provide funds for individuals or groups of teachers to attend **non-required** professional development for **mathematics** teachers? (a) yes *{99--72.3%}* (b) no *{38--27.7%}*

51. In the last three years have you attended **district-required** professional development addressing methodology used to teach mathematics concepts? (a) yes *{88--59.9%}* (b) no *{59--40.1%}*

52. In the last three years have you attended **district-required** professional development addressing knowledge about mathematics concepts? (a) yes *{81--55.1%}* (b) no *{66--44.9%}*

53. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach mathematics concepts: (a) every year *{69--46.6%}* (b) every other year *{30--20.3%}* (c) every 3-5 years *{31--20.9%}* (d) never *{18--12.2%}*

54. Frequency you **choose** to attend **non-required** professional development addressing knowledge about mathematics concepts: (a) every year *{64--43.2%}* (b) every other year *{33--22.3%}* (c) every 3-5 years *{30--20.3%}* (d) never *{21--14.2%}*

55. Average distance you usually travel to attend **non-required** professional development: (a) less than 5 miles *{8--5.7%}* (b) 5-30 miles *{38--27%}* (c) 31-60 miles *{34--24.1%]* (d) 61-120 miles *{40--28.4%}* (e) more than 120 miles *{21--14.9%}*

56. Which of the following best describes your knowledge about the publication <u>Curriculum and Evaluation Standards for School Mathematics</u>: (a) I have not heard of it.*{51--34.2%}* (b) I have heard of it but have no idea what it says.*{30--20.1%}* (c) I have general ideas about what it says. *{48--32.2%}* (d) I have begun implementation of ideas it presents. *{20--13.4%}*

57. Which of the following best describes your knowledge about the publication <u>Professional Standards for Teaching Mathematics</u>: (a) I have not heard of it. *{55--36.9%}* (b) I have heard of it but have no idea what it says. *{29--19.5%}* (c) I have general ideas about what it says. *{49--32.9%}* (d) I have begun implementation of ideas it presents. *{16--10.7%}*

58. Which of the following best describes your knowledge about the publication <u>Assessment Standards for School Mathematics</u>: (a) I have not heard of it. *{66--44%}* (b) I have heard of it but have no idea what it says. *{36--24%}* (c) I have general ideas about what it says. *{41--27.3%}* (d) I have begun implementation of ideas it presents.*{7--4.7%)*

59. Which of the following best describes your knowledge about the Amarillo National Resource Center for Plutonium: (a) I have never heard of it before this survey. *{99--65.6%}* (b) I have heard of it before this survey but have no idea about its purpose. *{37--24.5%}* (c) I have general ideas about its purpose. *{14--9.3%}* (d) I understand its purpose. *{1--.7%}*

How often do you use the following in mathematics instruction

60. Hands-on activities in which students use manipulatives: (a) daily *{16--10.7%}* (b) weekly *{60--40%}* (c) monthly *{52--34.7%}* (d) once a semester *{15--10%}* (e) never *{7--4.7%}*

61. Teacher demonstrations using manipulatives: (a) daily *{17--11.3%}* (b) weekly *{64--42.4%}* (c) monthly *{54--35.8%}* (d) once a semester*{9--6%}* (e) never *{7--4.6%}*

62. Collaborative or cooperative learning: (a) daily *{49--32.9%}* (b) weekly *{50--33.6%}* (c) monthly *{27--18.1%}* (d) once a semester *{11--7.4%}* (e) never *{12--8.1%}*

63. Computers for tutorials: (a) daily *{6--4%}* (b) weekly *{24--15.9%}* (c) monthly *{20--13.2%}* (d) once a semester *{10--6.6%}* (e) never *{91--60.3%}*

64. Computers for drill and practice: (a) daily *{7--4.6%}* (b) weekly *{27--17.9%}* (c) monthly *{21--13.9%}* (d) once a semester *{9--6%}* (e) never *{87--57.6%}*

65. Computers for instructional activities: (a) daily *{6--4%}* (b) weekly *{20--13.3%}* (c) monthly *{22--14.7%}* (d) once a semester *{9--6%}* (e) never *{93--62%}*

66. Calculators for graphing: (a) daily *{32--21.1%}* (b) weekly *{21--13.8}* (c) monthly *{12--7.95}* (d) once a semester *{13--8.6%}* (e) never *{74--48.7%}*

67. Calculators for computation: (a) daily *{65--43%}* (b) weekly *{29--19.2%}* (c) monthly *{29--19.2%}* (d) once a semester *{16--10.6%}* (e) never *{12--7.9%}*

68. Calculators for instructional activities (not graphing): (a) daily *{39--25.7%}* (b) weekly *{34--22.4%}* (c) monthly *{41--27%}* (d) once a semester *{17--11.2%}* (e) never *{21--13.8%}*

69. Problem-solving activities: (a) daily *{70--46.7%}* (b) weekly *{64--42.7%}* (c) monthly *{13--8.7%}* (d) once a semester *{1--.7%}* (e) never *{2--1.3%}*

70. Teacher lecture: (a) daily *{108--71.5%}* (b) weekly *{34--22.5%}* (c) monthly *{2--1.3%}* (d) once a semester *{0--0%}* (e) never *{7--4.6%}*

71. Discovery/Inquiry learning: (a) daily *{28--18.5%}* (b) weekly *{59--39.1%}* (c) monthly *{44--29.1%}* (d) once a semester *{7--4.6%}* (e) never *{13--8.6%}*

72. Alternative assessment: (a) daily *{9--6%}* (b) weekly *{33--22.1%}* (c) monthly *{46--30.9%}* (d) once a semester *{24--16.1%}* (e) never *{37--24.8%}*

Indicate the extent you need assistance with each of the following in your mathematics teaching.

73. New teaching methods: (a) definitely yes *{38--25.2%}* (b) probably yes *{80--53%}* (c) probably no *{33--21.9%}* (d) definitely no *{0--0%}*

74. Instructional materials: (a) definitely yes *{43--28.3%}* (b) probably yes *{66--43.4%}* (c) probably no *{42--27.6%}* (d) definitely no *{1--.7%}*

75. Resources available in our region: (a) definitely yes *{42--27.8%}* (b) probably yes *{87--57.6%}* (c) probably no *{21--13.9%}* (d) definitely no *{1--.7%}*

76. Programs available in our region: (a) definitely yes *{47--31.3%}* (b) probably yes *{87--58%}* (c) probably no *{16--10.7%}* (d) definitely no *{0--0%}*

77. Speakers available in our region: (a) definitely yes *{38--25.3%}* (b) probably yes *{83--55.3%}* (c) probably no *{26--17.3%}* (d) definitely no *{3--2%}*

78. Field trips available in our region: (a) definitely yes *{48--31.8%}* (b) probably yes *{78--51.7%}* (c) probably no *{23--15.2%}* (d) definitely no *{2--1.3%}*

79. Uses of Internet: (a) definitely yes *{53--35.1%}* (b) probably yes *{60--39.7%}* (c) probably no *{32--21.2%}* (d) definitely no *{6--4%}*

80. Discovery/Inquiry learning: (a) definitely yes *{37--24.5%}* (b) probably yes *{84--55.6%}* (c) probably no *{28--18.5%}* (d) definitely no *{2--1.3%}*

81. Collaborative or cooperative learning: (a) definitely yes *{22--14.5%}* (b) probably yes *{68--44.7%}* (c) probably no *{58--38.2%}*(d) definitely no *{4--2.6%}*

82. Manipulatives to model mathematics concepts: (a) definitely yes *{36--23.7%}* (b) probably yes *{72--47.4%}* (c) probably no *{42--27.6%}* (d) definitely no *{2--1.3%}*

83. Computers in mathematics classrooms: (a) definitely yes *{58--38.4%}* (b) probably yes *{69--45.7%}* (c) probably no *{22--14.6%}* (d) definitely no *{2--1.3%}*

84. Graphing calculators: (a) definitely yes *{34--22.5%}* (b) probably yes *{58--38.4%}* (c) probably no *{49--32.5%}* (d) definitely no *{10--6.6%}*

85. Calculators as instructional tools:. (a) definitely yes *{24--15.8%}* (b) probably yes *{64--42.1%}* (c) probably no *{59--38.8%}* (d) definitely no *{5--3.3%}*

86. Problem-solving: (a) definitely yes *{37--24.3%}* (b) probably yes *{77--50.7%}* (c) probably no *{37--24.3%}* (d) definitely no *{1--.7%}*

87. Alternative assessment: (a) definitely yes *{37--24.5%}* (b) probably yes *{78--51.75}* (c) probably no *{33--21.9%}* (d) definitely no *{3--2%}*

88. Patterns, relations and functions: (a) definitely yes *{24--15.9%}* (b) probably yes *{67--44.4%}* (c) probably no *{57--37.7%}* (d) definitely no *{3--2%}*

89. Number sense (not the competition, but comfort and ability to use numbers): (a) definitely yes *{27--17.9%}* (b) probably yes *{68--45%}* (c) probably no *{45--29.8%}* (d) definitely no *{11--7.3%}*

90. Euclidean Geometry: (a) definitely yes *{14--9.3%}* (b) probably yes *{47--31.3%}* (c) probably no *{72--48%}* (d) definitely no *{17--11.3%}*

91. Non-Euclidean Geometry: (a) definitely yes *{16--10.7%}* (b) probably yes *{56--37.3%}* (c) probably no *{61--40.7%}* (d) definitely no *{17--11.3%}*

92. Trigonometry: (a) definitely yes *{17--11.3%}* (b) probably yes *{39--25.8%}* (c) probably no *{65--43%}* (d) definitely no *{30--19.9%}*

93. Statistics: (a) definitely yes *{15--9.9%}* (b) probably yes *{64--42.1%}* (c) probably no *{57--37.5%}* (d) definitely no *{16--10.5%}*

94. Probability: (a) definitely yes *{14--9.2%}* (b) probably yes *{52--34.2%}* (c) probably no *{56--36.8%}* (d) definitely no *{9--5.9%}*

95. Proportions: (a) definitely yes *{13--8.6%}* (b) probably yes *{52--34.2%}* (c) probably no *{71--46.7%}* (d) definitely no *{16--10.5%}*

96. Reasonableness: (a) definitely yes *{22-14.5%}* (b) probably yes *{73--48%}* (c) probably no *{55--36.2%}* (d) definitely no *{11--7.2%}*

97. Estimation: (a) definitely yes *{19--12.5%}* (b) probably yes *{54--35.5%}* (c) probably no *{68--44.7%}* (d) definitely no *{11--7.2%}*

98. Matrices: (a) definitely yes *{17--11.3%}* (b) probably yes *{57--38%}* (c) probably no *{58--38.7%}* (d) definitely no *{18--12%}*

99. Calculus: (a) definitely yes *{31--20.5%}* (b) probably yes *{35--23.2%}* (c) probably no *{58--38.4%}* (d) definitely no *{27--17.9%}*

100. Mathematics of money/finance: (a) definitely yes *{17--11.3%}* (b) probably yes *{51--33.8%}* (c) probably no *{69--45.7%}* (d) definitely no *{14--9.3%}*

101. Integration of mathematics and science: (a) definitely yes *{34--22.4%}* (b) probably yes *{90--59.2%}* (c) probably no *{27--17.8%}* (d) definitely no *{1--.7%}*

102. Applications of mathematics in today's world: (a) definitely yes *{51--33.6%}* (b) probably yes *{79--52%}* (c) probably no *{22--14.5%}* (d) definitely no *{0--0%}*

103. Mathematics related career opportunities for students: (a) definitely yes *{57--37.5%}* (b) probably yes *{78--51.3%}* (c) probably no *{17--11.2%}* (d) definitely no *{0--0%}*

DATA SECONDARY SCIENCE TEACHERS SURVEY

There were 150 secondary teachers responding to the survey. The following is a question by question summary of percent answering each question. For those questions where more than 15 teachers did not respond, the actual number responding is given in addition to the percents.

1. Age: (a) 20-29 *{14%}* (b) 30-39 *{27.3%}* (c) 40-49 *{41.3%}* (d) 50-59 *{14%}* (e) 60 and over *{3.3%}*

2. Sex: (a) female *{55.6%}* (b) male {44.4}

3. Ethnic background: (a) African American *{.7%}* (b) Asian *{0%}* (c) Caucasian *{96.7%}* (d) Hispanic *{1.3%}* (e) Native American *{1.3%}*

4. Degree Status: (a) bachelor's *{19.9%}* (b) bachelor's plus hours *{55.6%}* (c) master's *{7.3%}* (d) master's plus hours *{16.6%}* (e) doctorate *{.7%}*

5. Number of years teaching experience, including this year: (a) 1-4 *{19.2%}* (b) 5-9 *{19.9%}* (c) 10-14 *{13.9}* (d) 15-19 *{14.6%}* (e) 20 or more *{32.5%}*

6. Number of schools where you held full-time teaching positions: (a) 1 *{27.2%}* (b) 2 *{37.7%}* (c) 3 *{18.5%}* (d) 4 *{8.6%}* (e) 5 or more *{7.9%}*

7. Number of years in your present school, including this year: (a) 1*{19.9%}* (b) 2 *{6%}* (c) 3-5 *{15.9%}* (d) 6-10 *{23.2%}* (e) 11 or more *{35.1%}*

8. Present School District: ______________________

9. Classification of high school your students will or do attend: (a) A *{2.7%}* (b) AA *{5.3%}* (c) AAA *{23.3%}* (d) AAAA *{58.7%}* (e) AAAAA *{10%}*

10. Current school: (a) public school *{99.3%}* (b) private school *{.7%}*

11. Current assignment: (a) junior high *{22.7%}* (b) middle school *{22%}* (c) high school *{50%}* (d) combination of junior high/high school *{5.3%}*

12. Teaching certificate: (a) elementary with science concentration *{5.4%}* (b) elementary with non-science concentration *{7.4%}* (c) composite science *{30.9%}* (d) two science fields *{15.4%}* (e) one science field and one non-science field *{36.2%}* (f) no certification in science *{4.7%}*

13. Are you certified to teach all the subjects you have been assigned to teach this year and last year? (a) yes *{91.2%}* (b) no *{8.8%}*

14. Your principal teaching assignment this year is (a) biology/life science *{38.7%}* (b) chemistry *{8.7%}* (c) earth science *{14%}* (d) physics *{4%}* (e) physical science *{15.3%}* (f) other *{19.3%}*

Approximately how many college courses have you completed in each of the following:

15. Geology: (a) 0 *{30.5%--39}* (b) 1 *{18%--23}* (c) 2 *{20.3%--26}* (d) 3-5 {9.4%--12} (e) 6 or more*{21.9%--28}*

16. Astronomy: (a) 0 *{63.4%--71}* (b) 1 *{17%--19}* (c) 2 *{5.4%--6}* (d) 3-5 *{12.5%--14}* (e) 6 or more *{1.8%--2}*

17. Meteorology: (a) 0 *{73.3%--77}* (b) 1 *{10.5%--11}* (c) 2 *{4.8%--5}* (d) 3-5 *{11.4%--12}* (e) 6 or more *{0%}*

18. Oceanography: (a) 0 *{76.5%--78}* (b) 1 *{13.7%--14}* (c) 2 *{2.9%--3}* (d) 3-5 *{4.9%--5}* (e) 6 or more *{2%--2}*

19. Chemistry: (a) 0 *{15.5%--20}* (b) 1 *{9.3%--12}* (c) 2 *{20.2%--26}* (d) 3-5 *{20.2%--26}* (e) 6 or more *{34.9%--45}*

20. Physics: (a) 0 *{28.9%--35}* (b) 1 *{13.2%--16}* (c) 2 *{19.8%--24}* (d) 3-5 *{20.7%--25}* (e) 6 or more *{17.4%--21}*

21. Biology: (a) 0 *{5.4%--8}* (b) 1 *{6.1%--9}* (c) 2 *{6.1%--9}* (d) 3-5 *{16.2%--24}* (e) 6 or more *{66.2%--98}*

22. Botany: (a) 0 *{16.3%--21}* (b) 1 *{26.4%--34}* (c) 2 *{20.9%--27}* (d) 3-5 *{17.1%--22}* (e) 6 or more *{19.4%--25}*

23. Zoology: (a) 0 *{17.6%--23}* (b) 1 *{20.6%--27}* (c) 2 *{10.7%--14}* (d) 3-5 *{20.6%--27}*(e) 6 or more *{30.5%--40}*

24. Environmental Science: (a) 0 *{42.6%--49}* (b) 1 *{23.5%--27}* (c) 2 *{9.6%--11}* (d) 3-5 *{13%--15}* (e) 6 or more *{11.3%--13}*

25. Number of years since your last college science class (approximately): (a) 0-2 *{20%}* (b) 3-5 *{26%}* (c) 6-8 *{12.7%}* (d) 9-11 *{13.3%}* (e) 12 or more *{28%}*

26. Frequency that you personally use computers: (a) less than once a month *{17.9%}* (b) once a month *{2.6%}* (c) every 2 weeks *{9.9%}* (d) weekly *{35.1%}* (e) daily *{34.4%}*

27. If you use computers for schoolwork, primary purpose: (a) word processing *{40%--52}* (b) record management *{30.8%--40}* (c) instruction *{18.5%--24}* (d) other *{10.8%--14}*

28. If you don't use computers for schoolwork, primary reason: (a) lack of access to computers *{27.8%--20}* (b) lack of training *{30.6%--22}* (c) lack of time *{13.9%--10}* (d) lack of software *{9.7%--7}* (e) other *{18.1%--13}*

29. Computers available for class use: (a) every period *{30.4%--42}* (b) once a day *{2.9%--4}* (c) once a week *{14.5%--20}* (d) once a month *{6.5%--9}* (e) less than once a month *{45.7%--63}*

30. Computer available for class demonstrations: (a) every period *{33.1%}* (b) once a day *{3.5%}* (c) once a week *{10.6%}* (d) once a month *{3.5%* (e) less than once a month *{49.3%}*

31. Internet access available: (a) in my classroom *{2.2%--3}* (b) in my school *{51.5%--69}* (c) in my district *{16.4%--22}* (d) none of these *{29.9%--40}*

32. Physics offered at your high school: (a) every year *{77.6%}* (b) every other year *{6.1%}* (c) never *{3.4%}* (d) do not know *{12.9%}*

33. Chemistry offered at your high school: (a) every year *{85.7%}* (b) every other year *{4.8%}* (c) never *{2.7%}* (d) do not know *{6.8%}*

34. Approximate percentage of students in your high school that complete 3 science courses: (a) 0-10% *{6.7%--7}* (b) 11-25% *{26.7%--28}* (c) 26-50% *{30.5%--32}* (d) 51-75% *{21.9%--23}* (e) over 75% *{14.3%--15}*

35. Approximate percentage of students in your high school that complete 4 science courses: (a) 0-10% *{39.6%--40}* (b) 11-25% *{40.6%--41}* (c) 26-50% *{17.8%--18}* (d) 51-75% *{0%}* (e) over 75% *{2%--2}*

Approximate percentage of students in your high school that complete a course in

36. chemistry: (a) 0-10% *{11.3%--11}* (b) 11-25% *{35.1%--34}* (c) 26-50% *{34%--33}* (d) 51-75% *{15.5%--15}* (e) over 75% *{4.1%--4}*

37. physics: (a) 0-10% *{51%--49}* (b) 11-25% *{21.9%--21}* (c) 26-50% *{19.8%--19}* (d) 51-75% *{4.2%--4}* (e) over 75% *{3.1%--3}*

38. biology: (a) 0-10% *{2.9%--3}* (b) 11-25% *{2.9%--3}* (c) 26-50% *{6.9%--7}* (d) 51-75% *{12.7%--13}* (e) over 75% *{74.5%--76}*

39. physical science: (a) 0-10%*{2%--2}* (b) 11-25% *{6.1%--6}* (c) 26-50%*{16.3%--16}* (d) 51-75% *{24.5%--24}* (e) over 75*{51%--50}*

40. Number of elective science courses other than Chemistry I and Physics I available in your high school: (a) 0 *{6.6%--7}* (b) 1 *{21.7%--23}*(c) 2 *{21.7%--23}* (d) 3 *{18.9%--20}* (e) 4 or more *{31.1%--33}*

41. Adequacy of equipment and supplies for conducting science labs in your school: (a) none available *{3.4%}* (b) barely adequate *{21.9%}* (c) adequate *{50.7%}* (d) more than adequate *{21.9%}* (e) not sure *{2.1%}*

42. Approximate percentage of time you are unable to do a laboratory activity because equipment and/or materials are not available: (a) 0-10% *{65%}* (b) 11-25*{17.1%}* (c) 26-50% *{10.7%}* (d) 51-75% *{4.3%}* (e) over 75% *{2.9%}*

43. Approximate percentage of time demonstrations are substituted for student laboratory activities because materials and equipment are not available for all students: (a) 0-10% *{63.8%}* (b) 11-25% *{17%}* (c) 26-50% *{12.1%}* (d) 51-75% *{5%}* (e) over 75% *{2.1%}*

44. Approximate percentage of time laboratory activities must be planned for a specific day because equipment and materials are shared: (a) 0-10% *{51.1%}* (b) 11-25% *{17.3%}* (c) 26-50% *{9.4%}* (d) 51-75% *{8.6%}* (e) over 75% *{13.7%}*

45. Number of times during a semester that you eliminate or substitute a laboratory activity because of the time required to prepare the laboratory materials: (a) 0 *{30.7%}* (b) 1-4 *{35.7%}* (c) 5-9 *{22.9%}* (d) 10-14 *{5.7%}* (e) over 15 *{5%}*

How important do you consider the following when deciding whether or not to attend professional development:

46. **where** it will be held: (a) very important *{51.7%}* (b) somewhat important *{41.1%}* (c) not important *{7.3%}*

47. **when** it will be held: (a) very important *{70.9%}* (b) somewhat important *{26.5%}* (c) not important *{2.6%}*

48. **how long** it will last: (a) very important *{33.1%}* (b) somewhat important *{53.6%}* (c) not important *{13.2%}*

49. **cost** to attend: (a) very important *{65.6%}* (b) somewhat important *{30.5%}* (c) not important *{4%}*

50. **topic** addressed: (a) very important *{88.1%}* (b) somewhat important *{11.3%}* (c) not important *{.7%}*

51. **who** is presenting it: (a) very important *{35.8%}* (b) somewhat important *{53.6%}* (c) not important *{10.6%}*

52. **how much time** you will be out of classroom: (a) very important *{64.2%}* (b) somewhat important *{31.1%}* (c) not important *{4.7%}*

Would you attend non-required professional development <u>relating directly to what you teach</u> if it is offered

53. in your school district: (a) definitely yes *{52.3%}* (b) probably yes *{43%}* (c) probably no *{4.7%}* (d) definitely no *{0%}*

54. at cluster sites near your district: (a) definitely yes *{27.5%}* (b) probably yes *{61.7%}* (c) probably no *{10.7%}* (d) definitely no *{0%}*

55. at an Education Service Center: (a) definitely yes *{23%}* (b) probably yes *{58.8%}* (c) probably no *{18.2%}* (d) definitely no *{0%}*

56. at a university (graduate credit): (a) definitely yes *{21.3%}* (b) probably yes*{50.7%}* (c) probably no *{27.3%}* (d) definitely no *{.7%}*

57. at a community college (undergraduate credit): (a) definitely yes *{15.5%}* (b) probably yes *{54.7%}* (c) probably no *{27.7%}* (d) definitely no *{2%}*

58. at a science center or museum: (a) definitely yes *{17.6%}* (b) probably yes *{61.5%}* (c) probably no *{20.9%}* (d) definitely no *{0%}*

59. after school: (a) definitely yes *{6.8%}* (b) probably yes *{52.7%}* (c) probably no *{32.4%}* (d) definitely no*{8.1%}*

60. at night: (a) definitely yes *{4.7%}* (b) probably yes *{40.9%}* (c) probably no *{40.9%}* (d) definitely no *{13.4%}*

