DOE/AL/85832--T8

Table of Contents

WORK PLAN PROGRESS REPORT
Electronic Resource Library
Period Covered: November 1, 1995 through January 31, 1996

Institution: Texas Tech University

Principal Investigator: Dr. Dale Cluff

Sub-Contract Number: UTA95-0206

Award Period: June 1, 1995 to May 31, 1996

Executive Summary

With guidance from the ANRCP, the Electronic Archive project was renamed to Electronic Resource Library (ERL).

During January, Dr. Dale Cluff replaced Dr. Nancy Van Cleave as the Texas Tech principal investigator for the Electronic Resource Library subproject.

1. Summary of activities during reporting period.

Initiated planning for a mirror scanning project in the Texas Tech University (TTU) library to scan government documents pertaining to the subject of plutonium. The government document collection at TTU is the only Full Regional Depository for Government Documents in the State of Texas except for the collection at the Texas State Library.

Completed the collection development plan, the technical plan and implementation plan.

Continued development of a distributed virtual library collection scheme. Creators of the "Library Without Walls" at Los Alamos Laboratories were contacted to avoid duplication of scanning efforts.

Provided a list of report titles resident at the Amarillo College reading room to Dr. Igor Carron, who is the Nuclear Group liaison to ANRCP from Texas A&M University.

Initiated collaborative effort with Corp of Engineers, Tulsa Division for access to electronically published environmental impact and project related documents.

Established relationships with various vendors specializing in electronic publishing and information access such as DRA Inc., VERTEC, ADOBE, and AMIGOS Bibliographic Council Inc., in order to finalize an effective Implementation Plan.

Collaborated with the Harrington Library Consortium to provide high speed electronic access to users of the ERL.

Investigated Internet providers that can deliver T1 access to the ERL for researchers and scientists.

2. Tangible accomplishments.

Accomplishments include development of (1) a Collection Development Plan, (2) a Technical Plan, and (3) an Implementation Plan. A prototype of the ERL was also completed during this period.

3. Important recommendations regarding the ANRCP Competitive Grants Program.

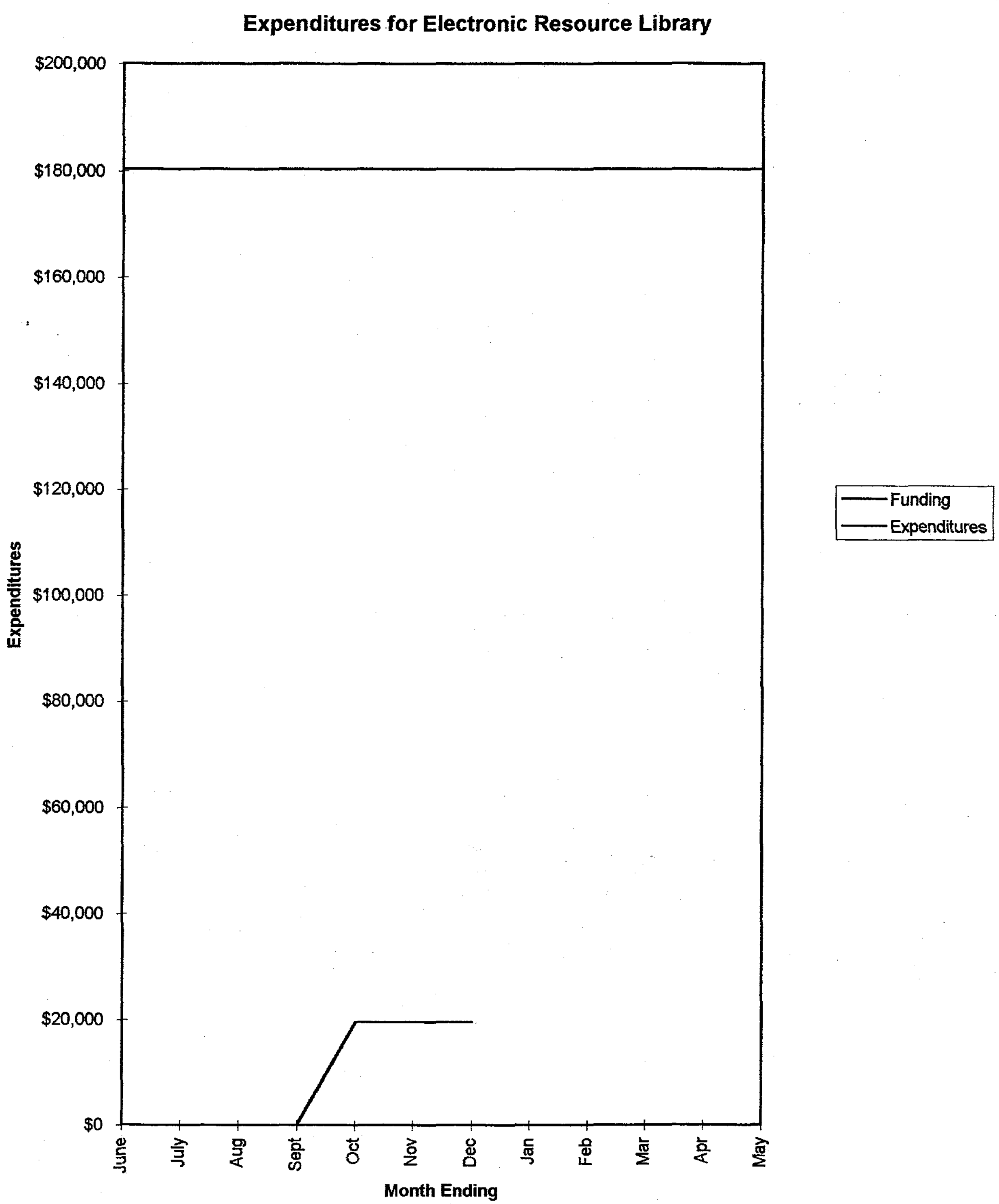
None.