61. on Saturdays: (a) definitely yes *{5.4%}* (b) probably yes *{43.2%}* (c) probably no *{37.8%}* (d) definitely no *{13.5%}*

62. for one or two days: (a) definitely yes*{8.1%}* (b) probably yes *{78.5%}* (c) probably no *{12.8%}* (d) definitely no *{.7%}*

63. once a month (week-days) during the school year: (a) definitely yes *{10.7%}* (b) probably yes *{58.4%}* (c) probably no*{28.9%}* (d) definitely no *{2%}*

64. once a month (Saturdays) during the school year: (a) definitely yes *{2.7%}* (b) probably yes *{36.2%}* (c) probably no *{47%}* (d) definitely no *{14.1%}*

65. on one week-day in the summer: (a) definitely yes *{18.9%}* (b) probably yes *{57.4%}* (c) probably no *{16.9%}* (d) definitely no *{6.8%}*

66. for one week in the summer: (a) definitely yes*{11.5%}* (b) probably yes *{42.6%}* (c) probably no *{31.8%}* (d) definitely no *{14.2%}*

67. for 1 week in the summer and follow-up during the school year: (a) definitely yes *{8.7%}* (b) probably yes *{43%}* (c) probably no*{36.2%}* d) definitely no *{12.1%}*

68. for 3 weeks in the summer and follow-up during the school year: (a) definitely yes *{6.8%}* (b) probably yes *{15.6%}* (c) probably no *{52.4%}* (d) definitely no *{25.2%}*

How many **SCIENCE** teacher organizations do you have membership in at the

69. local/state level (STAT, TABT, etc.): (a) 0 *{63.7%}* (b) 1 *{20.5%}* (c) 2 or more*{15.8%}*

70. national level (NSTA, NABT, etc.): (a) 0 *{73.6%}* (b) 1 *{22.1%}*(c) 2 or more *{4.3%}*

Have you attended a convention or conference for **SCIENCE** teachers in the last 3 years

71. in the Panhandle: (a) yes *{51.8%}* (b) no *{48.2%}*

72. in Texas but not in the Panhandle: (a) yes *{38.6%}* (b) no *{61.4%}*

73. in another state: (a) yes *{5.6%}* (b) no *{94.4%}*

74. Does your district provide funds for individuals or groups of teachers to attend **non-required** professional development for **science** teachers? (a) yes *{70.1%}* (b) no *{29.9%}*

75. In the last three years have you attended **district-required** professional development addressing methodology used to teach science concepts? (a) yes *{29.3%}* (b) no *{70.7%}*

76. In the last three years have you attended **district-required** professional development addressing knowledge about science concepts? (a) yes *{28.9%}* (b) no *{71.1%}*

77. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach science concepts: (a) every year *{28.3%}* (b) every other year *{21.4%}* (c) every 3-5 years *{25.5%}* (d) never *{24.8%}*

78. Frequency you **choose** to attend **non-required** professional development addressing knowledge about science concepts: (a) every year *{30.3%}* (b) every other year *{25.4%}* (c) every 3-5 years *{26.1%}* (d) never *{18.3%}*

79. Average distance you usually travel to attend **non-required** professional development: (a) less than 5 miles *{10.7%}* (b) 5-30 miles *{18.6%}* (c) 31-60 miles *{24.3%}* (d) 61-120 miles *{25.7%}* (e) more than 120 miles *{20.7%}*

80. Which of the following best describes your knowledge about the publication National Science Education Standards:
(a) I have not heard of it. *{37.6%}* (b) I have heard of it but have no idea what it says.*{28.2%}* (c) I have general ideas about what it says.*{30.2%}* (d) I have begun implementation of ideas it presents.*{4%}*

81. Which of the following best describes your knowledge about the Amarillo National Resource Center for Plutonium:
(a) I have never heard of it before this survey. *{56.8%}* (b) I have heard of it before this survey but have no idea about its purpose. *{25.3%}* (c) I have general ideas about its purpose.*{15.1%}* (d) I understand its purpose.*{2.7%}*

How often do you use the following in science instruction

82. Laboratory activities: (a) daily *{8.2%}* (b) weekly *{72.1%}* (c) monthly *{12.2%}* (d) once a semester *{2.7%}* (e) never *{4.8%}*

83. Teacher demonstrations: (a) daily *{8.8%}* (b) weekly *{57.8%}* (c) monthly *{27.2%}* (d) once a semester *{2%}* (e) never*{4.1%}*

84. Collaborative or cooperative learning: (a) daily *{19%}* (b) weekly *{50.3%}* (c) monthly*{14.3%}* (d) once a semester *{5.4%}* (e) never *{10.9%}*

85. Computer activities: (a) daily *{5.4%}* (b) weekly *{9.4%}* (c) monthly*{13.4%}* (d) once a semester *{13.4%}* (e) never *{58.4%}*

86. Teacher lecture: (a) daily *{31.5%}* (b) weekly *{62.4%}* (c) monthly *{4%}* (d) once a semester *{0%}* (e) never *{2%}*

87. Discovery/Inquiry learning: (a) daily *{19%}* (b) weekly *{46.3%}* (c) monthly *{21.8%}* (d) once a semester *{6.8%}* (e) never *{6.1%}*

88. Alternative assessment: (a) daily *{8.3%}* (b) weekly*{24.1%}* (c) monthly *{26.2%}* (d) once a semester *{17.2%}* (e) never *{24.1%}*

89. Field trips: (a) weekly *{2.1%}* (b) monthly *{2.7%}* (c) once a semester *{15.1%}* (d) once a year *{27.4%}* (e) never *{52.7%}*

Indicate the extent you need assistance with each of the following in your science teaching.

90. New teaching methods: (a) definitely yes *{23%}* (b) probably yes *{52.7%}* (c) probably no *{20.3%}* (d) definitely no *{4.1%}*

91. Instructional materials: (a) definitely yes*{24.2%}*. (b) probably yes *{49%}* (c) probably no *{26.2%}* (d) definitely no *{.7%}*

92. Resources available in our region: (a) definitely yes *{34.9%}* (b) probably yes *{53.7%}* (c) probably no *{10.7%}* (d) definitely no *{.7%}*

93. Programs available in our region: (a) definitely yes *{33.6%}* (b) probably yes *{60.4%}* (c) probably no *{5.4%}* (d) definitely no *{.7%}*

94. Speakers available in our region: (a) definitely yes *{34.2%}* (b) probably yes *{53.7%}* (c) probably no *{12.1%}* (d) definitely no *{0%}*

95. Field trips available in our region: (a) definitely yes *{36.9%}* (b) probably yes *{47.7%}* (c) probably no *{14.8%}* (d) definitely no *{.7%}*

96. Uses of Internet in science classes: (a) definitely yes *{39.6%}* (b) probably yes *{38.9%}* (c) probably no*{16.8%}* (d) definitely no *{4.7%}*

97. Discovery/Inquiry learning: (a) definitely yes*{26.2%}* (b) probably yes*{50.3%}* (c) probably no*{22.1%}* (d) definitely no*{1.3%}*

98. Collaborative or cooperative learning: (a) definitely yes *{14.2%}* (b) probably yes*{42.6%}* (c) probably no*{37.8%}* (d) definitely no*{5.4%}*

99. Computers in science classrooms: (a) definitely yes *{39.6%}* (b) probably yes *{43.6%}* (c) probably no *{13.4%}* (d) definitely no *{3.4%}*

100. Process skills: (a) definitely yes *{17.4%}* (b) probably yes *{47%}* (c) probably no *{32.2%}* (d) definitely no *{3.4%}*

101. Laboratory set-ups: (a) definitely yes *{18.1%}* (b) probably yes *{41.6%}* (c) probably no *{35.6%}* (d) definitely no*{4.7%}*

102. Laboratory safety: (a) definitely yes *{10.1%}* (b) probably yes *{34.2%}* (c) probably no *{44.3%}* (d) definitely no*{11.4%}*

103. Alternative assessment: (a) definitely yes *{17%}* (b) probably yes*{49%}* (c) probably no *{27.9%}* (d) definitely no*{6.1%}*

104. Maintaining live organisms for science instruction: (a) definitely yes *{13.4%}* (b) probably yes *{32.2%}* (c) probably no *{35.6%}* (d) definitely no *{18.8%}*

105. Botany: (a) definitely yes *{8.8%}* (b) probably yes *{33.1%}* (c) probably no *{42.6%}* (d) definitely no *{15.5%}*

106. Zoology: (a) definitely yes *{9.5%}* (b) probably yes *{31.8%}* (c) probably no *{43.2%}* (d) definitely no *{15.5%}*

107. Chemistry: (a) definitely yes *{18.6%}* (b) probably yes *{42.1%}* (c) probably no *{29%)* (d) definitely no *{10.3%}*

108. Physics: (a) definitely yes *{19%}* (b) probably yes *{37.4%}* (c) probably no *{30.6%}* (d) definitely no *{12.9%}*

109. Astronomy: (a) definitely yes *{22.6%}* (b) probably yes *{28.8%}* (c) probably no *{32.2%}* (d) definitely no *{16.4%}*

110. Geology: (a) definitely yes *{13.8%}* (b) probably yes *{31.7%}* (c) probably no *{36.6%}* (d) definitely no *{17.9%}*

111. Environmental science: (a) definitely yes *{21.8%}* (b) probably yes *{38.8%}* (c) probably no *{29.9%}* (d) definitely no *{9.5%}*

112. Meteorology: (a) definitely yes *{16.4%}* (b) probably yes *{33.6%}* (c) probably no *{32.2%}* (d) definitely no *{17.8%}*

113. Oceanography: (a) definitely yes *{15.1%}* (b) probably yes *{37.7%}* (c) probably no *{31.5%}* (d) definitely no *{15.8%}*.

114. Integration of mathematics and science: (a) definitely yes *{27%}* (b) probably yes *{43.9%}* (c) probably no *{23%}* (d) definitely no *{6.1%}*

115. Applications of science concepts in society: (a) definitely yes *{30.4%}* (b) probably yes *{50.7%}* (c) probably no *{14.9%}* (d) definitely no *{4.1%}*

116. Science related societal issues: (a) definitely yes *{24.8%}* (b) probably yes *{49.7%}* (c) probably no *{22.1%}* (d) definitely no *{3.4%}*

117. Science related career opportunities for students: (a) definitely yes *{38.9%}* (b) probably yes *{45.6%}* (c) probably no *{12.8%}* (d) definitely no *{2.7%}*

COMPARISONS ACROSS GRADE LEVELS

Age:	20-29	30-39	40-49	50-59	60+
Elem	19%	26%	35%	18%	2%
S. Math	15%	34%	34%	15%	2%
S. Science	14%	27%	41%	14%	3%

Number of Years Teaching Experience:

	1-4	5-9	10-14	15-19	20+
Elem	23%	23%	17%	16%	21%
S. Math	20%	24%	18%	11%	28%
S. Science	19%	20%	14%	15%	33%

Sex:	F	M
Elem	97%	3%
S. Math	75%	25%
S. Science	56%	44%

Ethnicity:	African Am.	Asian	Caucasian	Hispanic	Native Am.	Other
Elem	<1%	<1%	95%	3%	<1%	<1%
S. Math	0%	1%	96%	2%	1%	0%
S. Science	1%	0%	97%	1%	1%	0%

Degree Status:

	Bachelor	Bachelor +hrs.	Masters	Masters +hrs	Doctorate
Elem	35%	47%	10%	8%	<1%
S. Math	28%	47%	12%	13%	0%
S. Science	20%	56%	7%	17%	<1%

Number of Schools Where You've Taught:

	1	2	3	4	5+
Elem	40%	27%	17%	8%	9%
S.Math	26%	32%	20%	12%	10%
S. Science	27%	38%	19%	9%	8%

Secondary Math--Teaching Certificate Concentrations

	Elem math	Elem non-math	Sec. math 1st field	Sec. math 2nd field	Sec. math only field	Other
Jr high/middle	29%	12%	23%	11%	7%	18%
High school	3%	1%	58%	13%	5%	20%

Knowledge about Standards

	not heard of them	heard, but no idea	general idea	implementation
Elem. Science	48%	30%	20%	2%
Elem. Math	49%	21%	20%	10%
Sec. Science	38%	28%	30%	4%
Sec. Math	34%	20%	32%	14%

TECHNOLOGY

Frequency Computers Are Used:

	≤once a month	once a month	every 2 weeks	weekly	daily
Elem	18%	9%	7%	34%	32%
S. Math	18%	9%	9%	29%	36%
S. Science	18%	3%	10%	35%	34%
Yrs experience					
1-4	12%	6%	9%	32%	41%
5-9	13%	10%	8%	31%	39%
10-14	20%	8%	5%	35%	32%
15-19	18%	8%	10%	32%	32%
20 +	26%	5%	8%	38%	23%
School Size					
A	30%	8%	0%	31%	31%
AA	21%	6%	11%	32%	30%
AAA	24%	6%	7%	30%	33%
AAAA	14%	31%	9%	37%	32%
AAAAA	16%	7%	7%	25%	45%
Age					
20-29	7%	9%	9%	32%	43%
30-39	18%	9%	7%	26%	40%
40-49	18%	6%	9%	38%	29%
50-59	23%	5%	7%	39%	26%
60 +	39%	6%	6%	43%	6%

Primary Purpose For Computer Use:

	Word Processing	Record Management	Instruction	Other
Elem	38%	18%	28%	4%
S. Math	28%	43%	19%	10%
S.Science	40%	31%	19%	11%

Why Computers Are Not Used:

	Access	Training	Time	Software	Other
Elem	38%	34%	23%	8%	5%
S. Math	29%	26%	21%	16%	9%
S.Science	28%	31%	14%	16%	18%

When Computers Are Available for Class Use:

	Daily	Weekly	Monthly	Never
Elem	57%	36%	2%	5%
S. Math	45%	12%	6%	39%
S. Science	33%	15%	7%	46%
School Size				
A	62%	23%	0%	15%
AA	79%	14%	0%	7%
AAA	47%	30%	6%	17%
AAAA	43%	34%	4%	19%
AAAAA	63%	11%	2%	24%
Secondary science				
Jr. High/Middle	19%	23%	11%	46%
High	45%	8%	3%	45%

When Computers Are Available for Class Demonstrations:

	Daily	Weekly	Monthly	Never
Elem	45%	36%	8%	5%
S. Math	44%	12%	6%	39%
S. Science	37%	15%	7%	49%
School Size				
A	60%	28%	0%	12%
AA	76%	10%	0%	14%
AAA	43%	19%	4%	34%
AAAA	36%	23%	3%	39%
AAAAA	58%	0%	0%	42%

Internet Access:

	Classroom	School	District	None
Elem	5%	28%	33%	34%
S.Math	2%	50%	15%	33%
S.Science	2%	52%	16%	30%
School Size				
A	13%	50%	4%	33%
AA	5%	35%	40%	20%
AAA	2%	31%	28%	39%
AAAA	3%	43%	24%	30%
AAAAA	4%	27%	39%	30%

Calculators

Elementary: Are classroom sets of calculators available:

School size	A	AA	3A	4A	5A
Yes	57%	62%	59%	58%	58%
No	43%	38%	41%	42%	34%

Secondary: Kinds of calculators available:

	4 function	fraction	scientific	graphing	none
Jr/Middle School	17%	43%	11%	21%	8%
High School	8%	1%	6%	82%	3%

Professional Development

Where:	Very Important	Somewhat Important	Not Important
Elem	49%	45%	6%
S. Math	42%	49%	7%
S. Science	52%	41%	7%

When:	Very Important	Somewhat Important	Not Important
Elem	68%	29%	3%
S. Math	64%	31%	5%
S.Science	71%	27%	3%

How Long:	Very Important	Somewhat Important	Not Important
Elem	41%	54%	6%
S.Math	38%	51%	11%
S.Science	33%	54%	13%

Cost:	Very Important	Somewhat Important	Not Important
Elem	75%	23%	2%
S.Math	63%	34%	3%
S.Science	66%	31%	4%

Topic:	Very Important	Somewhat Important	Not Important
Elem	93%	7%	<1%
S.Math	94%	5%	<1%
S.Science	88%	11%	1%

Presenter:	Very Important	Somewhat Important	Not Important
Elem	42%	52%	6%
S.Math	39%	57%	3%
S.Science	36%	54%	11%

Time Out of Class:	Very Important	Somewhat Important	Not Important
Elem	71%	27%	2%
S.Math	70%	29%	1%
S.Science	64%	31%	5%

Ranked order-Very Important:

Elem		S.Math		S.Science	
Topic-	93%	Topic-	94%	Topic-	88%
Cost-	75%	Time out of class-	70%	When-	71%
Time out of class-	71%	When-	64%	Cost-	66%
When-	68%	Cost-	63%	Time out of class-	64%
Where-	49%	Where-	42%	Where-	52%
Presenter-	42%	Presenter-	39%	Presenter-	36%
How Long-	41%	How Long-	38%	How long-	33%

Frequency chose to attend non-required professional development addressing methodology used to teach science and math:

	every yr.	every other yr.	every 3-5 yrs.	never
Elem. Science	10.7%	16.7%	32.2%	39.4%
Elem.Math	26.3%	19.4%	37.1%	17.3%
Sec. Science	28.3%	21.4%	25.5%	24.8%
Sec. Math	46.6%	20.3%	20.9%	12.2%

Frequency chose to attend non-required professional development addressing science/math concepts:

	every yr.	every other yr.	every 3-5 yrs.	never
Elem. Science	11%	14.5%	32.9%	41.6%
Elem.Math	26.%	18.7%	35.3%	20%
Sec. Science	30.3%	25.4%	26.1%	18.3%
Sec. Math	43.2%	22.3%	20.3%	14.2%

Does the district provide funds for non-required professional development:

	School Size				
	A	AA	AAA	AAAA	AAAAA
Yes	71%	74%	66%	80%	73%
No	29%	26%	34%	20%	27%

The following is a summary of questions about assistance required on each of the three surveys. Data is ordered based on responses of definitely yes and on combined responses of definitely yes and probably yes. For secondary math and science, the data is given by junior high/middle school and high school.

SECONDARY MATH

Topics ordered by definitely yes responses to needing assistance

Jr.high/middle school		High school	
Computers in math classrooms	38%	Uses of internet	40%
Field trips available in our region	35%	Computers in math classrooms	40%
Uses of internet	31%	Math related career opportunities	35%
Programs available in our region	30%	Programs available in our region	34%
Uses of internet	28%	Instructional materials	33%
Problem solving	26%	Applications of math in world	30%
Speakers available in our region	25%	Resources available in our region	29%
Instructional materials	24%	Field trips available in our region	28%
New teaching methods	24%	New teaching methods	27%
Discovery/inquiry learning	23%	Discovery/inquiry learning	27%
Manipulatives to model math	22%	Alternative assessment	27%
Alternative assessment	22%	Speakers available in our region	26%
Math related career opportunities	22%	Manipulatives to model math	26%
Applications of math in world	21%	Graphing calculators	24%
Graphing calculators	21%	Problem solving	23%
Patterns, relations, & functions	21%	Calculus	22%
Reasonableness	17%	Cooperative learning	21%
Integration of math & science	16%	Integration of math & science	18%
Calculators as instructional tool	15%	Calculators as instructional tools	17%
Number sense	14%	Number sense	13%
Estimation	14%	Patterns, relations, & functions	12%
Math of money/finance	10%	Matrices	12%
Calculus	9%	Non-Euclidean geometry	12%
Proportions	8%	Trigonometry	11%
Probability	8%	Statistics	10%
Cooperative learning	8%	Euclidean geometry	9%
Trigonometry	6%	Math of money/finance	7%
Euclidean geometry	5%	Probability	6%
Matrices	5%	Estimation	5%
Statistics	5%	Reasonableness	5%
Non-Euclidean geometry	4%	Proportions	5%

Topics ordered by definitely yes and probably yes responses to needing assistance (secondary math)

Jr high/middle school		High school	
Programs available in our region	88%	Resources available in our region	93%
New teaching methods	79%	Programs available in our region	92%
Resources available in our region	79%	Field trips available in our region	90%
Discovery/inquiry learning	79%	Computers in math classrooms	89%
Computers in math classrooms	78%	Speakers available in our region	86%
Field trips available in our region	76%	Discovery/inquiry learning	81%
Alternative assessment	76%	Uses of internet	81%
Problem solving	73%	Instructional materials	80%
Uses of internet	69%	New teaching methods	80%
Manipulatives to model math	65%	Alternative assessment	77%
Instructional materials	63%	Problem solving	77%
Math related career opportunities	63%	Manipulatives to model math	76%
Patterns, relations, & functions	60%	Math related career opportunities	70%
Applications of math in world	59%	Applications of math in world	69%
Integration of math & science	56%	Integration of math & science	66%
Calculators as instructional tools	55%	Cooperative learning	66%
Graphing calculators	55%	Graphing calculators	65%
Cooperative learning	52%	Patterns, relations, & functions	61%
Reasonableness	47%	Calculators as instructional tools	59%
Number sense	45%	Number sense	50%
Probability	41%	Statistics	46%
Estimation	40%	Probability	46%
Math of finance/money	37%	Calculus	44%
Proportions	36%	Non-Euclidean geometry	40%
Statistics	33%	Reasonableness	38%
Non-Euclidean geometry	32%	Trigonometry	36%
Matrices	30%	Estimation	33%
Euclidean geometry	30%	Euclidean geometry	31%
Calculus	21%	Math of finance/money	31%
Trigonometry	19%	Proportions	29%

SECONDARY SCIENCE

Topics are ordered by definitely yes responses to needing assistance.

Jr high/middle school

Field trips available in our region	45%
Use of internet	44%
Programs available in our region	44%
Speakers available in our region	41%
Resources available in our region	41%
Science related career opportunities	38%
Computers in science classrooms	36%
Discovery/inquiry learning	33%
Applications of science in society	32%
Instructional materials	31%
New teaching methods	29%
Integration of science and math	28%
Laboratory set-ups	26%
Science related societal issues	24%
Process skills	24%
Alternative assessment	20%
Cooperative learning	18%
Laboratory safety	18%
Maintaining live organisms	14%

High school

Computers in science classrooms	43%
Science related career opportunities	40%
Uses of internet	37%
Field trips available in our region	30%
Applications of science in society	30%
Speakers available in our region	29%
Integration of science and math	26%
Programs available in our regions	26%
Science related societal issues	26%
Discovery/Inquiry learning	31%
Instructional materials	18%
Instructional materials	18%
New teaching methods	18%
Alternative assessment	15%
Process skills	12%
Laboratory set-ups	12%
Cooperative learning	11%
Maintaining live organisms	10%
Laboratory safety	4%

Topics are ordered by definitely yes and probably yes responses to needing assistance.

Jr high/middle school

Programs available in our region	91%
Applications of science in society	87%
Resources available in our region	86%
Science related career opportunities	85%
Speakers available in our region	83%
Field trips available in our region	78%
Discovery/inquiry learning	78%
Computers in science classrooms	78%
Uses of Internet	76%
Science related social issues	74%
New teaching methods	74%
Instructional materials	73%
Laboratory safety	73%
Integration of math and science	72%
Alternative assessment	69%
Process skills	65%
Laboratory safety	56%
Cooperative learning	55%
Maintaining live organisms	53%

High school

Programs available in our region	97%
Resources available in our region	90%
Field trips available in our region	89%
Computers in science classrooms	88%
Science related career opportunities	84%
Speakers available in our region	81%
Uses of internet	82%
Applications of science in society	78%
New teaching methods	77%
Science related societal issues	76%
Discovery/inquiry learning	76%
Instructional materials	74%
Integration of math & science	69%
Alternative assessment	64%
Process skills	63%
Cooperative learning	59%
Lab set-ups	50%
Maintaining live organisms	40%
Laboratory safety	36%

Subject areas are ordered by definitely yes responses to needing assistance.

Jr high/middle school		High school	
Astronomy	31%	Environmental Science	17%
Environmental Science	28%	Physics	17%
Geology	25%	Astronomy	16%
Chemistry	23%	Chemistry	15%
Meteorology	23%	Meteorology	11%
Physics	22%	Oceanography	11%
Oceanography	20%	Botany	6%
Zoology	18%	Geology	5%
Botany	12%	Zoology	2%

Subject areas are ordered by definitely yes and probably yes responses to needing assistance.

Jr high/middle school		High school	
Chemistry	71%	Environmental Science	55%
Astronomy	68%	Chemistry	53%
Meteorology	67%	Physics	52%
Environmental Science	66%	Oceanography	45%
Geology	65%	Astronomy	39%
Physics	64%	Botany	38%
Oceanography	63%	Meteorology	37%
Zoology	50%	Zoology	34%
Botany	47%	Geology	30%

ELEMENTARY SCIENCE

Topics are ordered by definitely yes responses to needing assistance.

Field trips available in our region	54%
Resources available in our region	49%
Programs available in our region	48%
Hands on activities	46%
Instructional materials	44%
Speakers available in our region	44%
Class demonstrations	41%
Technology in science classrooms	37%
New teaching methods	35%
Integration of math and science	32%
Uses of internet	32%
Science related career opportunities	31%
Discovery/inquiry learning	30%
Applications of science in society	29%
Environmental science	26%
Cooperative learning	25%
Astronomy	25%
Earth science	25%
Maintaining plants & animals	24%
Process skills	24%
Physical science	24%
Alternative assessment	23%
Life science	23%
Science related societal issues	23%

Topics are ordered by definitely yes and probably yes responses to needing assistance.

Programs available in our region	93%
Field trips available in our region	91%
Resources available in our region	91%
Speakers available in our region	89%
New teaching methods	89%
Instructional materials	87%
Technology in science classrooms	86%
Discovery/inquiry learning	86%
Class demonstrations	85%
Integration of math & science	85%
Hands-on activities	84%
Applications of science in society	81%
Environmental science	80%
Earth science	80%
Physical science	78%
Life science	76%
Science related career opportunities	75%
Process skills	74%
Science related societal issues	73%
Alternative assessment	73%
Cooperative learning	72%
Astronomy	72%
Maintaining plants & animals	69%
Uses of internet	66%

ELEMENTARY MATH

Topics are ordered by definitely yes responses to needing assistance.

Problem solving	44%
Field trips available in our region	40%
Applications of math in today's world	39%
Resources available in our region	39%
Integration of math and science	37%
Number sense	37%
Computers in math classrooms	36%
Math related career opportunities	35%
Use of manipulatives	34%
Speakers available in our region	34%
Instructional materials	32%
Patterns, relations, & functions	31%
New teaching methods	31%
Uses of internet	31%
Reasonableness	30%
Estimation	30%
Discovery/inquiry learning	29%
Use of calculators	28%
Measurement	28%
Fractions	27%
Alternative assessment	25%
Probability	24%
Geometry	23%
Cooperative learning	22%
Statistics	22%
Decimals	22%
Proportions	21%

Topics are ordered by definitely yes and probably yes responses to needing assistance.

Applications of math in today's world	86%
Programs available in our region	86%
Field trips available in our region	83%
Resources available in our region	83%
Integration of math and science	82%
Discovery/inquiry learning	81%
Speakers available in our region	80%
Patterns, relations, & functions	79%
Computers in math classrooms	78%
Number sense	77%
Math related career opportunities	75%
Instructional materials	75%
Reasonableness	74%
Use of manipulatives	72%
Estimation	72%
Cooperative learning	71%
Measurement	70%
Use of calculators	66%
Fractions	65%
Geometry	65%
Probability	63%
Uses of internet	61%
Alternative assessment	61%
Problem solving	59%
Proportions	59%
Decimals	57%
Statistics	55%

COMPARISONS BY SCHOOL SIZE

School size	A	AA	3A	4A	5A
When is physics offered:					
Every year	0%	86%	64%	85%	85%
Every other year	75%	0%	12%	2%	0%
Never	25%	0%	6%	1%	0%
Do not know	0%	14%	18%	11%	14%
Chemistry offered:					
Every year	75%	85%	74%	93%	79%
Every other year	25%	14%	9%	1%	79%
Never	0%	0%	6%	1%	0%
Do not know	0%	0%	12%	5%	14%
Percent of Students that complete 3 science courses:					
0-10%	0%	0%	4%	6%	24%
11-25%	33%	57%	25%	22%	38%
26-50%	33%	29%	33%	29%	38%
51-75%	33%	0%	29%	24%	0%
over 75%	0%	14%	9%	19%	0%
Percent of Students that complete 4 science courses:					
0-10%	0%	33%	33%	45%	38%
11-25%	100%	50%	42%	35%	50%
26-50%	0%	17%	25%	17%	12%
51-75%	0%	0%	0%	0%	0%
over 75%	0%	0%	0%	3%	0%
Percent of Students that complete a chemistry course:					
0-10%	25%	17%	9%	9%	24%
11-25%	25%	17%	43%	34%	38%
26-50%	50%	33%	22%	38%	38%
51-75%	0%	33%	17%	16	0%
over 75%	0%	0%	9%	3%	0%
Percent of Students that complete a physics course:					
0-10%	100%	50%	55%	48%	38%
11-25%	00%	0%	41%	18%	25%
26-50%	0%	50%	4%	25%	12%
51-75%	0%	0%	0%	7%	0%
over 75%	0%	0%	0%	2%	25%

School size	A	AA	3A	4A	5A
Percent of Students that complete a biology course:					
0-10%	0%	0%	4%	3%	0%
11-25%	0%	0%	0%	2%	25%
26-50%	0%	17%	12%	5%	0%
51-75%	0%	17%	4%	19%	0%
over 75%	100%	66%	80%	71%	25%
Percent of Students that complete a physical science course:					
0-10%	0%	0%	0%	4%	0%
11-25%	0%	17%	0%	9%	0%
26-50%	0%	17%	15%	16%	29%
51-75%	25%	17%	19%	31%	0%
over 75%	100%	49%	66%	40%	71%
Number of Science electives other than Chem I and Physics I:					
0	50%	0%	0%	8%	0%
1	0%	0%	59%	14%	11%
2	50%	17%	23%	22%	11%
3	0%	50%	9%	18%	33%
4 or more	0%	33%	9%	38%	45%
Adequacy of supplies and equipment for lab:					
none available	0%	0%	6%	1%	15%
barely adequate	0%	0%	12%	28%	31%
adequate	100%	100%	65%	38%	54%
more than adequate	0%	0%	8%	33%	0%
not sure	0%	0%	9%	0%	0%
Percent of Students that complete three years of math:					
0-10%	0%	0%	0%	2%	0%
11-25%	0%	0%	11%	2%	20%
26-50%	33%	0%	21%	16%	0%
51-75%	0%	0%	7%	14%	20%
over 75%	67%	100%	61%	66%	60%
Percent of Students that complete four years of math:					
0-10%	67%	0%	31%	18%	83%
11-25%	33%	50%	31%	58%	0%
26-50%	0%	25%	28%	16%	17%
51-75%	0%	25%	7%	4%	0%
over 75%	0%	0%	3%	4%	0%

Amarillo National Resource Center for Plutonium

Quarterly Progress Report
for the period
1 February 1996-30 April 1996

Nuclear Group

May 10, 1996

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1.5.1.2 COORDINATION AND TECHNICAL INFORMATION SUPPORT FOR NUCLEAR GROUP ACTIVITIES

Paul Nelson (PI), ANRCP/TAMU
Gia Alexander, ANRCP/TAMU
David R. Boyle, ANRCP/TAMU
Igor Carron, ANRCP/TAMU
Donna Greer, ANRCP/TAMU

PROGRESS REPORT
(1 February 1996-30 April 1996)

Research Activities

I. Flow of Information to the Nuclear Group

A. Technical Library Acquisitions

During this reporting period the following items have been acquired from the open literature, to form a nucleus for the planned Nuclear Group Library:

Open Literature Publications

Books:

Soviet-Designed Nuclear Power Plants in Russia, Ukraine, Lithuania, Armenia, The Czech Republic, the Slovak Republic, Hungary and Bulgaria, Fourth Edition 1996. Nuclear Energy Institute, Washington DC.

Technical Reports

V. L. Peterson, Reference Computations of Public Does and Cancer Risk from Airborne Releases of Uranium and Class W Plutonium, Nuclear safety technical report, EG&G Rocky Flats, RFP-4965, June 6, 1995.

T. E. Lindemer, Assessment of Gallium Effects in Processing and Performance of U-Pu Oxide LWR fuels, ORNL/MD/LTR-38. September 13, 1995.

R. E. Smith, A Methodology for Calculation of the Probability of Crash of an Aircraft into Structures in Weapon Storage Areas, SAND82-2409. February 1983.

N. Breazeal, K.R. Davis, R. A. Watson, David S. Vickers, M. S. Ford, Simulation-based Computation of Dose to Humans in Radiological Environments, Sandia Report, SAND95-3044. March 1996.

Screening of Alternate Immobilization Candidates for Disposition of Surplus Fissile Materials, Fissile Material Disposition Program, UCRL-ID-118819, February 1996.

PEIS Data Call Input Report: Immobilization of Surplus Fissile Material with Electrometallurgical Treatment of Spent Fuels, Fissile Material Disposition Program, UCRL-ID-122667, February 1996.

PEIS Data Call Input Report: Ceramic Immobilization Facility with Radionuclides, Fissile Material Disposition Program, UCRL-ID-122665, February 1996.

PEIS Data Call Input Report: Ceramic Immobilization Facility Using Coated Pellets without Radionuclides, Fissile Material Disposition Program, UCRL-ID-122666, February 1996.

PEIS Data Call Input Report: PEIS Data Call Input Report: New Glass Vitrification Facility, Fissile Material Disposition Program,UCRL-ID-122658, February 1996.

U.S.-Russian Joint Study Report for Geological Disposition Options, Combined Report, Second Draft, U.S./Russian Plutonium Disposition Study, March 18, 1996.

G. T. Allison, O. R. Cote, R. A. Flakenrath, S. Miller, Avoid Nuclear Anarchy, Containing the Threat of Loose Russian Nuclear Weapons and Fissile Material, CSIA Studies in International Security No. 12. The MIT Press, Cambridge MA, 1996.

Nuclear Fuels Technologies, Fiscal Year 1996 Research and Development test Matrices, Nuclear Materials and Stockpile Stewardship Programs Technology and Safety Assessment Division, Nuclear Materials Technology Division, Los Alamos National Laboratory. LA-UR-96-856 (Rev. 1).

R. Salmon, S.L. Loghry, R. C. Ashline, User's Manaul for the Radioactive Decay and Accumulation Code RADAC, ORNL/TM-12380, November 1995.

Critical Experiments with 4.31% Enriched UO2 Rods in Highly Borated Water Lattices, NUREG/CR-2709.

PuO2-UO2 Fueled Critical Experiments, WCAP-3726-1; UC-46.

Saxton Plutonium Program: Critical Experiments for the Saxton Partial Plutonium Core, EURAEC-1493;WCAP-3385-54.

Environmental Impact Statements

Stockpile Stewardship and Management Draft Programmatic Environmental Impact Statement. February 1996.

Storage and Disposition of Weapons-usable Fissile Materials Draft Programmatic Environmental Impact Statement. February 1996.

Draft Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components. March 1996.

B. Centralized Information Web Page

During this reporting period, a centralized information web page was created by Dr. Carron to allow Nuclear Group participants a rapid and efficient survey of documentation and news relevant to their subject of investigation. The site allows rapid and direct access to the DOE's and other organizations' library database. The holdings of the technical library were updated.

C. **Public Information Hearings**

Drs. Nelson and Carron participated at the DOE hearings on the three recent Environmental Impact Statements in Amarillo, Texas on April 22-23.

D. **Participation in DOE-MD Meetings**

Dr. Carron participated in several conference calls regarding the US/Russia Joint Studies activities.

Dr. Nelson represented the Center at the MD Technical Status meeting in Arlington VA, February 21.

Drs. Nelson and Carron represented the Center at the meeting of the Joint US-Russian Study Team on Nonproliferation, March 3-9, 1996.

Dr. Nelson represented the Center (along with Drs. Adams and Abdurrahman) at the MD Reactor Program meeting in Washington, March 18-19, 1996.

Dr. Nelson met in Albuquerque with representatives of the Transportation Project of the Center and Sandia staff working on MD-related transportation projects, April 30.

E. **Newsletter**

Newsletter 4 was sent electronically to the participants in the Nuclear Group.

F. **Technical Calendar**

No Calendar was sent electronically to the participants in the Nuclear Group during the reporting period.

II. Flow of Information from the Nuclear Group.

A. Organization of Quarterly Meeting for the Nuclear Group

The second quarterly meeting was organized during this reporting period. The meeting was held on March 29-30 in Amarillo, Texas. A delegation of the Los Alamos Laboratory (Drs. James Toevs, Carl Beard and Terry Cremers) and the Sandia National Laboratories (Dr. Larry Shipers) presented information on their activities pertaining to plutonium disposition and automation and robotics. Each Laboratory delegation discussed specific issues with Nuclear group researchers in smaller groups meetings.

B. Prepare Quarterly Progress Report Describing Activities of the Nuclear Group.

The third of these quarterly progress consists of the present document.

C. Technical Report Series

No Technical report were processed during this period. However, the proposed template for the Technical Report Series has been developed and sent to ANRCP for approval.

D. Annual Report

Dr. Nelson prepared material, subsequently forwarded to Amarillo, for an initial annual report for the Center.

III. Global Information Flow

A. Workshops Devoted to Specific Technical Issues of Interest to the Center and DOE-MD.

No actions were taken during this period.

B. National and International Conferences on Broad Topics of Interest to the Center and DOE-MD.

No action was taken during this period.

Most Tangible Accomplishments

The most tangible accomplishments on this subproject for the current reporting period are:

- Acquisition of technical reports from national labs and other organizations
- Constitution of a web page accessible to all Nuclear Group participants for general information on publicly available technical databases
- Electronic submission of a Newsletter for the Nuclear Group participants
- Nuclear Group quarterly meeting where Los Alamos and Sandia National Laboratories representatives were invited

1.5.2 Russian Interactions

1.5.2.1 SUPPORT OF RUSSIAN JOINT STUDIES ACCELERATOR-DRIVEN TRANSMUTATION

R. Wigmans (PI), ANRCP/TTU
M. Frautschi, ANRCP/TTU

PROGRESS REPORT
(1 February 1996-30 April 1996)

Introduction

We report our progress in investigation into the possibilities for accelerator catalyzed transmutation of spent nuclear fuel (high level waste). We report our progress in initiating a new research interest in Nondestructive Assay of containerized plutonium.

Activities

In this section activities of the investigators since the previous progress report to the ANRCP on 19 February 1996 are described.

An undergraduate student, Mr. Khondoker M. S. Shahriar, has concluded his activities with the TTU group. Mr. Shahriar assisted with the gathering of nuclear data through the world wide web.

On 28-29 March 1996 Wigmans and Frautschi attended the regular quarterly meeting of the ANRCP. Wigmans presented a talk summarizing our conclusions regarding direct (i.e. through neutrons produced in spallation reactions) Accelerator Driven Transmutation (ADT) of excess weapons grade plutonium and high-level radioactive waste. One highlight of the talk was the creation of Tc-98 from Tc-99 using the (n,2n) reaction. Tc-98, as reported in our previous progress report (2/19/1996), is not a fission product and is considerably more dangerous and long-lived than Tc-99.

Wigmans also presented results of calculations on the production of tritium by accelerator produced (spallation) neutrons. It appears that Avagadro's number makes this process prohibitively expensive, and that neutron generation through fission is an unavoidable ingredient of any reasonable tritium production scheme.

On 12 April 1996 Wigmans and Frautschi traveled to Los Alamos National Laboratory to visit with Gary Doolen, head, and other workers associated with the Accelerator Driven Transmutation Technologies project (ADTT). In addition to meeting with Doolen, several useful individual discussions were conducted with Charles Bowman, Brian Newman as well as a brief discussion that included Bill Sailor, Francesco Vanneri and Newman. Presentations were given by Francesco Vanneri and Gary Doolen.

The visit concluded with a tour of preparations for experiments at the Los Alamos Neutron Scattering Center (LANSCE, formerly LAMPF).

Several potential areas of cooperation were identified, including independent peer review of several technical aspects of the project, including neutron economics and electric power economics.

On 18 April 1996 Dr. Bill Harris, director of the ANRCP, submitted a letter to Wigmans informing the TTU group that, unfortunately, the ANRCP would not be able to continue funding of research related to ADT since these technologies fall outside the scope and time-frame of the ANRCP.

Accordingly, a two-track approach was adopted by the TTU group:

- A new proposal within the scope and time-frame of the ANRCP mission would be explored. This would allow contribution to the ANRCP effort within the near term.

- A longer term, unfunded, effort to generate the political will within DOE to consider the funding of ADTT research at a level sufficient to establish the viability or non-viability of these technologies as they apply to the national interest. The toxicity and security concerns associated with plutonium and high-level nuclear wastes with lifetimes exceeding recorded history by significant margins demand that technologies with the potential to reduce these compounds to nuclides with half-lives of thirty minutes or less be rigorously investigated. This political will, if found within DOE, could form the basis for a possible redirecting of the ANRCP mission.

Some progress has been made in both tracks:

- Professor Teruki Kamon of Texas A & M University has agreed to join our Nondestructive Assay letter of intent to be followed by a full proposal.

- We have contacted Jim Toevs and others in the plutonium facility, TA-55 at Los Alamos regarding contribution to the various NDA error calculations. We expect to hear initial reactions to our proposals within one week.

- We have contacted Lindsay Lovejoy, Assistant State Attorney General for the Environment Enforcement Division of the State of New Mexico for assistance. Lovejoy's experience includes monitoring compliance with EPA and DOE regulations at DOE facilities such as Los Alamos National Laboratories, Sandia National Laboratories and the Waste Internment Pilot Project (WIPP) in Carlsbad, NM.

- We are exploring the possibility of working with a journalist with scientific training, in particular, science writer Gary Taubes. We have his contact information and are considering contacting him for his input and possible collaboration in this project.

Outlook

We expect to identify several useful areas for analysis and contribution with the NDA groups at LANL in the coming weeks.

1.5.2.2 SUPPORT OF RUSSIAN JOINT STUDIES: EVALUATION OF MODULAR HIGH-TEMPERATURE GAS-COOLED REACTORS FOR UTILIZATION OF PLUTONIUM

F. R. Best (Co-PI), Department of Nuclear Engineering, Texas A&M University

D. R. Boyle (Co-PI), Department of Nuclear Engineering, Texas A&M University

PROGRESS REPORT
(1 February 1996-30 April 1996)

This project was intended to support information-gathering activities by the Center representative to the corresponding US/Russian Joint Study Team. This particular Study Team was canceled by the Joint Steering Committee at its meeting of early October. Reallocation of the resources committed to this project currently is under consideration.

We are collecting material related to the disposition of weapons plutonium in CANDU reactors. This is a redirect of the earlier project of using HTGR reactors. We are in the process of obtaining AECL documents related to the plutonium consumption program. Currently, we are forming an archive of documents related to the CANDU plutonium consumption program.

1.5.2.3 SUPPORT OF RUSSIAN JOINT STUDIES: EVALUATION OF FAST REACTORS FOR THE UTILIZATION OF PLUTONIUM

W. D. Reece (PI), ANRCP/TAMU

PROGRESS REPORT
(1 February 1996-30 April 1996)

Research Activities

Over the past quarter, efforts to collect the areas of expertise on fast reactors in this country have made considerable headway. The expertise and experience at Hanford's Fast Flux Test Facility (FFTF) has been folded into the joint work with the Russians. While meeting with the LWR-MOX group in ORNL, David Moses and I had a breakout meeting on the fast reactor work, including contacting Russian investigators. Dr. Moses and I will meet with our Russian counterparts in Washington DC next week to continue investigating the areas where joint work and collaboration can be done.

Concurrent with these efforts, I have been working with FFTF personnel to effect a transfer of the analysis codes used in design and operation of FFTF to Texas A&M. These codes can be used to train graduate students so that the lessons learned at FFTF will not be lost, and for certain applications, can be used to help analyze the Russian's BN600 for safety concerns, etc. The transfer has been agreed to in principle and the details of physical transfer and training are being worked out.

1.5.2.4 SUPPORT OF JOINT US/RUSSIAN TECHNICAL WORKING GROUPS FOR THE STUDY OF ALTERNATIVES FOR THE DISPOSITION OF EXCESS WEAPONS-GRADE PLUTONIUM

Paul Nelson (PI), ANRCP/TAMU
M. L. Adams, ANRCP/TAMU
D. R. Boyle, ANRCP/TAMU
Igor Carron, ANRCP/TAMU
A. Clearfield, ANRCP/TAMU
Dale Klein, ANRCP/TAMU
K. L. Peddicord, ANRCP/TAMU
W. D. Reece, ANRCP/TAMU
Mukul Sharma, ANRCP/UTA

PROGRESS REPORT
(1 February 1996-30 April 1996)

Support Activities

The majority of the effort on this activity during the reporting quarter has been directed toward providing administrative and logistical support for visits to the U.S. by Russian participants in this study, or toward travel to Russia in support of the study. Specific instances follow.

1. Professors Dale Klein and K. L. Peddicord represented the Center at the Joint Steering Committee meeting in Russia February 23, 1996.

2. The Center made arrangements for the Russian participants (Drs. Vladimir Chitaikin, Vadim Ptashny and Gennady Pshakin) of the newly formed Non-proliferation team. The meeting was held at the Rosslyn (Virginia) office of the Sandia National Laboratories on March 4-7, 1996. The Center was represented by Drs. Paul Nelson and Igor Carron.

3. The Center made arrangements for Dr. Vladimir Kagramanian to visit Steve Passman and Dr. Matthew Bunn in Washington, D.C. for the preparation of the executive summary of the US/Russia Joint Study activities. The Center was represented by Dr. Igor Carron.

4. The Center made arrangements for Yuriy Matyunin and Ludmila Petrova of the Immobilization team to meet with the U.S. Co-chair Dr. Tom Gould (Savannah River Laboratory) and Dr. Leonard Gray (Lawrence Livermore Laboratory) in Livermore, California, April 1-4, 1996. The Center was represented by Dr. Igor Carron.

5. The Center currently is coordinating with Steve Passman and all the U.S. Co-chairs for the upcoming Co-chairs meeting and the subsequent Joint Steering Committee meeting. The meeting will be held in Arlington, Virginia and scheduled for May 13-17, 1996.

Additional effort has been directed toward support of preparation of the individual Study Team reports, and of proposals for subsequent related projects intended to address issues of mutual interest that have been identified in the course of these studies. Some specific instances follow:

1. Dr. Marvin Adams worked with Mr. Bruce Bevard (US Co-chair for the Water Reactor Study) to refine the four currently extant proposals for future efforts related to water reactors, particularly in regard to ensuring that ANRCP capabilities will be brought fully to bear on these projects if they are approved and funded.

2. Dr. W. Dan Reece worked with Dr. David Moses (US Co-chair for the Fast Reactor Study) to identify sources of information and expertise within the US that have the potential to bear on any subsequent joint projects related to fast reactors.

3. Dr. Mukul Sharma worked with Dr. Carron and Dr. Les Jardine (LLNL, US Co-chair of the Borehole Study) to coordinate plans for an extended visit by Dr. Tatiana Gupalo (Russian Co-chair of the Borehole Study) following the scheduled May 13-17 meeting of the Joint Steering Committee and the Co-chairs.

1.5.3 Plutonium Storage

1.5.3.1 OVERVIEW OF STORAGE-RELATED WORK

David R. Boyle (PI) ANRCP/TAMU

PROGRESS REPORT
(1 February 1996-30 April 1996)

Introduction

This report covers tasks originally aimed at supporting the Joint US/Russian Study of the HTGR. The redefined tasks now encompass:

1. Programmatic coordination of ANRCP storage-related activities, and
2. Generation of a college-level academic program addressing materials disposition topics.

These tasks will fall under the Nuclear Group's general program administration area beginning 1 June 1996.