4. Approach changes. None

5. Performance variances. None

6. Open items. None

7. Status assessment and forecast. Continue with original schedule.



Expenditures for Electronic Resource Library
$200,000
$180,000
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Expenditures
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Month Ending
Funding
Expenditures

WORK PLAN PROGRESS REPORT
Multi Attribute Utility Analysis Team
Period Covered: November 1, 1995 through January 31, 1996

Institution: University of Texas at Austin

Principal Investigator: Dr. James Dyer
The University of Texas
Austin, TX 78712

1. Executive Summary

During the period 1 November 1995 - 31 January 1996, the MAU team continued work ondisposition of surplus plutonium project. The team continued the analysis and constant revision of the pre-decisional draft of the methodology report. The latest draftPreliminary Multi-Attribute Utility Analysis for the Disposition of Surplus Plutonium,was completed on January 19, 1996 and is currently being reviewed by personnel from the Office of Fissile Materials Disposition (OFMD), Department of Energy. This latest draft is 259 pages and includes analysis from all of the alternative and cross cutting teams. A meeting was scheduled for late January to brief the Secretary for the Department of Energy on the latest draft, however, the meeting was rescheduled for a later date yet to be determined. The team also met with a number of personnel from the various alternative and cross-cutting teams as well as officials from OFMD.

2. Collaborative/Support Status (UT Austin, Texas A&M)

This summary is a joint report by the universities collaborating in the ANRCP Decision Analysis effort.

TECHNICAL PERFORMANCE

PEIS Support:

Meetings were held with personnel from OFMD to discuss data to be submitted.

ROD Support:

The MAUA team continues to participate in the weekly conference call meetings with the National Laboratory directors, Alternative Team leaders and members of the OFMD staff. The purpose of the meetings is to ensure that every one is on track with the ROD schedule.

Other Technological Performance ResponsibilitiesThe MAUA team continues to analyze data from the various alternative and cross cutting teams for incorporation into the final draft document.

Baseline or Scope of Work Changes: None

WORK PLAN PROGRESS REPORT
Senior Technical Review Group
Period Covered: November 1, 1995 through January 31, 1996

Institution: Amarillo National Resource Center for

Principal Investigator: Bill Harris
Amarillo National Resource Center for Plutonium

1. Executive Summary

The Senior Technical Review Group (STRG) did not meet during this reporting period. A Meeting was originally scheduled for October 11, 1995; however, this meeting was rescheduled to January 11, 1995 because information to be provided by the DOE laboratories was not available. The January 11 meeting was rescheduled to February 1-2, 1995 due to bad weather in the Washington DC area.

The scope of the meeting planned for the February 1-2, 1996 meeting is to consider and comment on the overall Fissile Materials Disposition Program, and the following three elements of that program: immobilization alternatives, joint U.S. Russian programs, and deep borehole disposition. The agenda for the STRG meeting is attached for your reference. A report for the February 1-2 STRG meeting will be included in the next quarterly report due April 30, 1995.

2. Collaborative/Support Status

All meetings are coordinated as appropriate with Greg Rudy, Howard Canter, and Andre Cygelman of DOE, and with lab officials involved in the issues being addressed at each Senior Technical Review Group meeting.