Research Activities

1. In March the PI attended a conference addressing weapons materials storage and disposition issues in Lansdowne, VA. While at Lansdowne, I was able to meet with various DOE and laboratory personnel and accomplish numerous storage program coordination actions. I also obtained study materials for the new course on nuclear materials management to be offered this fall at Texas A&M.

2. The PI presented a summary of Nuclear Group storage-related activities at the ANRCP Quarterly meeting in Amarillo. During that visit to Amarillo I arranged for and conducted meetings between Pantex engineers and ANRCP PIs working on storage monitoring projects. These meetings resulted in improved understanding of actual storage scenarios among the PIs and helped to focus the ANRCP research on the highest value-added tasks.

3. LANL requested that the ANRCP perform independent thermal and nuclear criticality analyses for a proposed national consolidated storage facility design now under review. I'm working with Warren Wood (LANL storage POC) and Bill Gregory (LANL thermal analyst) to obtain the necessary design drawings from Fluor Daniels, Inc. We have identified ANRCP experts at Texas Tech and UT who can perform the needed work.

4. The PI arranged a visit to Pantex and the ANRCP by COL. E.J. Stobbs. COL. Stobbs, from the Office of the Assistant to the Secretary of Defense (Atomic Energy), manages the Russian surplus weapon materials storage effort of the Comprehensive Threat Reduction Program (Nunn-Lugar). He will participate in technical exchange meetings with key ANRCP personnel on 14 May and with Pantex officials on 15 May.

5. In response to a request by the State of Texas, I conducted a review of DOE's recently released Draft Stockpile Stewardship and Management Programmatic Environmental Impact Statement (PEIS). On 17 April, the PI presented the results of this review to the Pantex Plant Citizens Advisory Board and answered questions at a public meeting.

Most Tangible Accomplishments

Review of Stockpile Stewardship and Management PEIS and associated public briefing is the most tangible accomplishment for the current reporting period and forwarded to the State of Texas.

1.5.3.2 ROBOTICS, AUTOMATION, AND TELE-OPERATION PROGRAM FOR SAFE HANDLING AND LONG-TERM STORAGE OF NUCLEAR COMPONENTS

Alan A. Barhorst (PI), ANRCP/TURAC/TTU
Richard A. Volz (Co-PI), ANRCP/TURAC/TAMU;
George V. Kondraske (Co-PI), ANRCP/TURAC/UTAr.
Jose Macedo, ANRCP/TURAC/TTU
Mica Endsley, ANRCP/TURAC/TTU
William Kolarik, ANRCP/TURAC/TTU
Michael Parten, ANRCP/TURAC/TTU
Hua Li, ANRCP/TURAC/TTU
Jeff Woldstad, ANRCP/TURAC/TTU
Jeffrey Trinkle, ANRCP/TURAC/TAMU
Louis Everett, ANRCP/TURAC/TAMU
John Poston, ANRCP/TURAC/TAMU
S. V. Sreenivasan, ANRCP/TURAC/UT

PROGRESS REPORT
(1 February 1996-30 April 1996)

Introduction and Overview

This report will be structured as prescribed:

1. Result Summary
2. Most Tangible Accomplishments
3. Programmatic Coordination with DOE
4. Recommendations to the ANRCP

Result Summary

The research project is composed of six areas of study. The research team is composed of members from five distinct institutions. This section will be completed on a research task basis.

General Information

Since the last report, training on most of the commercial software required for this project has been completed and investigators and task-aware students have been in contact with each other and have shared useful information in regards to operation of the software. With respect to this, an inter-institutional meeting was held between Texas A&M University (TAMU) and Texas Tech University (TTU) at TAMU. Constant contact is also being maintained through the use of e-mail. Also, these larger teams are continuing to hold individual weekly meetings to keep their respective groups informed of all progress. In addition, a meeting was held with Sandia, Pantex, and DOE personnel to discuss closer collaboration and how we can better complement their efforts.

Research Activities

1. Storage Automation

This task is the focus of the first year's funding and the remaining five tasks are considered to support this task. To this end, and as a task in itself, the following is applicable.

Contacts have been established within the DOE complex and Fluor-Daniel, the Architect and Engineering firm, relative to the design of the storage facility. Meetings have been attended at Fluor-Daniel headquarters and design documents have been acquired. Discussions on how the present research in interface design, navigation, and material handling can be integrated into the design specification are ongoing.

Further contacts with DOE Laboratory Robotics and Automation groups has been established, specifically with Sandia and Los Alamos. These groups have extensive experience with automated techniques for nuclear weapons and hazardous waste handling. In order to compare whether their systems might be useful for future storage systems, the DOE Labs have each forwarded specifications on various automated programs within and without the nuclear industry.

In addition to systems developed by DOE National Labs, contact has been established with several vendors who supply services such as decontamination to the nuclear power industry. There has been less success in acquiring capabilities in this sector due to proprietary obligations of the vendors, however, several alternatives are being investigated, e.g., how DOE handles similar situations.

International sources of technology are proving to be very difficult to acquire for a variety of reasons including language barriers and classification problems. For example, we have recently obtained an overview document describing the Russian storage facilities, but we have been told that the more detailed description will not be declassified in the near future.

Regarding the development of navigation algorithms:

- Calibration of structured-light vision system for 3-dimensional ranging has been completed. The setup uses a single stripe of light projected by a laser and a CCD camera located in any arbitrary position. The method developed finds model parameters required for 3-dimensional reconstruction of scanned objects.

- A hand-eye calibration method on a 2-dimensional plane for the Staubli robot has been completed. The method developed uses a simple least squares procedure to find the mapping between camera coordinates on a fixed computer vision system and robot tool coordinates on a 2-dimensional working plane.

- Robot tracking of 2-dimensional curves using a wrist attached CCD camera has been accomplished. The setup uses a CCD camera mounted on the robot end-effector to track any arbitrary curve in a plane.

In support of the mobile platform modeling and navigation, we have been continuing our efforts on developing a simulator for studying planning and control of wheeled mobile robots in a nuclear facility. The emphasis is to develop an interactive graphical software that can be used to investigate "course" and "fine" motion of various mobile robot configurations. This software will also allow the user to input various floor plans of storage automation facilities.

We have developed dynamic modeling schemes for wheeled mobile platforms by treating it as a multi-rigid body system. The presence of closed kinematic loops in these mechanical systems, and the presence of nonholonomic constraints in these vehicles makes these problems distinct from classical multi-body dynamic problems. We have found that a particular form of the Kane's dynamic formulation leads to efficient simulation schemes. We are in the process of adapting this scheme to develop a versatile simulator for the purpose of storage automation, and are in the process of developing trajectory tracking control schemes.

2. Simulation Testbed

Simulation and training work for the quarter consisted of installing a newer version of TELEGRIP at both sites. Along with fixing several serious bugs in the software, this version provides 3D stereo graphics support. Work has also been done concerning the exploration of the functions of TELEGRIP as well as converting existing models of some of our laboratory devices which were established via Solid Surface Modeler (SSM) into Deneb models which are compatible with the TELEGRIP input file format. This will allow us to integrate models of our equipment into the TELEGRIP Consolidated Storage Facility (CSF) simulation.

A TELEGRIP model of the Staubli RX-130 has been created and used in trade with Deneb Robotics Inc. to obtain all the robots in the Deneb library. The RX-130 model has also been used in a complete simulation mockup of the RX-130 workcell at TTU. This model will assist in the implementation of many theoretical aspects of the project including interface design, navigation, and telerobotic interaction.

CSF simulation models received from Sandia National Laboratory have been installed. The installation of these models has helped to further enhance the usability of TELEGRIP and has helped to avoid any overlap in the development of simulation packages for specific functionality.

Use of virtual reality (VR) technology in conjunction with the CSF simulation is being explored. Progress from the last quarter concerning the VR devices is discussed in Section 3: Human & Automation Integration.

An important aspect to this VR capability is the need for collision detection in a real-time manner. The collision detection provided by TELEGRIP is sufficient for VR simulation. However, for grasping and manipulation, a more detailed method of collision detection is required. TELEGRIP only provides an indication that a collision has occurred. It does not indicate how the collision occurred (i.e., which topological elements of the respective objects contacted each other). To resolve this problem, a study of an efficient collision detection software package has been conducted. I-COLLIDE (developed by Jonathan D. Cohen, Ming C. Lin, et al. at the Dept. of Computer Science, University of North Carolina) is an exact collision detection system which can provide contact information on the occurrence of contacts among multiple bodies in a generic manipulator. The hope is that I-COLLIDE will provide the contact detection capability which we require to handle the grasping motion of our generic manipulator in a more efficient and detailed way.

Another important aspect of developing the simulation testbed is the capability of controlling devices from a remote location. In an effort to make the simulation test bed remotely controllable by TTU, TAMU ported all InterAgent applications, such as network software that enable the control of robots over the internet, onto the machines at TTU. A unidirectional link between TTU and TAMU was established, and TTU has succeeded in remotely controlling devices at TAMU using this method.

In order to make the operation bidirectional, TAMU visited the facilities at TTU, and gained a better understanding of what needs to be done. The initial steps at creating a tele-link via InterAgent at TAMU and TTU has been quite successful.

Work is progressing in developing a virtual robot (the RX-130 mentioned above) for the bi-directional telerobotic interface. This tool will be used in the interim while hardware is being delivered and configured to bring both the Staubli and PUMA at TTU on line with the InterAgent protocol.

3. Human & Automation Integration

Development of a control interface for a simulated teleoperation system has been pursued with a working paper prepared to document preliminary design features. These features include:

1. graphical/camera views of the teleoperator environment,
2. displays of forces and torques at the telemanipulator,
3. displays of task status in terms of elapsed time, parts completed and errors, and
4. system menus for selecting different combinations (levels) of human and/or computer control of teleoperator functions and choosing types of grippers and materials to be used in teleoperations.

Modeling of the interface features has begun using ModelGen and X-Motif on a Silicon Graphics workstation with 40% of all features currently developed. Specifically, all menus and displays of force, torque and task status will be developed. Functionality of these features is currently being facilitated using TELEGRIP on the same system. Both the Graphic Simulation Language (GSL), used in TELEGRIP for off-line programming of graphic robot models, and C will be used to code functions of specific interface features. Completion of a alpha version of the functional control interface is expected by 15 May. Subsequently, the designed levels of human and computer control of the simulated teleoperation system will be facilitated using the interface.

Use of the virtual reality capabilities installed during the last quarter has been intensified to include additional functionality. For example, six degree of freedom position and orientation sensing was established via Ascension's Flock of Bird Trackers. The unit was integrated into our testbed and a demonstration of this capability was created where a robot uses a tool which is guided by the hand motions of the user.

Three dimensional stereo viewing was also established via Virtual Research System's VR4 head-mounted display. A demonstration of this capability was created where the user can view and manipulate a robotic device in 3D.

An integrated capability between the above two devices was also established where the 3D stereo viewpoint can be modified the user's head motions. A demonstration was created through which the user can "inspect" a virtual object by moving his head in a way similar to inspecting an actual object. The 6 DOF trackers read the user's head orientation and update the stereo graphics accordingly.

A video of the above functionality and demos was created and shown at the last quarterly meeting. Additional VR equipment with further capabilities to enhance the human-machine interface has been ordered. These capabilities are laying the foundation for advanced simulation and inspection systems to be developed in the coming year.

Also, a dissertation on "Neuromotor Workload Measurement" was completed and defended. This work represents a major step in the continuing process of validating our new model and contains a major data analysis of real telerobotic experiments. The objective and unobtrusive neuromotor workload metric was shown to be highly repeatable and sensitive enough to discriminate workloads associated with tasks that would be expected to produce different workloads. We will now be turning our attention to the preparation and submission of journal articles based on this material. A related effort involves a complete review and documentation of methods incorporated into algorithms that serve as the core of our latest software package for performance and workload measurements.

4. Component and Material Handling

With respect to component and material handling, experiments are being performed on a simple manipulator/gripper design tool. This manipulator consists of a palm and two double-linkage fingers. TELEGRIP is used to perform a simulation of this tool using kinematics to enable the manipulation motion for the fingers. Contact between the manipulator and the workpiece is detected and maintained throughout the manipulation.

Work is currently underway to replace the current TELEGRIP kinematics with a more flexible Denavit-Hartenberg method. This enables better motion planning for the exact manipulation of the workpiece.

Also, work is progressing towards the implementation of general contact models for robots in the TELEGRIP simulation language. Presently models for revolute joint robots have been investigated.

In regard to path planing, we have been working on PID and neural network based controller to close the loop for robot contact force trajectory planning applications. The control algorithm is under development with a statistical based approach. This algorithm will be used as a comparison to PID and Neural Network based algorithms. We have been making progress towards the first phase mathematical formulation of single-input-single-output and multiple-input-and-single-output model. Programs written in C were developed for preliminary testing. The hope is with the proposed algorithm, we will be able to use vision guidance and pressure sensor mechanism to control the robot contact trajectory within user predefined range.

5. Safety/Reliability Studies

A literature study regarding robot safety has been completed. A study regarding material flow and operations is in progress. The study covers the entire process of weapons transportation, disassembly, and storage. This study is shared with the automation initiative.

Real-time reliability models compatible with system self-assessment of survival (over a given mission) have been reviewed and are in the process of modification and extension. Current model technology allows for one physical input variable, and predicts conditional probability of survival relative to one output failure mode.

Research and development efforts continue on technology in combining evolutionary computation techniques and neural networks for the purpose of addressing multivariate process control in automated systems, as are likely to be encountered in hazardous waste materials handling.

6. Automation Studies

Concerning the realm of automation studies, this past quarter has been spent concentrating on material flow patterns through the Pantex facility, particularly in the storage end of the cycle. As a major step towards accomplishing this goal, a complete step-by-step analysis of storage and inventory operations has been completed, including a preliminary dose analysis. Continuing toward this goal, numerous dismantlement procedures, which are currently considered classified, are going through a declassification process and will be available as of May 6, 1996. We will then be able to develop a more complete model.

Additionally, dose information associated with those procedures will be available by the end of May, 1996. At that time further domain analysis can be performed within the Zone 4 weapons dismantlement area.

The results from this work will better help us to determine areas in which process automation is most appropriate.

Most Tangible Accomplishments

The most tangible result are:

1. The uni-directional telerobotic link between TAMU and TTU,
2. The working design for the user interface,
3. Functionality with purchased software,
4. Task-aware students,
5. Progress on all tasks, and
6. A working relationship with the DOE complex.

Programmatic Coordination with DOE

The DOE coordination has been within the areas of storage facility design and automation and robotics. The colleagues currently in cooperation are:

1. Sandia -- Larry Shipers
2. Los Alamos -- Warren Wood
3. Pantex -- Ken Franklin
4. DOE -- Robert Behrens

1.5.3.3 AIR MONITORING FOR DETECTING RELEASES OF PLUTONIUM IN A FUTURE INTEGRATED STORAGE FACILITY

Howard Liljestrand (PI), ANRCP/UTA
Richard L. Corsi, ANRCP/UTA
William H. Marlow, ANRCP/TAMU
Andrew R. McFarland, ANRCP/TAMU
P. K. Dasgupta, ANRCP/TTU
S. R. Liu, ANRCP/TTU

PROGRESS REPORT
(1 February 1996-30 April 1996)

see next page for subproject 4

Subproject 4

Plutonium Leak Detection by Conductivity Methods, and Optical Detection of Plutonium Aerosols

William H. Marlow, ANRCP/TAMU

PROGRESS REPORT
(1 February 1996-30 April 1996)

Research Activities

The sole activities of this project conducted this FY are investigations relating to the optical detection of plutonium aerosols. In this regard, a citation of work performed at Lawrence Livermore Laboratory indicated the fabrication of aerogels with pore sizes in the 30 micrometer range. The LLL lead was pursued and we were referred to 3M Corporation and to Sandia National Laboratory. From the 3M reference, we learned that they do not manufacture low density microcellular materials (LDMM) with appropriate characteristics for aerosol sampling for optical analysis of captured aerosols. Contacts at SNL proved more beneficial. Dr. Aubert of that lab discussed their work in the fabrication of polystyrene LDMM and at this time he is sending us samples with 10 micrometer pore sizes. One beneficial property of this material is the existence of an oil which matches the polystyrene index of refraction, thereby making the material appropriate for optical interrogation of deposited particles. A number of contacts were made regarding LDMM's but none other than the above proved useful.

Most Tangible Accomplishments

The identification of Dr. Aubert's group's work on LDMM fabrication and his agreement to forward samples for our utilization in this project will enable us to measure the performance of this material as a unique aerosol collection medium this summer.

Programmatic Coordination with DOE Laboratory Personnel

Dr. William Wilson of Sandia, Livermore manages the DOE/MD Fissile Materials Disposition Program under which materials storage safety issues are considered. He was apprised of the gas conductivity detection technique proposed here for development. On 4 April, Dr. Marlow spoke with Dr. Wilson who indicated that primary responsibility for storage surveillance rests with personnel at Los Alamos National Laboratory.

On 8 April 1996, Dr. Marlow contacted Mr. George Carlson of Los Alamos National Laboratory who is responsible for surveillance once materials are in storage, specifically with respect to the AT 400A system. Mr. Carlson expressed interest in the potential contributions to surveillance methodology offered by the proposed conductivity monitoring approach. Dr. Marlow agreed to communicate progress in the development of the conductivity monitoring method to Mr. Carlson as well as with Mr. Lloyd Montoya also of LANL. In addition to written and phoned contact, Dr. Marlow and his student conducting this research will periodically visit LANL to report their progress and focus their work toward the needs of the surveillance program. The support for Mr. Carlson's work is from DOE/Defense Programs, DOE-Albuquerque Operations Office where Mr. Ron Chevalier is Program Engineer for Pit Surveillance. Mr. Chevalier reports to Mr. Ralph Levine, Manager for Weapons Evaluation Program.

1.5.3.4 RADIATION DAMAGE AND MICROSTRUCTURAL CHANGES OF STAINLESS STEEL DUE TO LONG-TERM IRRADIATION BY ALPHA PARTICLES FROM PLUTONIUM

Ron R. Hart, ANRCP/TAMU (Co-PI)
Kenan Ünlü, ANRCP/UTA (Co-PI)

PROGRESS REPORT
(1 February 1996-30 April 1996)

Introduction

This ANRCP sponsored project is a study to determine the alpha-particle-induced radiation damage and microstructural changes of the stainless steel cover that encloses weapons grade Pu. An ion accelerator will be used to implant He-3 and He-4 up to levels that would be received by the stainless steel cover due to the alpha decay of weapons grade Pu during long term storage of Pu pits. Primary measurement techniques include Neutron Depth Profiling, Rutherford Backscattering and Channeling Analysis, Scanning Electron Microscopy, and Transmission Electron Microscopy.

Research Activities

During the period of 2/1/96 to 4/30/96 the following were accomplished.

1. Sample preparation equipment was delivered, setup and tested.
2. 316-Stainless Steel samples were cut; optimum sample polishing techniques were established; and initial samples were polished.
3. Mehmet Saglam, a graduate student working for this project, completed his training of electron microscopy measurements (SEM, TEM).
4. Using a surface implanted aluminum sample, preliminary NDP measurements were performed to prepare the facility for stainless steel sample measurements.
5. Dr. Hart and Dr. Ünlü participated at a meeting at TAMU on Feb. 7, 1996 with ANRCP personnel and OFMD and DOE personnel. Dr. Ünlü gave a brief presentation describing the UT Reactor Facility.
6. Dr. Ünlü gave a seminar entitled, "Neutron Beam Projects at the University of Texas Reactor", to the Mechanical Engineering Department at UT Austin on February 22, 1996. This ANRCP project was discussed during the presentation.
7. Dr. Ünlü and Mehmet Saglam visited Dr. Hart and his students at the Ion Accelerator Laboratory at Texas A&M University on March 20-21, 1996.
8. Dr. Hart and Dr. Ünlü presented an overview of the project and a progress report at the Nuclear Group Second Quarterly Meeting at Amarillo on March 30, 1996.
9. Dr. Hart and Dr. Ünlü participated in a meeting with ANRCP participants and ORNL personnel at Oak Ridge, TN on April 17, 1996.

10. In preparation for Rutherford backscattering analysis it was found that a Canberra multichannel analyzer card had failed. The card was repaired and then successfully tested.

11. Rutherford backscattering analysis was begun using a test implant of 100 keV Ze into Si. The measurement beam was 150 keV He. Although the measurement was successful, some electronic problems were found and will be corrected during the next quarter.

Most Tangible Accomplishments

The most tangible accomplishments of the project during this report period were:

- Initial 316 stainless steel samples have been polished
- Preliminary NDP measurements have been performed
- Preliminary Rutherford backscattering analysis has been performed.

Other accomplishments related to the project were to participate in a number of meetings with ANRCP, DOE, LANL, and ORNL personnel.

Nuclear Analytical Techniques with Neutron Beams at The University of Texas at Austin

Kenan Ünlü and Bernard W. Wehring

The University of Texas at Austin

Neutron beams produced by nuclear research reactors can be used for analytical chemical analysis by measuring nuclear radiation produced by neutron capture. Prompt Gamma Activation Analysis (PGAA) and Neutron Depth Profiling (NDP) are two such analytical techniques. During the last three decades, these techniques have been applied at a number of research reactors around the world. Within the last four years, we have developed NDP[1-2] and PGAA[3-5] facilities at The University of Texas at Austin research reactor, a 1-MW TRIGA Mark II reactor. See Fig. 1. Brief descriptions of the facilities and summaries of activities for these analytical techniques at The University of Texas at Austin will be discussed in this paper.

The tangential beam port of the reactor is used for Neutron Depth Profiling at the University of Texas (UT). The UT-NDP facility consists of a neutron collimator assembly, a 40.6 cm diameter aluminum target chamber with thin aluminum windows, a paraffin, boric acid, and lead loaded beam catcher, and standard data acquisition and process electronics. A detailed description of the UT-NDP facility can be found in references 1, 2. The UT-NDP facility has been utilized for the determination of boron-10 depth profiles in various semiconductor materials and helium-3 depth profiles in metals and alloys. Semiconductor wafers obtained from Intel Corporation, Santa Clara, and Sematech, Austin, have been analyzed for boron-10 depth concentrations. A full energy spectrum of particles emitted by the ^{10}B reaction for a borophosphosilicate glass (BPSG) sample is given in Fig. 2. The glass thickness, the homogeneity of boron concentration, and the boron dose can be obtained from the information presented in Fig. 1.

Currently two studies are underway at the UT-NDP. Boron doses in semiconductor materials from various vendors are being measured in collaboration with scientist from Advanced Micro Devices, Austin. The results will be used to complement the measurements done with other techniques. Also, an independent analysis will be performed to form a basis for accurate dose calibration of commercial ion implant systems. Another study, which we are currently pursuing, is the determination of radiation damage and microstructural changes in stainless steel samples by helium irradiation using NDP and Transmission Electron Microscope (TEM) measurements. The goal of this study is to determine long-term effects of high-dose alpha particle irradiation to the stainless steel cover of weapon grade Pu pits during storage. This study is sponsored by the Amarillo National Resource Center for Plutonium.

A cold neutron beam obtained from the Texas Cold Neutron Source (TCNS)[3,4,6] is used for PGAA. The TCNS facility, which is unique, consists of a mesitylene moderator cooled to ~ 30 K by a neon thermosyphon and a 6-m long curved neutron guide.[7] Cold neutrons, coming from the cooled moderator, are transported down the curved neutron guide which is coated with ^{58}Ni and has a 300 m radius of curvature. Guided cold neutrons are focused by a converging guide focusing system which was designed at the UT.[7] The converging guide consists of four rectangular truncated cone sections whose inside walls are coated with NiC-Ti supermirrors. Samples for the UT-PGAA are located at the focal point of the converging guide focusing system which is 24 cm from the converging guide exit. The UT-PGAA facility components are a sample handling system, high purity germanium gamma-ray detector, detector shielding, and standard data acquisition and processing systems. Detailed descriptions of UT-PGAA facility can be found in references 3-5.

The UT-PGAA system components were tested and preliminary measurements of samples containing boron were performed. The thermal-equivalent neutron flux at the sample point was determined to be 4 x 10^7 n/cm^2 sec at full reactor power. However, the cold-neutron focused beam was not as uniform at the focal area as expected. We are currently adjusting the alignment of the curved guide and converging guide focusing system in order to improve the neutron flux uniformity at the focal point of the converging guide. Two studies are planned using the UT-PGAA system. They are nondestructive determination of trace amounts of gadolinium in biological materials and the measurement of hydrogen content in semiconductor materials.

Nuclear analytical techniques with neutron beams (both PGAA and NDP) have unique capabilities which provide solutions to a wide variety of analytical problems in science and technology.

REFERENCES

1. K. ÜNLÜ and B. W. WEHRING "Neutron Depth Profiling at the University of Texas," *Nucl. Instr. and Meth. in Phys. Res.* **A 353** 402 (1994).

2. K. ÜNLÜ and B. W. WEHRING, "Applications for the University of Texas Neutron Depth Profiling Facility," *Trans. Am. Nucl. Soc.*, **71**, 163, (1994).

3. C. RIOS-MARTINEZ, Ph. D. Dissertation, "Prompt Gamma Activation Analysis using the Texas Cold Neutron Source," The University of Texas at Austin, (1995).

4. K. ÜNLÜ, C. RIOS-MARTINEZ, and B. W. WEHRING, "Prompt Gamma Activation Analysis with Texas Cold Neutron Source," *J. of Radioanal. Nucl. Chem., Articles*, **193**, No.1, 145 (1995).

5. B. W. WEHRING, C. RIOS-MARTINEZ, and K. ÜNLÜ, "Cold-Neutron Prompt Gamma Activation Analysis Facility at the University of Texas at Austin," *Trans. Am. Nucl. Soc.* **72**, 112 (1995).

6. K. ÜNLÜ, C. RIOS-MARTINEZ, and B. W. WEHRING, "The University of Texas Cold Neutron Source," *Nucl. Instr. and Meth. in Phys. Res.* A **353** 397 (1994).

7. B. W. WEHRING, J. Y. KIM, and K. ÜNLÜ, "Neutron Focusing System for the Texas Cold Neutron Source," *Nucl. Instr. and Meth. in Phys. Res.* A 353 137 (1994).

FIGURE CAPTION

Fig. 1. Photograph of the NDP facility (lower) and PGAA facility (upper) at the University of Texas research reactor.

Fig. 2. UT-NDP measurement of the energy spectrum of particle emitted by the ^{10}B reaction for a 780 nm thick borophosphosilicate glass film on a silicon wafer. Alpha-0 and Lithium-0 are alpha and lithium particles emitted when Li is formed in the ground state, Alpha-1 and Lithium-1, when Li is formed in an exited state.

Fig. 1.

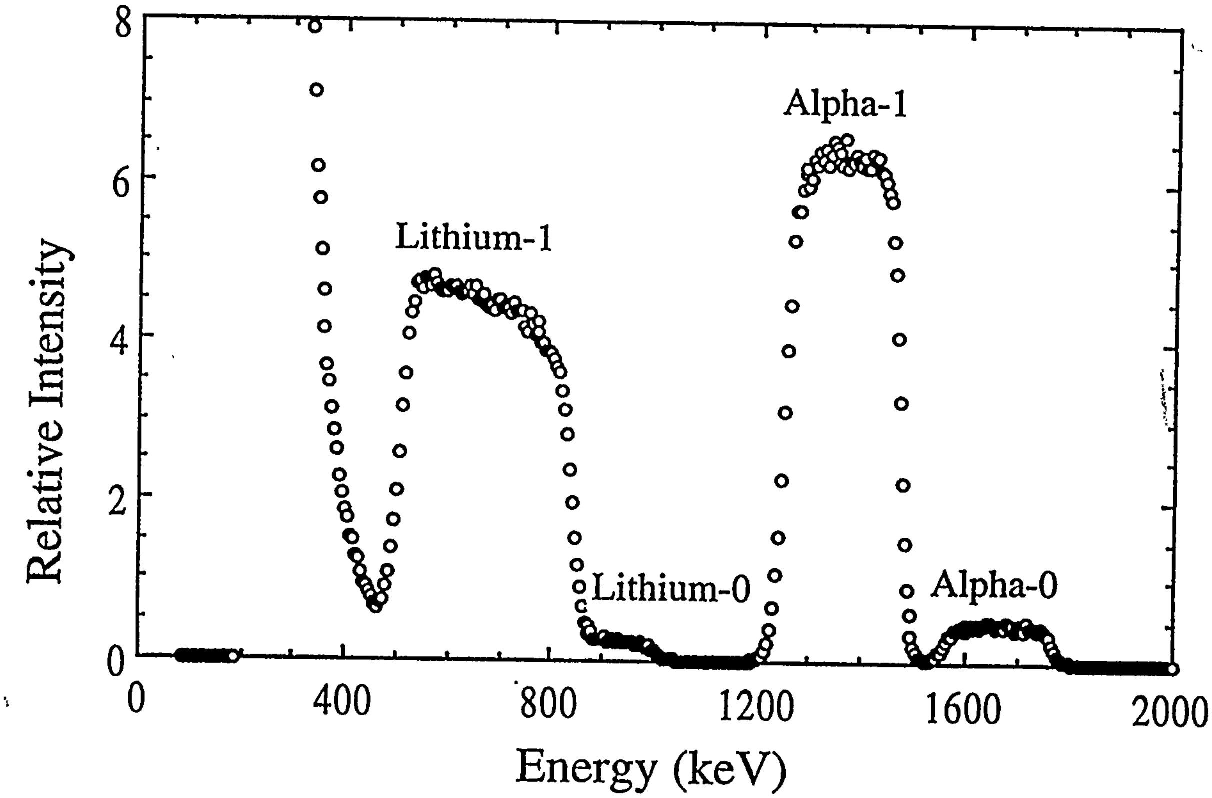
Relative Intensity
Energy (keV)
Lithium-1
Lithium-0
Alpha-1
Alpha-0
0
2
4
6
8
0
400
800
1200
1600
2000

Fig. 2.

1.5.4 Plutonium Disposition

1.5.4.1 WATER REACTOR OPTIONS FOR DISPOSITION OF WEAPONS-GRADE PLUTONIUM

N. M. Abdurrahman, ANRCP/UT (Co-PI)
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F. R. Best, ANRCP/TAMU
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Y. A. Hassan, ANRCP/TAMU
T. A. Parish, ANRCP/TAMU
W. W. Pitt, ANRCP/TAMU
J. A. Rennie, ANRCP/TAMU
D. M. Roundhill, ANRCP/TTU
K. Ünlü, ANRCP/UT

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Research Activities

1. MOX Data Repository

A dedicated web server has been established for MOXDAR. The temporary URL is http://nalab1.me.utexas.edu. The URL will be changed to http://www.mox.utexas.edu. The server combines Nestscape 2.0 Server, IBM Database2 (DB2) and the IBM database-internet interface DB2WWW.

We have order a high capacity (black & white) scanner with document feeder and Adobe Acrobat Capture software which will be used to scan, process, index, and place documents on MOXDAR.

A preliminary database model has been completed and implemented. The database has been modeled as a relational database with a simple user interface. The tables of the database exhibit sufficient structural and data independence to allow ease of management and enhancement.

We continued our effort to gather data and documents on MOX fuel primarily from domestic sources. We are still trying to get some data from foreign sources, especially the Belgian and the French. Drs. Lee Peddicord and Dale Klein are helping us with contacting the Belgian and the French, respectively. A University of Texas student will be going to Belgium and Germany this summer to identify and explore potential data sources, and in the process collect some documents.

2. Design of Within-assembly Enrichment Distributions

A student (Abdelhalim Alsaed, Texas A&M Nuclear Engineering) spent approximately six weeks in Monroeville using Westinghouse codes to finalize his design of MOX assemblies for use in transition cores. The assembly design is of course coupled to the loading patterns, so Mr. Alsaed became involved in designing the 1st transition cycle. Westinghouse was pleased with his work, and as a result he took on more responsibilities in the design of the second and third transition cycles, which were essentially complete by the end of his stay. Mr. Alsaed is now documenting his work (in the form of a M.S. thesis).

ABB-CE has reaffirmed its desire for us to fulfill the same function with them. We are working toward a meeting to finalize the details.

3. Sol-gel Processes for MOX Fabrication

In previous quarter the survey of sol-gel processes was completed. In this quarter our results were presented at an AIChE meeting. We are attaching the paper.

4. Design of Transition-Cycle Loading Patterns

The reactor vendors have been tasked with designing transition fuel cycles to go from full-U to partial- or full-MOX cores, with the restriction that no integral burnable absorbers be used. Westinghouse and ABB-CE expressed great interest in a collaborative effort in which ANRCP would design transition cycles with integral burnable absorbers present. This would show what might be gained (in Pu through put or in economics) by using such absorbers. In this quarter, we laid much of the groundwork needed to perform this task:

- Obtained verbal commitments from Westinghouse and ABB-CE to provide consulting-type assistance to us at no cost to ANRCP or DOE;
- Obtained consensus among ORNL researchers (Don Spellman, Trent Primm) and MD staff (Pat Rhoads) that the project has value to the program; and
- Identified student to do the work.

Also, see (2) above for a description of ANRCP assistance in the design of transition cores with no integral absorbers.

5. Design of Multipurpose Reactor

Maintained contact with ABB-CE, who affirm their continued interest in this task. ABB-CE is no longer certain that Palo Verde is the appropriate starting point; they are thinking this over, and they may conclude that a new System 80+ reactor is the more likely tritium producer. Either way, they have agreed to collaborate with us at no cost to us or to DOE.

We also identified contacts at Pacific Northwest Lab, where the design of tritium targets is underway. We have a student, Chris Gesh, who is a former employee of PNL and who, in fact, was involved with tritium target design during his tenure at the lab. He is proving to be a valuable resource as far as making contacts is concerned.

We remark that with the recent decision that will cause a portion of ANRCP's funding to come from Defense Programs, this project could take on added importance.

6. Study of VVER Utilization of MOX Fuel

We have held discussions with European reactor analysts who are familiar with VVERs, and we have obtained some plant-simulation input files from them. We have held discussions with ORNL researchers to determine the scope of the needed work. It appears that it may be appropriate for ANRCP to focus its efforts on transient analysis; this should become clearer during the next quarter, with increased clarification of the US-Russian joint study proposals.

We have also participated in the creation of the US-Russian joint study proposals, by providing input to Bruce Bevard and David Moses of ORNL.

7. Characterization of Spent MOX Fuel

We have selected SCALE 4.3 as the principal tool for performing fuel depletion and spent fuel characterization. The code has been installed and tested with sample depletion problems. Part of the design and operating data for BWRs (GE) have been obtained. We have been trying to get W and CE PDS reports for similar PWR data but had no success yet. One graduate student is working on this task.

8. Evaluation of Analysis Tools

We have selected two critical experiments programs that were carried out in the US in the sixties that involved mixed-oxide fuels. These were performed at the Westinghouse Rector Evaluation Center (WREC) in 1965 and 1967.

The first WREC experimental program (1965), also known as Saxton critical experiments, consisted of critical experiments with water moderated single-region and multi-region MOX fueled cores. They were carried out in support of the Saxton Plutonium Program. The purpose was to verify the nuclear design of the Saxton partial plutonium core. Measurements included buckling, power distribution, reactivity, control rod worth, soluble poison, and power peaking.

The second WREC program (1967) consisted of a series of critical experiments using two plutonium fuels with a variation in the Pu-240 isotopic content and one low enrichment uranium fuel and included buckling, reactivity, and power distribution measurements.

We have started performing MCNP benchmark calculations using the Saxton experiments. One of the single-region core (19 x 19 PuO2-UO2 with 6.6 w/o PuO2) experiments has been modeled in detail and the preliminary results of k-effective calculations show good agreement with measurements. We intend to continue this effort with other calculations and for the various lattices and configurations for both experiments.

Other tools will be considered for similar evaluations. We have proposed to Westinghouse to benchmark their production codes. They expressed interest in our proposal if we are able to get some of the European critical experiments such as the Belgium VIP and the French EPICURE. We are trying to get data from these two experimental programs.

9. MOX Fuel Demonstration

Held extensive discussions with ORNL, MD, and LANL staff to try to determine the goals of the MOX fuel demo. The goals shift significantly and often. Nevertheless, we have obtained a planning grant from ANRCP to design what we believe is the best test we can do for the program. We have begun our design effort, which will determine the details of a multi-capsule test that could be started in the Texas A&M TRIGA as early as this fall. Preliminary calculations have shown that temperature and heat-flux constraints on the fuel, cladding, and pool water can be satisfied simultaneously.

In addition, we have been asked by ORNL to determine the feasibility (cost & schedule) of building a pressurized water loop in the Texas A&M TRIGA facility. We are doing this, but at a lower level of effort than the capsule design. We have contacted other research reactors that have high-pressure loops, and we will likely conduct a site visit to determine in detail what would be required to install one at Texas A&M.

10. Exploration of Gallium Removal

Developed solid ties and coordination with LANL, the lead lab on MOX fuel fabrication. Brought Max Roundhill of Texas Tech, who has experience with gallium chemistry, on board. Work on this task will begin in earnest this summer, as it is not really funded until then.

Most Tangible Accomplishments

We played a significant role in the Westinghouse design of a MOX fuel assembly for use in transition-cycle cores, and in the design of the transition-cycle loading patterns. We expect to co-author a paper with Westinghouse documenting the non-proprietary portions of this work.

We also made further progress toward recognition as a key player in the water-reactor disposition program, and toward tight coordination with the many entities involved (DOE/OFMD, ORNL, LANL, Westinghouse, GE, ABB-CE, AECL). Through our efforts and the efforts of OFMD and ORNL (mainly Pat Rhoads, Sherrell Greene, Trent Primm, and Don Spellman), we have now established a sort of management structure that provides us technical guidance and helps ensure that our efforts are coordinated with the rest of the program. In this structure, our primary point of contact is Don Spellman of ORNL, who also has the responsibility of coordinating the efforts of the fuel vendors. To kick this off, several professors from ANRCP (Naeem Abdurrahman and Kenan Ünlu from University of Texas; Marvin Adams, Fred Best, Ron Hart, Yassin Hassan, Ted Parish, and Dan Reece from Texas A&M) met with ORNL staff in April. We now stay in close contact with Don Spellman and others (such as Trent Primm and Bruce Bevard) at ORNL.

IMMOBILIZATION STUDIES:

IMMOBILIZATION OF PLUTONIUM IN CERAMIC MATERIALS

A. Clearfield (PI), ANRCP/TAMU
Anatoly Bortun, ANRCP/TAMU
Lyudmila Bortun, ANRCP/TAMU
Roy Cahill, ANRCP/TAMU
Rick Carroll, ANRCP/TAMU

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Research Activities

In this quarter, the substitution of CeO_2 into the framework of $CaTiO_3$ was examined using solid state synthesis techniques. Studies were also conducted on producing zirconolite samples of a higher crystallinity than those reported previously. (More crystalline samples are essential to enable use of Reitveld analysis.)

Experimental Work

TiO_2(anatase), $CaCO_3$ and CeO_2 were ground together in an agate mortar and pestle in the ratios shown in Table 1. These samples were then placed in a Pt crucible and heat treated at 1000 °C in a muffle furnace for 24 h. The samples were then removed and allowed to cool in a desiccator to room temperature. X-ray powder diffraction (XRD) methods were then conducted to determine phase purity. The titanate materials were then reground and subjected to a second heat treatment.

Table 1. Synthesis compositions and idealized formulae for the cerium substituted $CaTiO_3$.

Sample	Ca:Ti:Ce mole ratio	mole % Ce	Idealized Formula ($CaTiO_3$)
Ce -Per-1	1:0.95:0.05	5%	$CaTi_{0.95}Ce_{0.05}O_3$
Ce-Per-2	1:0.90:0.10	10%	$CaTi_{0.90}Ce_{0.10}O_3$
Ce-Per-3	1:0.85:0.15	15%	$CaTi_{0.85}Ce_{0.15}O_3$
Ce-Per-4	1:0.99:0.01	1%	$CaTi_{0.99}Ce_{0.01}O_3$
Ce-Per-5	1:0.98:0.02	2%	$CaTi_{0.98}Ce_{0.02}O_3$

Attempts at further crystallization of zirconolite samples were conducted by grinding samples L1 and L2 from the previous report in an agate mortar and pestle and subsequent heat treatment in a 1100 °C furnace for a period of 34 h. After which, the samples were removed and allowed to cool to room temperature in a desiccator. X-ray diffraction data was then collected.

Results

It is apparent upon examination of the XRD patterns for the calcium titanates that less than 1 mole percent of Ce dissolved in the $CaTiO_3$ perovskite phase using solid state synthesis techniques. Samples which underwent a second grinding and heating procedure showed no significant change. The probable reason for this low amount of substitution is the difference in ionic radii of Ce^{4+} and Ti^{4+}, 1.01 Å versus 0.68 Å, respectively. The size of the counter ion, in this case Ca^{2+}, may also play a role in the substitution of Ce for Ti. The second reason will be investigated but using sol-gel techniques for mixing the reagents in place of solid state techniques.

For the zirconolite materials, it was found that further crystallization can be achieved by additional heat treatments. This increased crystallinity can be done without the advent of additional phases forming. Comparison of crystallinities can be done by examining the width of the peak at half height (FWHM). Figure 1 shows the XRD patterns of L2 and L2 after annealing at 1100 °C. All the peaks in the annealed samples possessed smaller FWHM's over that of the original compounds. Attempts at indexing the new patterns are currently being made.

Programmatic Coordination with DOE or Doe Laboratory Personnel

Leonard Gray is the co-chair of the joint U.S. - Russia Plutonium Immobilization Program (the principle investigator is a member of this committee) and Coordinator of the Fissile Material Disposition Program at Lawrence Livermore National Laboratory (LLNL). During the last report period, I visited Leonard Gray and informed him of our program and progress. Subsequently, I suggested a collaborative program on immobilization of Pu either in ceramic or glassy materials. Dr. Gray is considering this offer of how best to effect a collaboration. In the meantime, he has made available to me the latest reports from the National Laboratories and particularly "Immobilization of Surplus Fissile Material with Electrometallurgical Treatment of Spent Fuels", Lawrence Livermore National Laboratory, Livermore, CA, Feb. 9, 1996 and the predecisional Draft of the Joint U.S./Russian Plutonium Disposition Study, Westinghouse Savannah River Co., March 20, 1996.

Immobilization of Plutonium in Ceramic Materials

Quarterly Report

by

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Introduction

Synroc is a ceramic made from a mixture of Al_2O_3, BaO, CaO, TiO_2 and ZrO_2. This mixture when fired at 1200-1300°C produces several phases, chief among them is zirconolite of formula $CaZrTi_2O_7$. Other phases detected include perovskite $CaTiO_3$. Other phases detected include perovskite $CaTiO_3$, Hollandite, $BaTi_6O_{16}$ containing excess Al and TiO_{2-x}. Our strategy is to investigate the characteristics of the individual phases in order to be able to determine with certainty the amount of Pu and Gd incorporation and the stability of the individual phases. A secondary objective is to see if Cs^+ and Sr^{2+} can also be incorporated into the ceramic phases to act as a radiation shield to prevent recovery of Pu from these phases.

Experimental

The first phase to be prepared is zirconolite, $CaZrTi_2O_7$. Zirconolite $CaZrTi_2O_7$ is regarded as one of the most promising materials for Pu immobilization. This is connected with its ability to entrap plutonium with a formation of extremely chemically and thermally stable ceramic, which satisfies the stringent storage requirements.

Traditional methods of zirconolite preparation include the reaction between finely dispersed metal oxides, taken in equimolar ratio, at elevated temperature (1300-1400°C) for a certain period of time. In this case the yield of product and the extent of its crystallinity is greatly dependent on the use of carefully sized powders and their proper mixing, which is a drawback of the method. In our opinion this disadvantage could be overcome considerably by using a different approach for $CaZrTi_2O_7$ synthesis, namely, preparation by sol-gel methods. It is known that gel methods allows preparation of highly homogeneous and reactive mixtures of different hydrous oxides, including those of titanium and zirconium. Taking this into consideration, we studied the following reaction system:

$$TiCl_4 - ZrOCl_2 - CaCl_2 - (CH_2)_6N_4 - (NH_2)_2CO.$$

In all cases the metal salts were taken in the molar ratio 2:1:1, respectively. $(CH_2)_6N_4$ and $(NH_2)_2CO$ were taken in amounts sufficient for the partial neutralization of the reaction mixture.

The typical procedure of synthesis was the following:

To a mixture of 20 ml of 2 M $ZrOCl_2{\cdot}8H_2O$, 20 ml of 2 M $CaCl_2$ and 40 ml of 2 M $TiCl_4$ mixed in a 200 ml beaker a solution of 40 ml of 3 M $(CH_2)_6N_4$ and $(NH_2)_2CO$ (in 2:1 ratio) was added slowly under constant stirring. In acid media $(CH_2)_6N_4$ and $(NH_2)_2CO$ undergo decomposition according to schemes:

$$(CH_2)_6N_4 + H_2O \dashrightarrow CH_2O + NH_3;$$

$$(NH_2)_2CO + H_2O \dashrightarrow CO_2 + NH_3,$$

with the release of free NH_3 into the reaction system. This base serves as a mild neutralizing agent leading to polyvalent metal hydroxide polymerization with the formation of a homogeneous glass-like gel. The gel formation is accelerated considerably with increase of the temperature (it takes only 20-60 s at 80-90°C instead of 20-120 min at 25°C), but in this case non-transparent gels are formed. After the gel was formed it was dried at 90-100°C for 2 h and then put into the oven (800-1200°C) without preliminary grinding for 3-4 h. The final products were white powders which were studied without any additional treatment. Ten different batches were prepared under the conditions shown in Table I. X-ray powder patterns of the products were recorded to determine phase composition.

Results

Two types of X-ray patterns were obtained. The gels heated to 800°C gave X-ray patterns as shown in Figure 1, no CeO_2 added, and Figure 2 containing 0.2 M of CeO_2. The remaining X-ray patterns were obtained after heating the gel samples to 1000°C. The X-ray patterns for the ten samples listed in Table I are shown in figures 3 and 4. These latter X-ray patterns are more complex and all the peaks can be accounted for by the zirconolite structure together with the presence of a small amount of the calcium titanate perovskite phase, $CaTiO_3$ (peak at 2.71 Å). In Table l the Ti/Zr ratio in the reactant mix varied from 2.1 to 1.9 for the pure zirconolite samples. However, the X-ray patterns were practically the same (Figure 3, samples L1-L5). This result is in accord with published data[1] for zirconolite that shows the limits of solid solution vary from

Ti/Zr of 1.31 to 2.55. At the lower temperature a simpler pattern is obtained that may indicate a precursor cubic phase that converts to the monoclinic zirconolite at higher temperature.

The results obtained upon addition of CeO_2 is ratios of 0.1 CeO_2/Zr to 0.7 are shown by the X-ray patterns L6 to L10 (Figure 4). As the amount of CeO_2 added is increased we note a peak at d = 3.11 Å appears in pattern L7 (0.2 M CeO_2) and increases steadily in intensity as more CeO_2 is added. Also a peak at d = 1.626 Å appears in the L8 X-ray pattern and increases in L9 and L10. These two peaks are characteristic of CeO_2 and indicate that saturation is achieved between CeO_2 additions of 0.1 to 0.2 moles per mole of zirconolite in the case that the Ti/Zr ratio is 2. However, these samples need to be reheated to 1200°C for 10-20 h before the correct solid solution limit is obtained i.e., the samples need to reach their equilibrium stoichiometries.

In the next quarter we shall carry out the additional heating and prepare a new batch of samples in which the CeO_2 content is varied between 0.1 and 0.2 mole additions to narrow down the solid solution limit. Also, additional runs will be made in which new ratios of titanium to zirconium are explored.