TASK 3

- **Bioremediation of HE**
- **Vadoze Zone Remediation**
- **Chromium Remediation**

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:	November 1, 1994 to March 31, 1996
Report Period:	November 1, 1995 to January 31, 1996

1. Briefly summarize research activities during the period of 11/01/95 to 1/31/96 relating progress to objectives described in your work plan, and attach copies of reports or papers produced.

Progress was reported in three major task areas: bioremediation of HE and chlorinated solvents, vadose zone remediation, and chromium remediation.

Bioremediation of HE

The preliminary work on RDX and HMX concluded with the discovery of a mixed culture that effectively degrades RDX . Surprisingly, this culture was derived from soil taken from an urban playa in Lubbock, Texas. The soil was provided by Dr. Mollhagen at Texas Tech University. According to Dr. Mollhagen, the Alderson Playa soil, named for the junior high school that is across the street, acclimated faster and performed better in degrading industrial waste in previous experiments. Preliminary data indicated that the Alderson Playa (AP) culture could aerobically degrade forty percent of the RDX in fed batch reactors in approximately twelve days. However, in an ongoing experiment, the AP culture degraded over fifty percent of the RDX from fed-batch reactors in the same amount of time. If the rate of disappearance continues for the remainder of the current degradation experiment, RDX will be completely removed from solution in approximately 22 days. It seems that with each successive experiment, the AP culture continues to acclimate and increase its ability to utilize RDX.

RDX is considerably more soluble than HMX in aqueous solutions. Consequently, HMX is more difficult to work with than RDX. We chose to initiate our acclimation studies with both compounds, but track on RDX. As the details of the protocols are developed with RDX, similar studies will be initiated with HMX. We expect to begin the HMX studies within one month.

Based on the success of the AP culture, the emphasis has shifted to metabolite identification and kinetic parameter determination. Kinetics studies will provide valuable information, in the form of Michaelis-Menten coefficients , on the rate of RDX utilization as it relates to culture growth. Currently, enrichment of the AP culture is proceeding toward the start of the first set of kinetic studies. Concurrently, development of an adequate GC/MS method for the identification of RDX and HMX metabolites is also progressing. The presence of multiple metabolites is probable based on HPLC chromatograms which illustrates the development of alternative peaks with similar elution times to that of RDX and HMX.

In other directions, research into RDX and HMX degradation using facultative microorganisms has begun. The process of facultative acclimation will begin with the AP soil samples because of their good performance in the aerobic degradation studies. Based on the oxidative state of RDX and HMX, it is logical that sequencing anaerobic and aerobic environments may be the most efficient manner to completely degrade both compounds. A facultative culture that can thrive under both aerobic and anaerobic conditions may yield the most promise for removing RDX and HMX in this manner.

In-Situ Bioremediation of TCE-Contaminated Groundwater

During ongoing work on biostimulation of PTX06-1012 sediments in headspace bottles, headspace concentrations of oxygen, carbon dioxide, and methane have been analyzed over time and have indicated the continued presence of biological activity. These stimulated sediments will be utilized in the near future for batch biodegradation studies of radiolabeled trichloroethylene (^{14}C-TCE).

A new approach has been implemented for biostimulation of aquifer sediments which supplies oxygen, nutrients, and substrates (phenol and methane) in dissolved form, rather than supplying oxygen and methane from the headspace of a bottle. This method was developed by Dolan and McCarty (1995); however, analytical methods were modified to accommodate the small sample volumes and available instrumentation. Fluid in the tubes has been exchanged approximately once every 10 - 15 days. After the incubation period, decreases in dissolved oxygen, methane, and phenol concentrations have been observed, indicating an increase in populations of indigenous methanotrophs and phenol degraders.

Upcoming experiments will determine the ability of stimulated organisms to degrade ^{14}C-TCE and the extent of complete conversion to carbon dioxide. The method used for TCE degradation assays was developed by Closmann (1989). Replicate 6-mL vials will be prepared with approximately 2 g of stimulated aquifer material, along with enough groundwater to provide saturated conditions. Groundwater will be spiked with a known amount of ^{14}C-TCE. Degradation of ^{14}C-TCE over time are determined using a modified purge and trap technique that separates $^{14}CO_2$ and ^{14}C-TCE for quantification by liquid scintillation counting. Much work has been done in developing and testing this method to ensure acceptable mass balance closure.

References:

Closmann, F. B. 1989. The Cometabolism of Chlorinated One-Carbon and Two-Carbon Compounds in Unsaturated Soil Systems by Methylotrophic Organisms. M.S. Thesis, The University of Texas at Austin.

Dolan, M.E. and P.L. McCarty. 1995. "Small-Column Microcosm for Assessing Methane-Stimulated Vinyl Chloride Transformation in Aquifer Samples." Environmental Science and Technology 29(8):1892-1897.