Conclusions

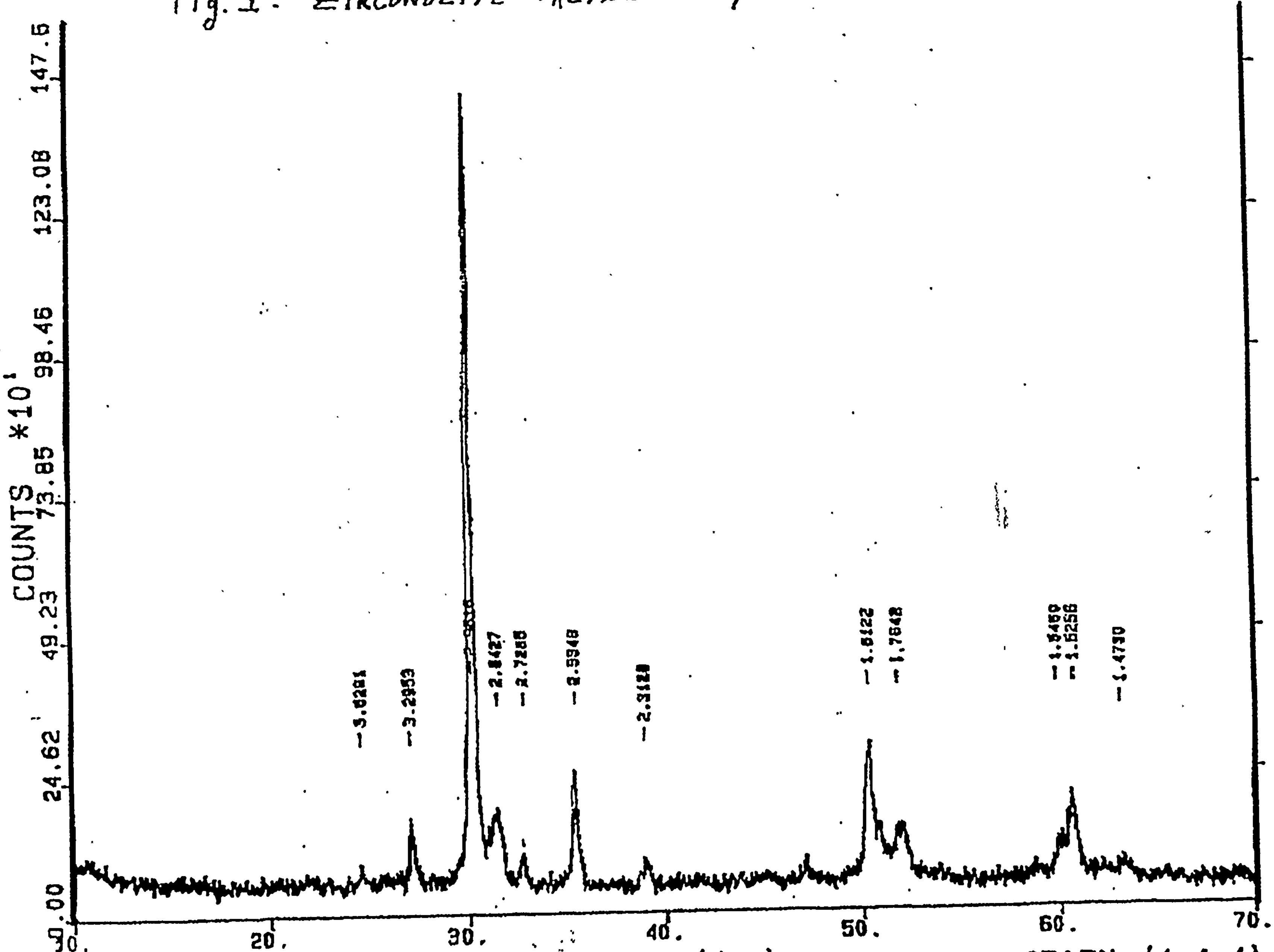
The proposed method of zirconolite synthesis by sol-gel method proved to be valid. Such an approach gives not only the possibility to decrease considerably the temperature of its preparation (from 1300-1400°C to ~1100°C), but, theoretically, even the exclusion of the stage of PuO_2 separation from the technological solution. This is connected with the possibility of adding all the necessary ingredients for zirconolite gel formation into the plutonium containing solution, its gelation and thermal treatment leading to Pu immobilization in the $CaZrTi_2O_7$ ceramic.

Table 1. Experimental Conditions Utilized for Formation of Zirconolite and Ce^{4+} Doped Zirconolite (in ml).

Sample	$TiCl_4$, 2M	$ZrOCl_2$, 1M	$Ca(NO_3)_2$, 1M	$(CH_2)_6N_4$, 2M	$(NH_2)_2CO$, 1M	$Ce(NO_3)_3$, 1M
L1	5.0	5.0	5.0	7.5	5.0	-
L2	5.25	5.0	5.0	7.5	5.0	-
L3	4.75	5.0	5.0	7.5	5.0	-
L4	5.0	5.25	5.0	7.5	5.0	-
L5	5.0	4.75	5.0	7.5	5.0	-
L6	5.0	5.0	5.0	7.5	5.0	0.5
L7	5.0	5.0	5.0	7.5	5.0	1.0
L8	5.0	5.0	5.0	7.5	5.0	1.5
L9	5.0	5.0	5.0	7.5	5.0	2.5
L10	5.0	5.0	5.0	7.5	5.0	3.5

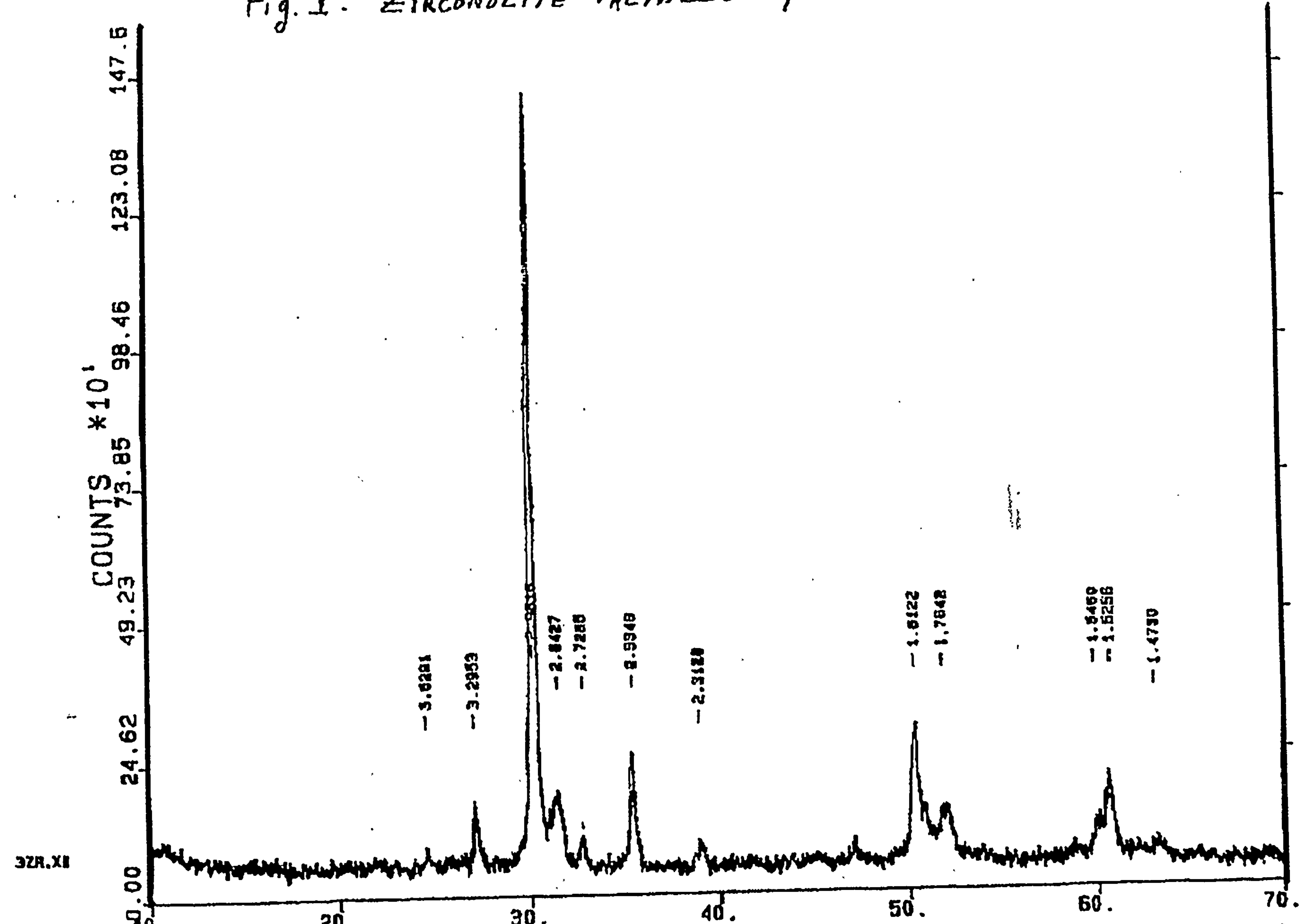
The reagents used were mixed in amounts shown in Table and after that the reaction mixture obtained was heated for 5-10 min at 90°C in order to form homogeneous oxides gel. All the gels were dried in oven at 70-80°C before their thermal treatment at 1000°C (10 h).

Fig. 1. Zirconolite Prepared By Sol-Gel Method at 800°C



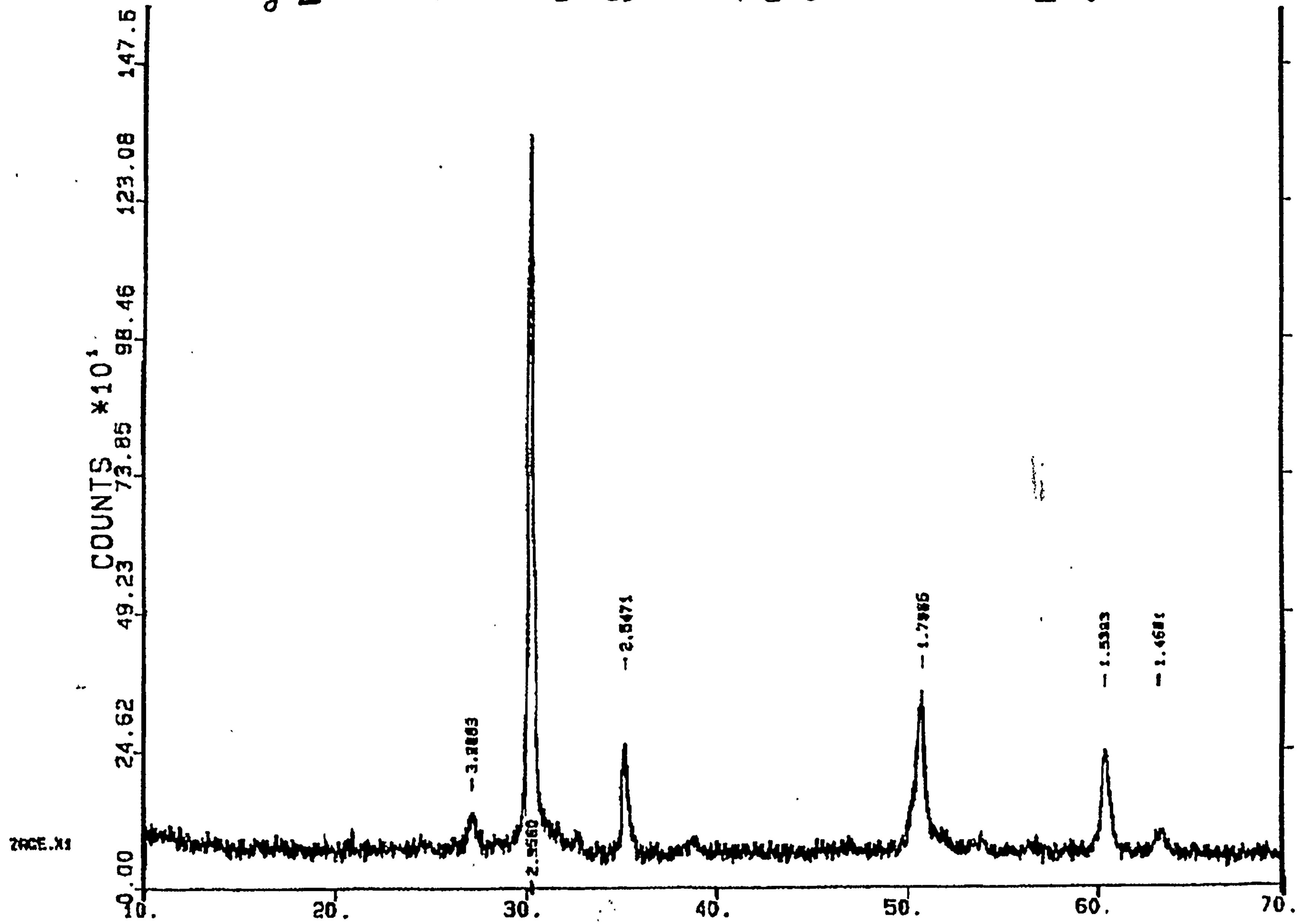
Cu K-abar
ZR3
Date: 18-OCT-85 10:25:14 Start: 10.00 stop: 70.00 step: 0.040 time: 1.20
Plot of 2-theta versus X-ray intensity

Fig. 1. Zirconolite Prepared By Sol-Gel Method at 800°C



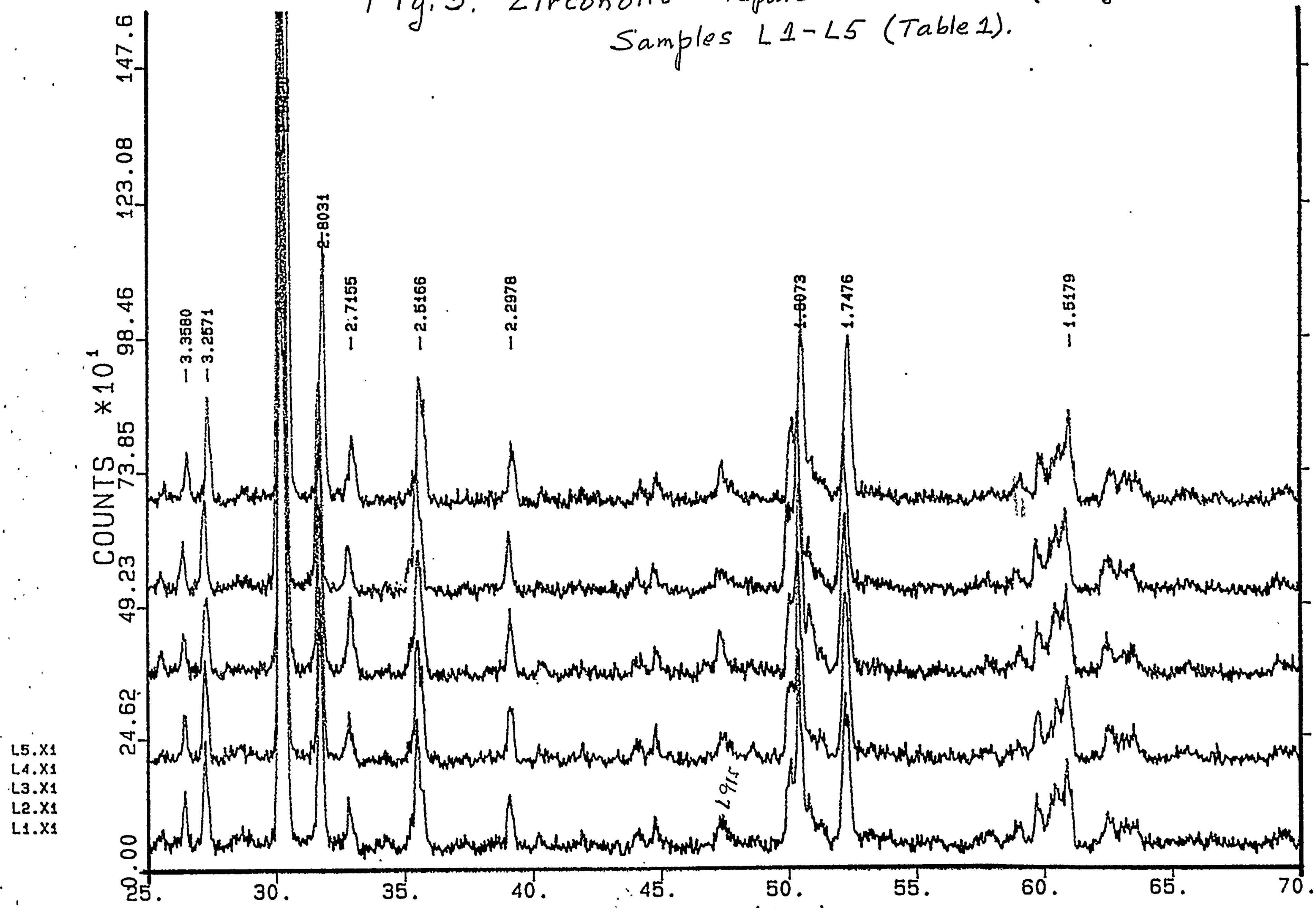
Cu K-abar
ZA3
Date: 18-OCT-85 10:25:14 Start: 10.00 stop: 70.00 step: 0.040 time: 1.20
Plot of 2-theta versus X-ray intensity

Fig. 2. ZIRCONOLITE CONTAINING 0.2 MOLES CeO_2 (800°C)



Cu K-abar
ZR4, +CE, 800 C
Date: 18-OCT-95 11:23:58 Start: 10.00 stop: 70.00 step: 0.040 time: 1.20
Plot of 2-theta versus X-ray intensity

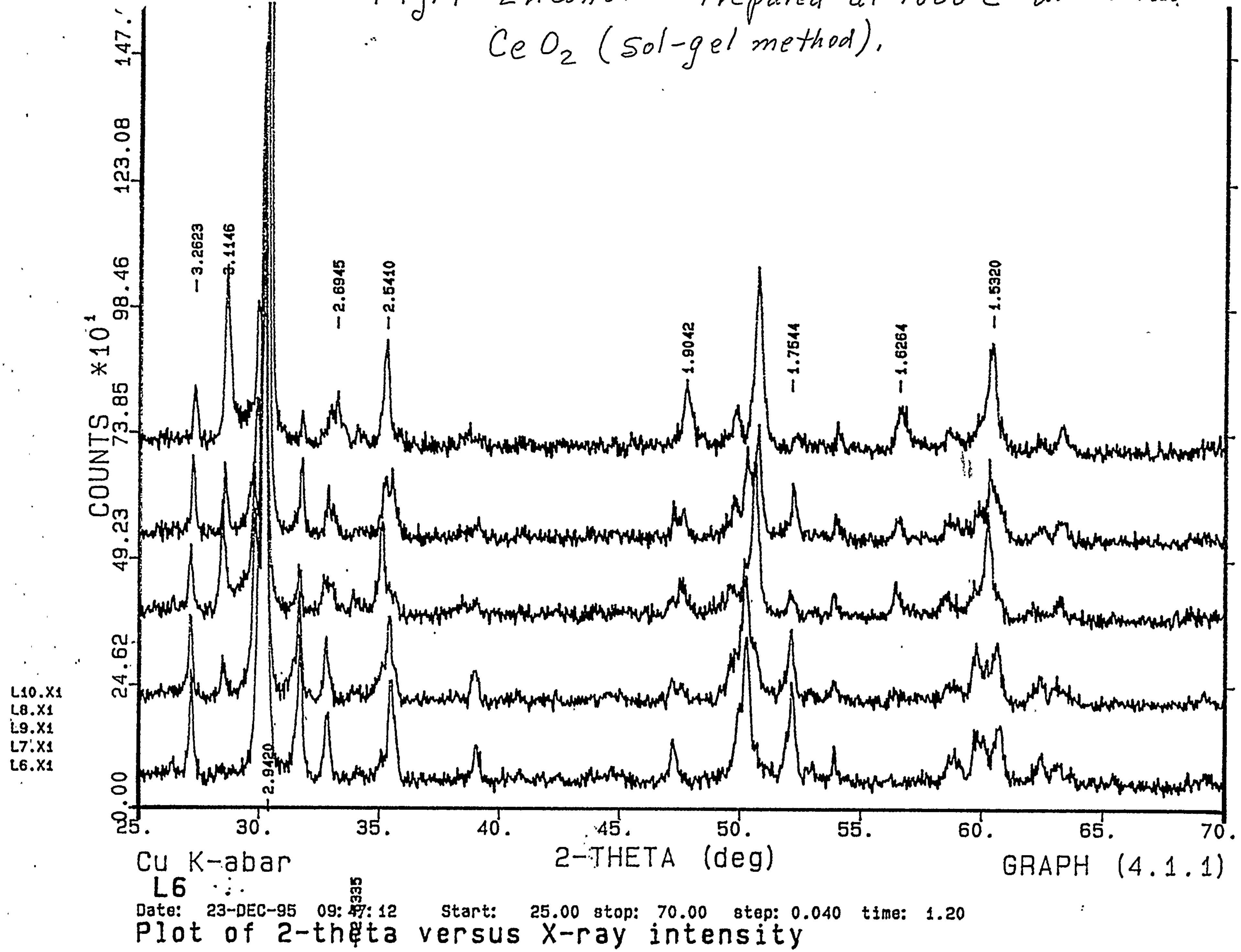
Fig. 3. Zirconolit prepared at 1000°C (Sol-gel method
Samples L1-L5 (Table 1).



GRAPH (4.1.1)

Cu K-abar
L1-L5
Date: 23-DEC-95 09:55:17 Start: 25.00 stop: 70.00 step: 0.040 time: 1.20
Plot of 2-theta versus X-ray intensity

Fig. 4 Zirconoli Prepared at 1000°C with adde[illegible] CeO_2 (sol-gel method).



1.5.4.3 IMMOBILIZATION STUDIES:

GEOLOGIC DISPOSAL OF IMMOBILIZED PLUTONIUM IN VERY DEEP BOREHOLES

M. Sharma (PI), ANRCP/UTA

R. T. Johns, ANRCP/UTA

PROGRESS REPORT (1 February 1996-30 April 1996)

Research Activities

The progress made in the period Feb 1996 to April 1996 is summarized below.

1. The experimental apparatus we have built to measure diffusion rates of plutonium surrogates in bentonitic type materials was used to measure the diffusion rate of tritium and chloride 36 in a bentonitic shale at a confining pressure of 5000 psi. The flux of the ions was monitored bymeasuring the effluent concentration of tritium as a fixed concentration of tritium was circulated across one end. Because of the low rates of diffusion the effluent has to monitored for several days to weeks to obtain reliable and consistent results. These results indicate that the transport of ions is significantly retarded. This hydrodynamic retardation of tritium indicates that in microporous rocks such as shales and granites the pore size is small enough to reduce the diffusion rates of ions by several orders of magnitude. The experiments are being repeated for smaller confining stresses to check the influence of microcracks on ion transport.

2. I am currently reviewing a report we have completed on colloid mediated radionuclide transport in the geosphere.

3. We have recruited Dr. Suhas Bodwadkar as a Post Doctoral Fellow to conduct research on geochemical modeling for plutonium transport. He will begin work on the project on June 1 1996.

1.5.4.7 THERMAL AND MECHANICAL ANALYSIS OF THE CAN-IN-CANISTER OPTION

Kenneth S. Ball (Co-PI), ANRCP/UT
Edward E. Anderson (Co-PI), ANRCP/TTU
Theodore L. Bergman, ANRCP/UT
Eric M. Taleff, ANRCP/UT
Jaime F. Cardenas-Garcia, ANRCP/TTU
Javed Hashemi, ANRCP/TTU

PROGRESS REPORT
(1 February 1996-30 April 1996)

Research Activities

Past efforts have been:

1. developing global models for the thermal response of the glass jet,
2. building low temperature experiments so that void formation can be observed,
3. developing a detailed model to predict void formation, and
4. developing high temperature experiments so that actual glass pours can be made. Progress to date in each category will now be briefly summarized.

1. Global Models

Global models have been developed so that the temperature of the glass jet, upon impacting the canister or cooler molten glass pool, can be estimated. The "landing temperature" determines the viscosity of the molten glass upon impact, which varies by about several orders of magnitude over the temperature range of the glass pour (1050 °C to 750 °C). Viscosity is an important parameter leading to void formation because (as will be shown) the low temperature experiments have revealed sensitivity of void formation to viscosity.

Figure 1 is a schematic of the global model. The model (which is a very preliminary one) considers radiative and convective cooling of the glass jet, along with the thermal capacitance of the metal canister and melt pool. Radiative and convective cooling of the canister to the surroundings is included. The molten glass temperature and canister temperature are assumed to be the same.

Simulations were performed to make estimates of the sensitivity of the "landing viscosity" to various parameters such as the wall thickness and emissivity. The "landing" viscosity is most sensitive to the pouring rate and pour temperature as shown in Figs. 2 and 3. Here, the "landing" viscosity, "landing" temperature, and canister temperature are shown from top to bottom. Sensitivity to the canister wall thickness (its thermal capacity), wall emissivity, and initial canister temperature was small.

2. Room Temperature Experiments

Room temperature experimentation using analogous liquids was developed. Based upon old experiments at Sandia, 42/43 corn syrup was identified as a good analogous liquid due to its extreme variation of viscosity with temperature. This liquid's viscosity can be varied by two orders of magnitude for temperatures ranging from 0 °C to 40 °C. The corn syrup viscosity and density are the same order as that of the glass.

An injection apparatus was built so we can force steady flows of the liquid through a nozzle to produce a jet of controlled thickness (similar to that of the real glass). The jet free-falls for two meters. Dimensionless parameters (of the glass and corn syrup) are approximately matched, since the dimensional parameters are all of the same order of magnitude.

Figure 4 shows sketches of a jet instability and the void distribution in pours made with 133 poise, 931 poise and 2590 poise viscosity syrup for a pour rate of 10 cc/s. The jet begins to meander as the higher viscosity liquid impacts the pool. This jet instability entraps voids near the surface of the liquid pool. At the highest viscosity, a tall mound of liquid develops and then collapses, entrapping big voids. Small voids occur in the low viscosity pours, medium voids in the medium viscosity pours, and a wide range of void sizes in the high viscosity experiments.

Figure 5 shows shadowgraphs of the high viscosity experiment. Frame 2, taken about 10 seconds after the pour was initiated, shows the mound buildup. About 2 seconds later (Frame 3), the mound has collapsed (entrapping large voids) and jet instability is evident. Jet instability continues (note the "ropey" structure in Frame 5) and void formation is induced by the instability and subsequent mound collapse (Frame 6).

3. Detailed Modeling

FIDAP is used to model the experiments. Figure 6 shows the predicted jet instability and mounding behavior at the jet-pool interface. The six plots show the syrup at times separated by 0.15 seconds. The predicted behavior agrees qualitatively with the behavior observed experimentally. Note also the large regions of entrapped voids.

4. High-temperature Experiments

An experimental apparatus is being fabricated to allow the same type of experimental observation using molten glass as has been observed with the syrup. The test equipment is presently being assembled, and preliminary experiments will begin in earnest in the near future. A simple test using molten glass at 900 °C was performed by manually pouring from a crucible. A similar jet instability was observed as in the low temperature experiments.

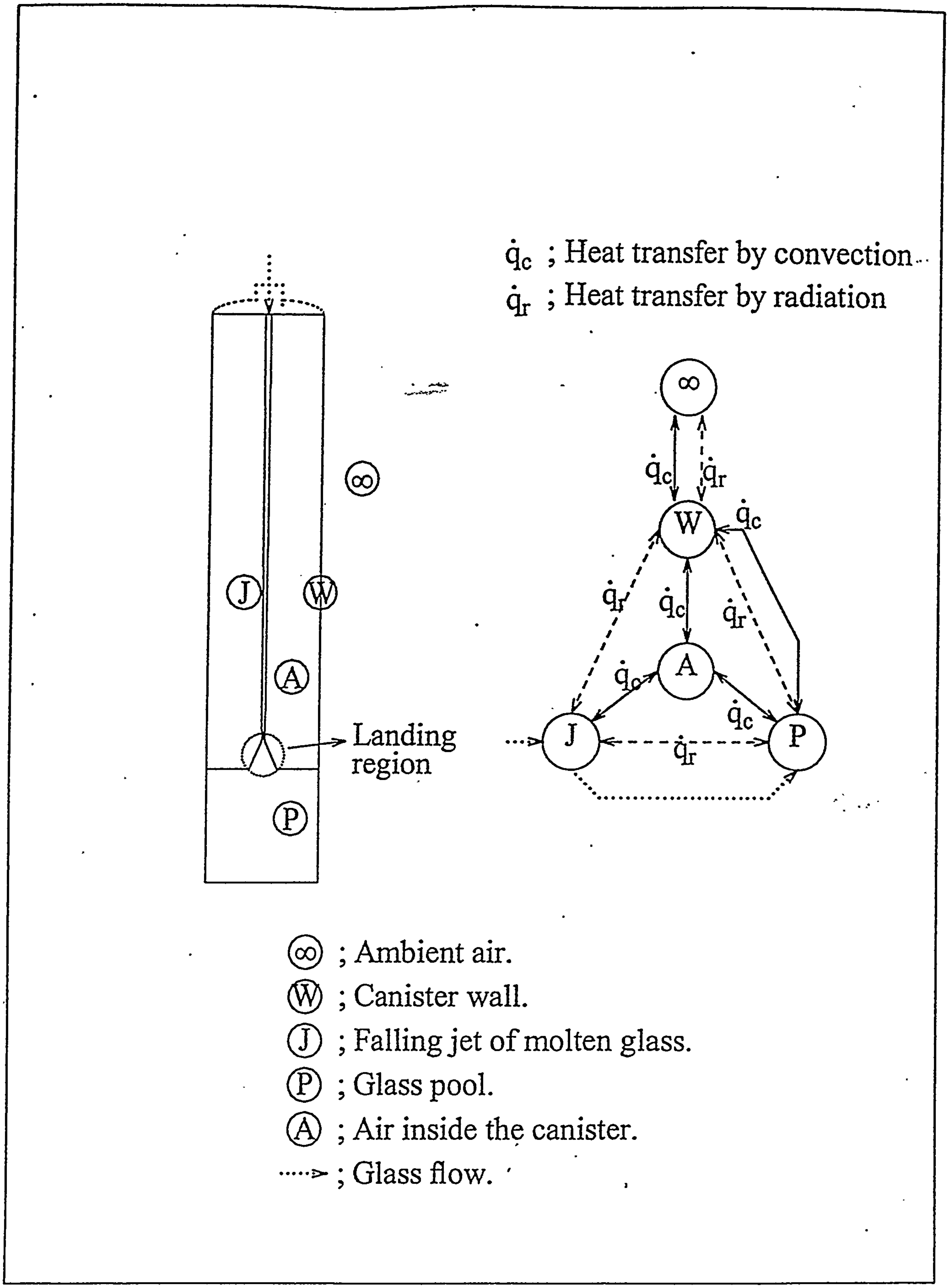


Figure 1. Schematic of the global model.

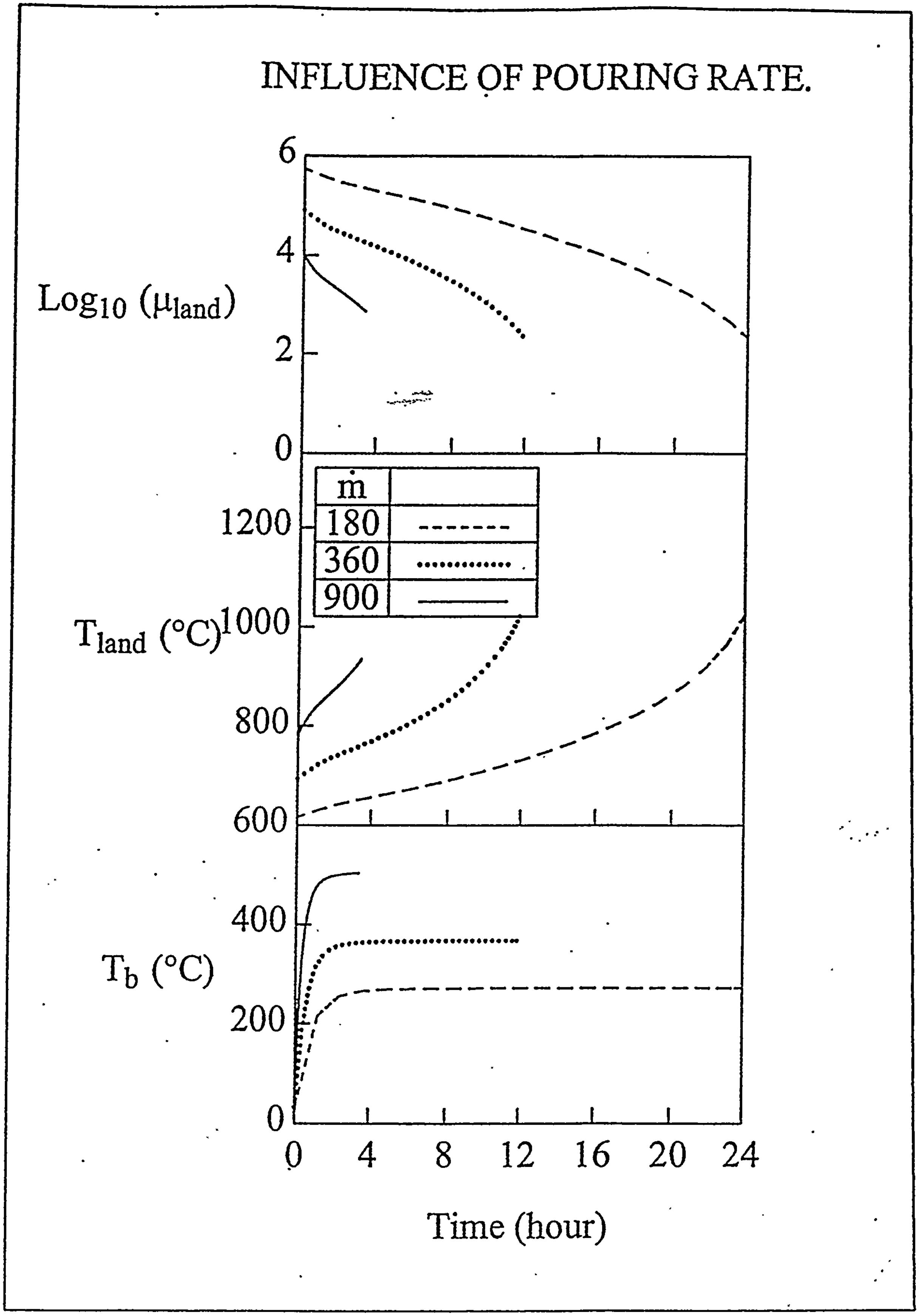


Figure 2. Sensitivity of the system's thermal response to the glass pouring rate.

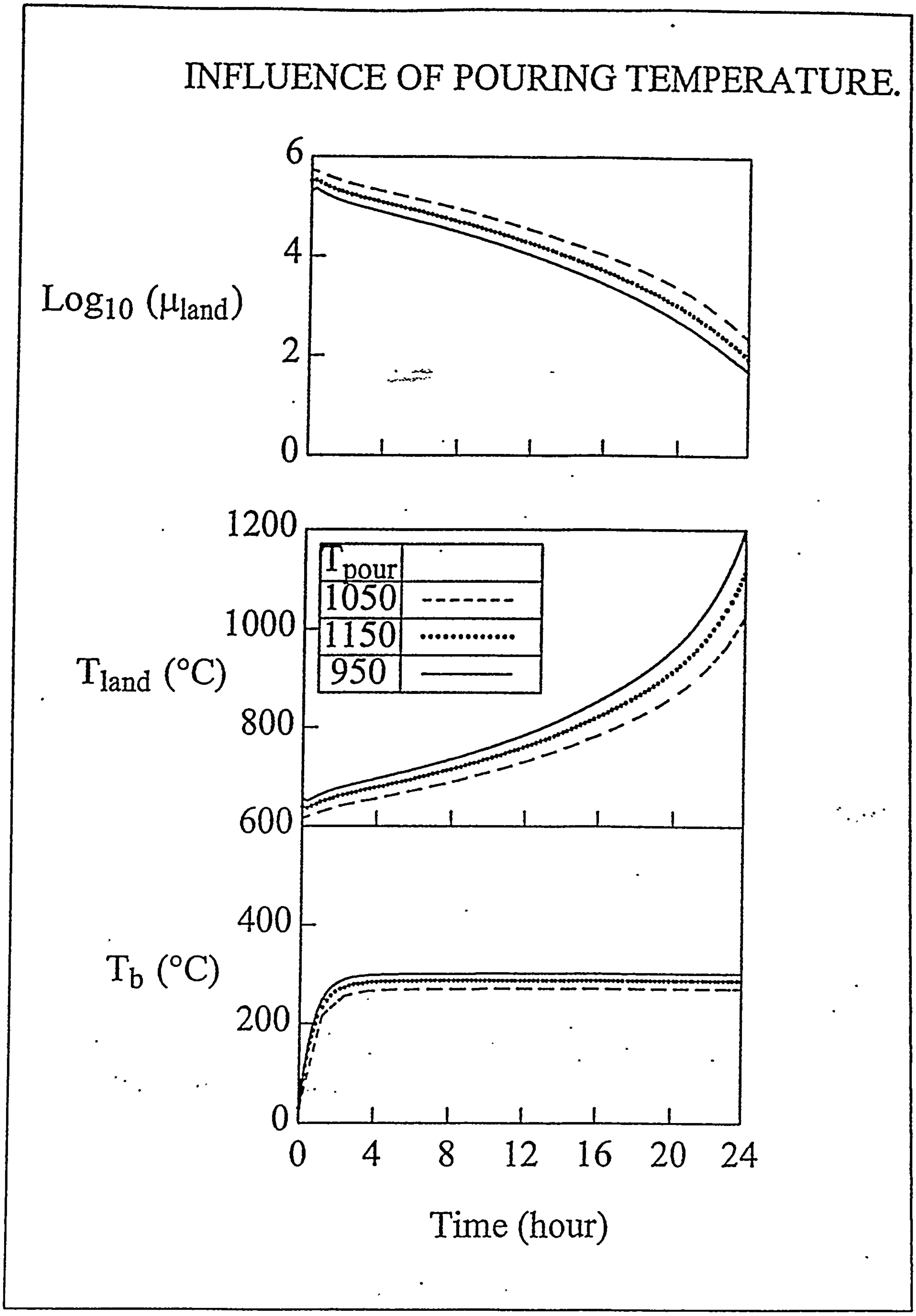


Figure 3. Sensitivity of the system's thermal response to the glass pouring temperature.

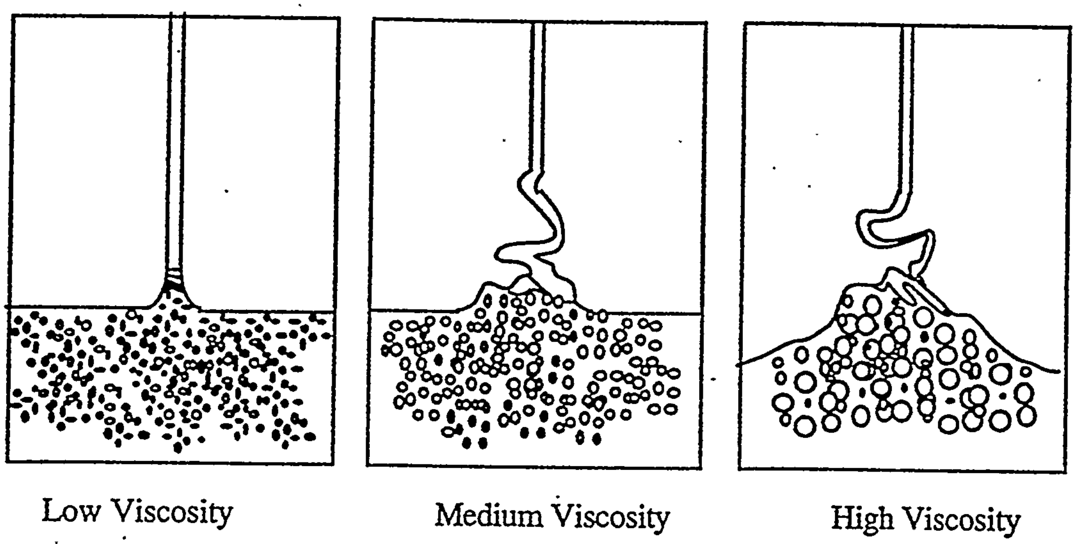
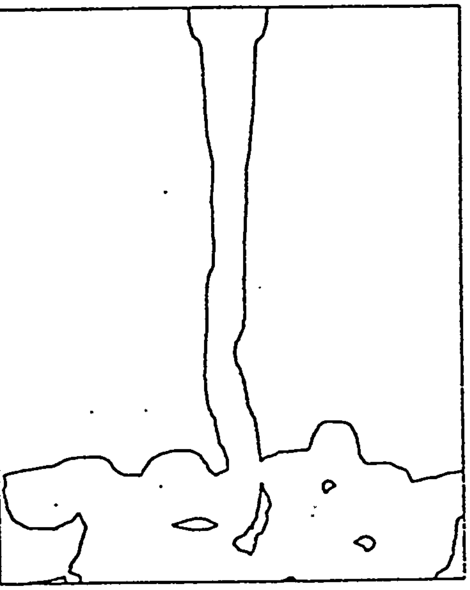


Figure 4. Schematics of observed jet instability and void distributions for low, medium and high viscosity pours using the analogous fluid.

Figure 5. Shadowgraph image of the jet instablity and mounding phenomenon in the high viscosity analogy fluid pour.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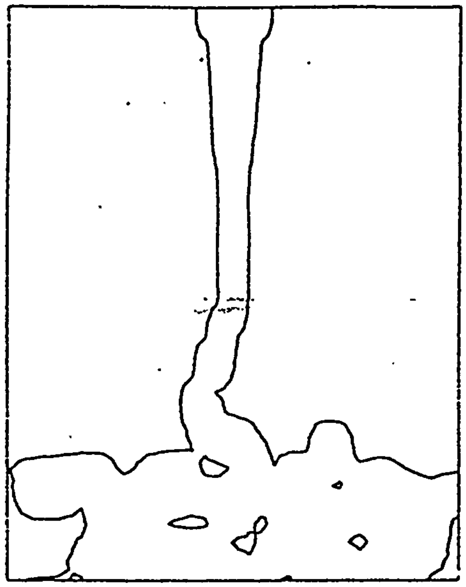
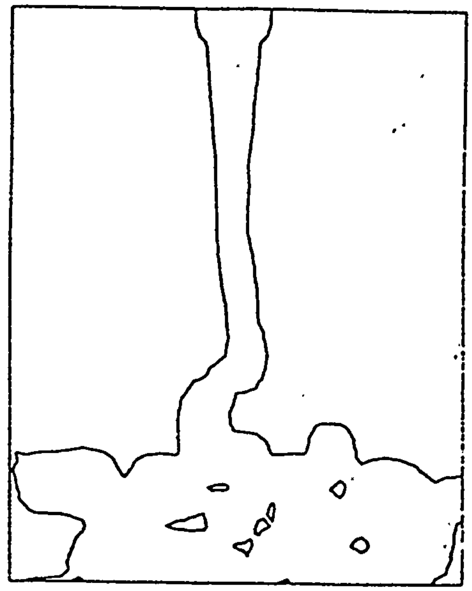
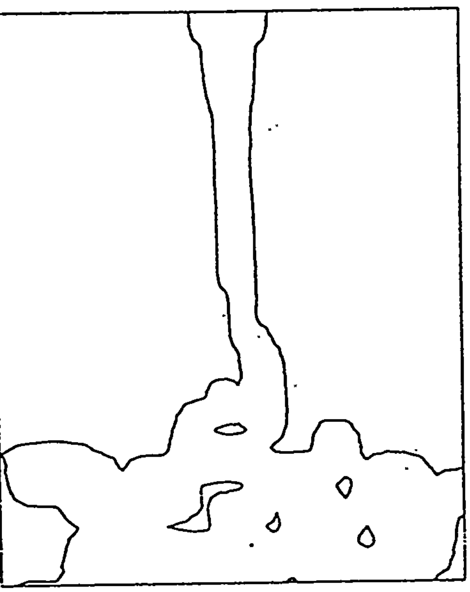
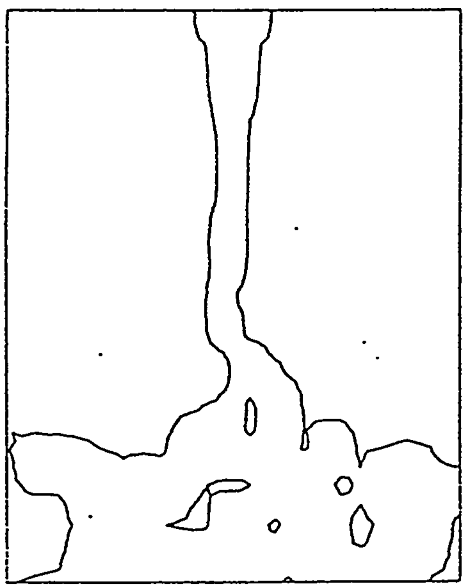

b: t = 5.25 sec


c: t = 5.40 sec


d: t = 5.55 sec


e: t = 5.70 sec

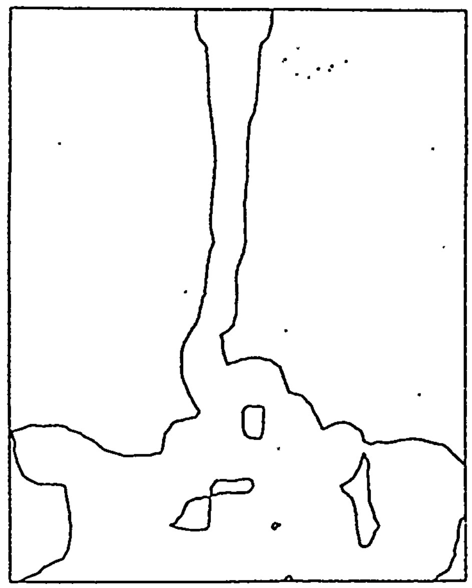

f: t = 5.85 sec

Figure 6. Direct simulation of the jet instability and void distribution using FIDAP.

Most Tangible Accomplishments

The global modeling has shown that engineering models can predict that sensitivity of the jet "landing" viscosity to operating conditions (pouring temperature and pouring rate are the most important parameters). The low temperature experiments have allowed us to observe new and unexpected mechanisms for void formation (a jet instability coupled with a mound collapsing phenomenon). The particular void formation mechanisms are directly related to "landing" viscosity and, in turn, "landing" temperature.

The detailed models have revealed similar jet instabilities and void entrapment as observed experimentally. Parametric simulations performed with the detailed model have shown similar sensitivity to the liquid viscosity. The high-temperature experiments have shown whether similar phenomena occurs in the molten glass pour.

The combination of global and detailed modeling, along with low and high temperature experimentation, will allow us to develop

1. A global understanding of void formation mechanics and, then,
2. Engineering approaches to minimize void formation.

Coordination with Doe or Doe Laboratory Personnel

Our group has had extensive interaction with personnel at Lawrence Livermore National Laboratory (LLNL) and Westinghouse Savannah River Company (WSRC). The modeling effort at LLNL is led by Peter Raboin and Werner Stein. The can-in-canister demonstration program and test pours have been coordinated by Nick Kuehn, and the glass characterization has been led by Gene Ramsey.

Members of our research group have met on three separate occasions at SRS with representatives of LLNL and WSRC, most recently on 21 February 1996. In early May, we will meet again at SRS to examine the latest destructive evaluation of the 20-can demonstration pour. We are also planning regular meetings with the LLNL group, to share our experimental results, which are unique and invaluable to the modeling efforts, and to discuss the various modeling issues. This interaction is only expected to increase as we obtain more results and the research progresses. Below is a list of personnel with whom we have had meaningful interaction:

LLNL:

P. Coyle, L. Gray, T. Kan, J. Kass, P. Raboin, and W. Stein

WSRC:

B. Hardy, J. Jerrell, N. Kuehn, W.G. Ramsey, and K. Sullivan

1.5.5. Cross-cutting Issues

1.5.5.1 DEVELOPMENT OF NONDESTRUCTIVE ASSAY METHODS FOR WEAPONS PLUTONIUM AND MOX FUEL SAFEGUARDS

Naeem M. Abdurrahman (PI), ANRCP/UTA
Bernard W. Wehring (CO-PI), ANRCP/UTA

PROGRESS REPORT
(1 February 1996-30 April 1996)

Research Activities

The objective of this research project is to investigate and develop nondestructive fissile assay (NDA) methods capable of determining the fissile contents of plutonium pits and fresh as well as spent mixed-oxide (MOX) nuclear fuel for verification and safeguards purposes. The following is a summary of the main activities during the third quarter of the project.

We continued our effort to investigate the technological safeguards issues related to weapons plutonium and mixed-oxide nuclear fuels and to conduct a thorough assessment of current measurement technologies for fissile assay and isotopic determination. A report on safeguards issues and technologies, with emphasis on the light water reactor option, is near completion. Assuming the LWR option, the FMDP safeguards boundaries include Pu processing facilities, MOX fabrication facilities, reactors, HLW repositories, and transportation.

As to the our developmental program, we focused our investigation during this period on the lead slowing down time spectrometer (LSDTS). The neutron source requirements for the LSDTS are quite stringent. A pulsed neutron source with sufficient intensity and short pulse-width would be required to drive the LSDTS. We have completed the evaluation of the various accelerator and neutron generator options for neutron production that would constitute suitable neutron sources for the LSDTS. A report on suitable neutron sources for these devices is near completion.

We have narrowed the selection of the neutron source for the LSDTS to two options which will be investigated further. Option 1 is to add a pulsing high voltage source to the University of Texas Nuclear Engineering Teaching Laboratory (NETL) 14 MeV neutron generator. Under suitable timing specifications, a peak current of 10 A would give an increase of 104 in the neutron pulse intensity. Option 2 is to design and build a pulse power neutron source powered by ion diode capable of delivering currents to the target up to 100 kA producing 140 ns pulses of 1012 neutron per pulse. This option also employs a DT reaction therefore producing 14 MeV neutrons.

We have completed our scoping neutronics calculations of an idealized spherical LSDTS. These results have shown that a 14 MeV neutron source is a suitable source for the proposed LSDTS and thus were very encouraging. Some of the results have been presented during the Second Quarterly Meeting of the Nuclear Group in Amarillo (3/28-3/29). The next phase of our computational program will address the neutronics of a more realistic geometry, and will investigate the various design parameters required to determine the engineering feasibility of the proposed system.

We have been working on improving coordination and exploring collaboration opportunities with the appropriate groups and personnel from the DOE National Labs. We have scheduled visits to LANL and SNL May 7-9, 1996 to meet with some of these groups. We have identified the following groups and persons as our contacts for our integration and coordination effort and have initiated contacts and discussions with them that we find very encouraging:

1. LANL/NIS-5: Safeguards Science & Technology Group
Victor Gavron (Group Leader)

Mark Abhold
Phil Rinard
Tom Prettyman
Merlyn Krick

2. LANL/NIS-7: Safeguards Systems Group
Richard Strittmatter (Group Leader)
Bryan Fearey
Bruce Erkkila

3. SNL/05000: National Security Programs
Dennis Mangan
Cal Jaeger

Dennis Mangan who has been serving as Sandia Lab Manager for Technical Support to the DOE/FMDP has recently been replaced by Bill Wilson of Sandia/California. Our next step would be to initiate contact with Bill Wilson.

Our planned visit to LANL and SNL should serve to focus our discussions on specific activities, and hopefully lead to a better understanding, coordination, and possible collaboration. Since the purpose of our project is measurement methods and instrumentation development for nondestructive assay of fissile materials, we expect that the major part of our future coordination and collaboration will be with NIS-5. This is the lead group responsible for developing techniques and instrumentation for nondestructive assay measurements. NIS-7 is more into nonproliferation systems studies, development of information analysis software and information management systems. We expect to have some level of interaction with NIS-7 but to a lesser extent than that with NIS-5. In both groups our contacts thus far indicated willingness and enthusiasm to collaborate with us.

LANL appear to be interested in our work on the LSDTS. This was evidenced by the interest of LANL in the presentation of this project during the Second Nuclear Group quarterly meeting in Amarillo and by an invitation from NIS-5 to the PI to visit LANL and give a presentation on the LSDTS to the group.

Most Tangible Accomplishments

In summary, the most tangible accomplishments thus far include completing the scoping neutronics calculations of the LSDTS which have established the adequacy of 14 MeV neutron sources for the proposed LSDTS. We have concluded our literature search on safeguards issues and technologies. We have completed our information gathering effort on neutron generators and other suitable neutron sources and system components for the proposed LSDTS. We intensified our effort to strengthen our national and international contacts in the area of safeguards and to have better coordination with groups at the two lead National Labs in the area of safeguards and safeguards technology, namely LANL and SNL. As part of our coordination plans, Drs. Naeem Abdurrahman, Bernard Wehring, and Paul Nelson are scheduled to visit LANL and SNL early May 96. Two reports, one on safeguards issues and technologies and the other on suitable neutron sources are near completion. The two PI's have participated in the Second Quarterly Meeting on the Nuclear Group and have given a presentation on the computational and experimental programs of the project and on the coordination and integration plans with the National Labs and MD.

1.5.5.2 TRANSPORTATION ANALYSIS

Hani Mahmassani (PI), Center for Transportation Research
The University of Texas at Austin

R. Radha, Department of Civil Engineering
Ziaul Huque, Department of Mechanical Engineering
Prairie View A&M University

Y. A. Hassan, W. H. Marlow, A. Caldwell and Paul Nelson
Department of Nuclear Engineering
Texas A&M University

D. C. Wunsch, Department of Electrical Engineering
James Dunyak, Department of Mathematics
Texas Tech University

PROGRESS REPORT
(1 February 1996-30 April 1996)

Purpose

The purpose of this project is to develop and apply tools for the absolute and comparative analysis of risks arising in the transportation stage of various projected scenarios for the disposition of surplus weapons fissile material. Specific subprojects are described on the following pages.

Subproject 1

Transportation of Mixed-Oxide Fuel

Hani S. Mahmassani (PI), ANRCP/UT

PROGRESS REPORT
(1 February 1996-30 April 1996)

Research Activities

The general objective of this project is the identification and study of transportation-related issues that arise in conjunction with the disposal of spent-plutonium.

The UT-Austin team has continued in its advisory role to the efforts of the Prairie View A&M team in reviewing methodologies for routing hazardous substances, especially nuclear fuels. Several references were shared, and interaction has increased between the two groups.

The TRANSNET program, developed at Sandia labs, has been obtained and set up at UT-Austin, as it has by the Prairie View and TAMU teams.

In addition, the UT-Austin team has continued the development of practical procedures for transport route generation when the network experiences dynamically varying risk characteristics. Additional progress was accomplished in terms of formulating the problems relevant to the transport of plutonium, and characterizing the type of solution.

Most Tangible Accomplishments

A list of references was submitted to sponsors.

Conceptually, the review led the study team to separate the issue of risk estimation and assessment from the problem of developing routing strategies given risk estimates. The focus of the UT-Austin effort is primarily on the latter problem, recognizing its multi-objective nature, and the dynamically varying stochastic nature of the network.

In addition, two problems have been identified:

1. a priori routing strategy, and
2. real-time route modification.

Work Plan for Next Quarter

Continue development of conceptual framework for routing procedure, taking into account various sources of risk and characteristics of the network. Develop conceptual linkage between these procedures and existing software tools. Continue and extend interaction with DOE personnel, especially at SANDIA.

Programmatic Coordination with DOE or DOE Laboratory Personnel

A meeting took place between the PI for this project and researchers at Sandia Laboratories in Albuquerque. The meeting was also attended by other ANRCP researchers involved in the transportation study. The purpose was to exchange information on ongoing activities and identify issues of mutual and complementary interest, and establish a framework for continued interaction and exchange.

Subproject 2

Modeling for Safe Routing and Transport Surplus Weapons Fissile Materials

Dr. Paul Nelson, ANRCP/TAMU
Dr. R. Radha, ANRCP/PVAMU

PROGRESS REPORT
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The A&M Transportation Group has further defined its project to cover the risk analysis associated with the hypothetical transportation of plutonium pits and/or the fabricated MOX fuel to the Savannah River DOE facility and to the Palo Verde Nuclear Generating Station from the Pantex facility. The risk associated with these routes will be evaluated using RADTRAN 4, a transportation radiological risk computer code developed at Sandia National Laboratories.

Supporting documentation for "Risk Analysis Data for Transportation of HEU and Pu Pits for Tritium Supply" (a Weapons Complex Reconfiguration Program report), containing accident probabilities obtained from DOE/DOT empirical data bases, was located through the assistance of the DOE Reading Room in Washington, D.C. Volumes 2,3, and 4 of the RADTRAN 4 manuals have been received; NTIS supplied volume 4 (programmer's manual) and an author of the manuals (Fran Kanipe at SNL) supplied volumes 2 (the technical manual) and 3 (the user's guide). These manuals have furnished much needed definitions of the variables used in RADTRAN 4, along with RADTRAN 4's input parameters and defaults. Access to TRANSNET (of which RADTRAN 4 is part) has been accomplished through the establishment of an account for Texas A&M by the administrators of TRANSNET at SNL. TRANSNET also contains the codes HIGHWAY, used to determine the routes along which the shipments will travel, and TICLD, used to assess the transportation individual centerline dose for individuals downwind from hypothetical accident release sites.

Subproject 3

Development of Source Term Components for Formation and Initial Release of Plutonium-Containing Aerosol for Conditions and Effects Not Treated by Existing Models for Transportation Incidents

Yassin A. Hassan, ANRCP/TAMU
Z Huque, ANRCP/PVAMU
William H. Marlow, ANCRP/TAMU

PROGRESS REPORT
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Programmatic Coordination with DOE Laboratory Personnel

Dr. Ervin Copus of Sandia National Laboratories, Albuquerque, New Mexico, is the principal contact with DOE/National Laboratory programmatic interests. He is supported by DOE/MD under the Fissile Materials Disposition Program. On 23 October 1995, at an introductory meeting with SNL personnel, Dr. Copus and we first met and discussed the objectives of our proposed work. On 29 November, in a phone conversation, we gained further information from him on current treatments of transportation accidents and he suggested that additional information of use to us and to transportation needs was available, and he would attempt to identify it for us. He located the references on that information, and on 18 December we had an extensive phone conversation. We discussed the current work as encompassed by the RADTRAN code, and he pointed out that explosion-driven disposition is the current focus of work. Since this source term generally does not generate fine particles, it has little health impact on surrounding populations. In contrast, Dr. Copus pointed out that fire-driven source terms would be much more important for local human exposure; this source term is not currently available, and if we developed this term, it would be a useful addition to existing modeling capabilities. On 22 March 1996 we discussed the work proposed above and how to coordinate our developments with DOE/MD needs. Dr. Copus pointed out that what we are proposing is work on the local scale, while their work is on the national scale, including classified information.

On 30 April, our groups travelled to SNL to meet with Drs. Copus and Miller and Mr. Kevin Seager of the Transportation and Packaging Technologies Project. Their activities and responsibilities and the optimal mode of interaction with this project was discussed. The importance of the information to be developed in this project wa pointed out as being governed by order-of-magnitude issues for risk to the public. At present, public health risk from explosive dispersal of plutonium is at least an order of magnitude less that other factors associated with transportation. Thus, for a plutonium fire to have an impact, it would require elevation o the current risk factor by 100. They indicated both metallic and oxide forms of plutonium should be included in calculations of fire-driven aerosol formation.

Subproject 4

Investigation of Neural and Fuzzy Logic Analysis Techniques for Surety Issues in Transportation of Fissile Materials

James Dunyak, ANRCP/TTU
Paul Nelson, ANRCP/TAMU
D. C. Wunsch, ANRCP/TTU

PROGRESS REPORT
(1 February 1996-30 April 1996)

See preprint entitled, "Quantitative Assessment for Nuclear Surety in Transportation Applications: Fuzzy and Neural Network Approaches." This preprint was submitted last quarter and should be on file.

Also, additional references for the literature search phase of this subproject have been gathered.

1.5.5.3 USE OF COMPUTER-BASED MOLECULAR MODELING TO STUDY THE MICROENVIRONMENT OF PLUTONIUM ENCAPSULATED IN SYNROC

Richard A. Bartsch (PI) ANRCP/TTU
Keith L. Pannell, ANRCP/UT-El Paso

PROGRESS REPORT
(1 February 1996-30 April 1996)

Research Activities

To support the experimental investigations of Dr. Clearfield on the feasibility of immobilizing plutonium by incorporation in the ceramic medium called SYNROC, computer-based molecular modeling studies of the microenvironment of plutonium encapsulated in SYNROC are being undertaken. It had previously been established that in SYNROC plutonium can be substituted isomorphically into zirconium, calcium, barium sites depending on the mineral phase and the oxidation state of the plutonium. Since this was a new research area for us, the first phase of the subproject was to conduct a literature survey to learn the methodology by which computer-based molecular modeling of cation-doped mineral phases can be conducted. From this survey, we determined that molecular modeling studies should be feasible for the immobilization of plutonium in SYNROC.

In the second phase of the subproject, the native crystal structure of zirconolite, the primary mineral phase in SYNROC, was taken from the Cambridge Crystallographic Database. The zirconolite structure is now being studied by molecular mechanics and dynamics simulations. These simulations will provide a model for the behavior of an "ideal" equilibrium system. Plutonium(IV) is being doped randomly into the zirconium sites in this mineral with variations in the ratio of the doped actinide to the bulk crystal. The goal is to determine the effect of such doping on the thermodynamic stability of the system. The computational simulations are being performed using the CAChe molecular modeling system, version 3.7, running on a Power Macintosh computer. The molecular dynamics and mechanics simulations utilize the CAChe Dynamics and Mechanics modules, respectively.

Most Tangible Accomplishments

Since delays were encountered in obtaining the funding necessary to support the hardware, software, and manpower for this subproject, progress has been slower than anticipated. However the calculations are now underway and we will know be the end of the summer how fruitful this approach will be.

Programmatic Coordination with DOE or DOE Laboratory Personnel

For this subproject, there is no coordination with DOE or DOE Laboratory Personnel.

1.5.6 Other Material Studies

1.5.6.1 HIGH EXPLOSIVES WORK PLAN PROGRESS REPORT

Grant Willson, University of Texas at Austin

PROGRESS REPORT
(1 February 1996-30 April 1996)

1. Summary of Research Activities

Task 1

A series of design and test experiments have been carried out with the goal of establishing designs for both "3-D" (Spherical wave) and "2-D" (plane wave) work pieces for explosive compression of materials. The goal of this effort has been to supply sufficient energy in the form of heat and pressure to convert carbon, in the form of C-60, into diamond and to successfully recover the samples. The work has been guided by application of sophisticated "hydro code" that was acquired from Sandia National Laboratories. This code was developed for the purpose of modeling the explosive compression of plutonium. The code has been used extensively to model the compression of plutonium but little or no work has been done to model the decompression cycle since compression of plutonium is designed to initiate other energetic processes. The compression of non-fissionable materials is followed by a decompression that tends to impart strong shear stresses on materials, the result of which is mechanical failure and dispersion of the metal into small particles which are dispersed over great distances. The design work has progressed to the state that the 2-D devices can be detonated and the sample recovered. Detonation of the latest iteration of the 3-D design resulted in formation of but two large hemispherical fragments which were split at the point of assembly. We are confident that the next test will allow us to recover an intact sample holder after detonation.

A collaboration has been established with Hoechst A.G., a supplier of C-60. The arrangement provides cost free samples of C-60 for testing. Sources of "nano-cobalt" and nano-nickel" have been established. These finely divided metals are efficient catalysts for allotropic conversion of C-60 to diamond. Protocols have been established for handling these high surface area metals under inert atmosphere, compressing the samples of metal and C-60 to maximum density and hermetically sealing them in the work pieces under oxygen and water free conditions. Protocols for recovery and analysis of the materials from the explosively compressed work pieces have also been established. A series of "2-D" experiments have been statistically designed that will allow establishment of the influence of materials parameters and sample formulation on diamond yield at maximum compression and compression duration.

Task 2

Discussions have been held with representatives of the Amarillo based SPS Co. These discussions led to the conclusion that it would be difficult if not impossible to create a coal analogous fuel formulated from waste high explosives that met the requirements for use in system generates temperatures that are above the decomposition point for most organic the SPS power generation facility. The preheating of the powdered coal in the existing feed including the compounded high explosives. We did discuss the use of a licensed second injection port on the SPS generation plant but the capital cost for implementation of a new feed system is sufficiently high it is unreasonable to consider for this study.

Fortunately, we have located three generation facilities in Texas that are licensed to burn municipal waste for power generation. These facilities appear to be ideal for combustion of the pelletized fuel we propose to create from the recovered high explosives and recycled plastics. A source of recycled plastics has been found. There is a stream of thermoplastic materials that is separated from the valuable polycarbonates and polyesters, for example, for which there is no end use. This material is available for the price of shipping it.

A procedure has been established at Pantex that allows the recovered high explosives to be reduced to rubble. The process involves hydrojet machining. We have identified a group at the Naval Air Warfare Center Weapons Division, China Lake (NAWCWPNS) that has the experience, equipment and expertise to carry out the experiments required to establish specification limits on the explosive rubble and on the formulated fuel that will insure that it is impossible for the material to detonate. This same group is equipped to establish the thermodynamic properties of the fuel and to establish the detailed nature of the combustion products. Knowledge of the combustion products is required to insure that combustion of the fuel derived from recovered explosives is not a source of new pollutants and that use can be made of the fuel without exceeding currently established and/or planned environmental guidelines.

Unfortunately, this entire project has been slowed by an inability to establish a contract between The University of Texas at Austin and NAWCWPNS. Early demands by the Navy for prepayment for services rendered were overcome by special dispensation from the office of the Governor of Texas. Attempts to negotiate an acceptable indemnity agreement between the University and the DOD laboratory were not successful. The funds for the sub-contract have now been successfully transferred back to the University of Texas, from UT to the ANRCP, from the ANRCP to the state of Texas, from the state of Texas to DOE and the process of transfer from DOE to DOD is currently being negotiated. Establishment of this subcontract has been a rather remarkable saga and a learning experience.

1.5.6.2 HEU VULNERABILITY ASSESSMENT

Robert Canaan (PI), ANRCP/UTA
K. L. Peddicord, ANRCP/TAMU
W. W. Pitt, ANRCP/TAMU

PROGRESS REPORT
(1 February 1996-30 April 1996)

Overview

The objective of the HEU Vulnerability Assessment is to assess the environmental, safety, and health (ES&H) aspects associated with DOE's storage and handling of its current HEU holdings. A "vulnerability" is a condition or weakness which could lead to unnecessary or increased exposure of workers or the public to radiation or to HEU-associated chemical hazards, or to the release of radioactive materials to the environment. The assessment will identify and prioritize ES&H vulnerabilities and will also serve as an information base for identifying corrective actions for the safe management of HEU.

Research Activities

An important aspect of this effort is the gathering and assessment of site-specific information and HEU data. A number of databases are currently being created in order to identify, record, assess, and prioritize HEU vulnerabilities. One of these databases is the Operating Experience and Events Database, which contains information concerning HEU-related historical events which have impacted ES&H. This database provides a record of past problems with HEU storage and handling and can therefore serve to guide the current assessment.

I have been working on this database for DOE Germantown on behalf of ANRCP since mid-February. I have conducted searches of both DOE and international databases which include: Office of Scientific and Technical Information, DOE's OPENNET database, DIALOG database, the International Atomic Energy Agency's INIS database, as well as general internet searches. The result is a 150 page document which contains the abstracts of pertinent material as well as source information. This report has been submitted for publication as an ANRCP document and has also been submitted to DOE-EH in Germantown. It was distributed to the sites at the HEU Vulnerability Orientation in San Antonio on April 8.

Most Tangible Accomplishments

The primary accomplishment this Quarter related to the HEU Assessment was the successful completion of the HEU Vulnerability Assessment Orientation, held April 9 - 12, 1996 in San Antonio, Texas. The ANRCP played a major role in the planning, development, and execution of this training. I served as the primary point-of-contact between DOE and the Texas Engineering Extension Service (TEEX) and was heavily involved in the preparation phases. TEEX, under ANRCP funding, provided the following services during the training:

1. Use of their state-of-the-art facility located on the Hemisfair Plaza.

2. Hosting the participants at a registration reception.

3. Coordination of all logistics, e.g. hotel, bus transportation to and from the training facility, lunches, etc..

4. Development and printing of training materials, e.g. a 3-ring binder, notepads, etc..

5. Facilitation-monitoring of all technical training sessions.

6. Teaching course modules in Team Building and Conflict Resolution.

The participants at the training included DOE personnel from both headquarters and the area offices; laboratory representatives; independent consultants, and external stakeholders. The total number of participants was estimated to be around 150.

The response and feedback from the participants was overwhelmingly positive. Essentially all of the participants indicated in a formal evaluation that the training was useful and effective.

Other Accomplishments

The ANRCP has offered to DOE a great deal of expertise in the form of experienced personnel who have volunteered their services to the ongoing HEU Vulnerability Assessment. Below is a list of experts whose resumes were submitted to DOE Germantown for the purpose of this Assessment:

Texas A&M University

Dr. J.W. Poston - Health Physics
Dr. K.L. Peddicord* - Nuclear Engineering/materials disposition
Dr. W. W. Pitt* - Nuclear Engineering
Dr. J.C. Rock - Industrial Hygiene
Dr. J. P. Wagner - Fire Protection/detection
Dr. A. R. McFarland - Aerosol Science

Texas Engineering Extension Service (TEEX)

Dr. K. Bennett*
Dr. L. Teverbaugh*
Dr. R. Bass*
Mr. J. Leyendecker*
Mr. E. Vallejo*
Mr. C. Schwab*
Mr. D. Webster*

The University of Texas at Austin

Dr. R. E. Canaan* - Nuclear Engineering
Dr. H.M. Liljestrand - Nuclear Air Cleaning
Dr. R. L. Corsi - Nuclear Air Cleaning
Dr. D. E. Klein - Nuclear Engineering/Media Relations

ANRCP

Mr. B. Harris - Media Relations

'*' indicates individuals who are currently participating in the Assessment.

Future Work

Following the successful completion of the training in San Antonio, the real work of the Assessment lies ahead. Representatives of ANRCP will continue to play a role in the conduct of the assessment and the evaluation of its results.

Currently, future responsibilities include:

- Dr. R. E. Canaan, will serve as a member of DOE's Home Team, which assesses the 14 Sites which do not receive a Working Group Assessment Team Visit.

- Dr. K.L. Peddicord, will coordinate ANRCP activities and participate directly in site evaluations.

- Dr. W. W. Pitt is also a member of the Home Team and a deputy team leader for scheduled Home Team site visits.

- Dr. R. Bass, will lead TEEX efforts to provide follow-up to the team building/conflict resolution course during the actual site assessments.

It is hoped that ANRCP involvement in this Assessment will continue to grow as the assessment matures. It is very likely that opportunities for further significant contribution will arise as the assessment results are pulled together and brought into final form.