Vadose Zone Remediation

During the past quarter, work on the Pantex Plant vadose zone remediation study at UT focused on the design of a proposed Pantex site inter-well tracer test. Progress included a review of unsaturated zone tracer test literature, design of laboratory column experiments, and preliminary modeling of the proposed tracer test.

Approximately forty articles were reviewed and summarized. The literature review covers tracer selection, tracer applications, experimental and field procedures, and modeling of tracer test results. Researchers have used analytical and numerical modeling of tracer tests to meet several objectives. These objectives include improved understanding of water infiltration through the unsaturated zone, characterization of permeability heterogeneity and contaminant dispersivity, investigation of mass transfer limitations, estimation of residual oil or NAPL saturation, and estimation of porous media wettability.

Laboratory column experiments to determine appropriate tracer test design parameters are being conducted at UT. These tests will be used to establish appropriate sampling and analysis techniques to use in the field test at the Pantex site, examine the behavior of various candidate tracers in typical sand packed columns as well as those packed with soil from the Pantex site.

The Pantex site inter-well tracer test is being modeled with UTCHEM, a compositional chemical flood simulator developed by the Petroleum Engineering Department at the UT. Previous researchers have modeled similar tracer tests with UTCHEM. The tracer test will be designed to provide both an estimate of water saturation and a measure of the permeability heterogeneity in the vadose zone. To date, preliminary two-dimensional and three-dimensional model runs have been made. Once critical model parameters, such as optimal time step size, are determined, the model will provide valuable information in the design of the field tracer test.

During sorption studies of VOCs, TAMU researchers have measured single component adsorption isotherms on Pantex and have already shown that they do collapse into a single isotherm when the adsorbed amount is normalized with the amount corresponding to a monolayer coverage. We have also developed the methodology to predict, a priori, the single component isotherms on Pantex soil given the nitrogen BET data for the soil. However, in soil vapor extraction, normally more than one contaminant is involved as is the case at the Pantex site. In addition, water present as moisture, has a significant effect on adsorption of VOCs. Therefore we are now studying binary isotherms with the objective of predicting multicomponent isotherms from pure component data or predictions.

Soil is a complex heterogeneous solid made up of different solid phases (sand, different clays, organic matter, etc.). Due to this heterogeneity, soil has a large pore size distribution and particle sizes vary over a wide range, both of which introduce two additional variables to the study of multicomponent adsorption. Therefore, initially we are using a well defined matrix of very narrow particle size and pore size distribution, silica gel. In these initial studies or objective is to develop the methodology so that we can use the same approach with soil from the Pantex site.

We will be addressing two major topics including prediction of adsorption isotherms of binary mixtures of volatile organic compounds on a solid matrix and characterization of how physical properties of the organics affect adsorption on the solid matrix. Hence, binary mixtures of "non-polar/non-polar, polar/non-polar and polar/polar" combinations are being examined. Adsorption isotherms for single as well as for binary mixtures are measured using the "frontal analysis chromatography" technique. Using the adsorption isotherms for single compounds, the isotherms for binary mixtures will be predicted using models for multicomponent adsorption out of the literature. The evaluation of these results may give a better understanding of binary adsorption of organics on soil.

The silica gel used in this study is a silica gel "Davisil", grade 645 from Aldrich. The surface area, pore size distribution and particle porosity were measured the nitrogen/BET-method. The packed bed density was calculated by weighting a known volume of particles. The VOCs used in this study are non-chlorinated and chlorinated organic compounds, also found at the Pantex site. The non-chlorinated compounds were n-hexane and benzene and the chlorinated compounds were carbon tetrachloride, chloroform, trichloroethylene and chlorobenzene. When two organics are simultaneously adsorbing, the front of the stronger adsorbed species travels slower than the front of the weakly adsorbed species (n-hexane).The slower one displaces the faster one, leading to a rise in the effluent concentration of the faster one above the inlet concentration. The procedure of analysing the data is the same as that for the single VOC adsorption. However it is worth to notice, that the "roll-up" area is negative and therefore corresponds to a desorbed mass.

For binary systems, the adsorption isotherm of one component was measured over the whole range of vapor pressure while the concentration of the second component was fixed. Different concentrations of the second component were considered. The adsorption isotherms were measured for n-hexane in the presence of benzene (non-polar/non-polar - system), n-hexane in the presence of trichloroethylene (non-polar/polar - system) and chloroform in the presence of chlorobenzene (polar/polar - system). All adsorption isotherms of binary systems were fitted with the BET equation. Interpretation of the observed data continues.

At TTU, work continues on the two-dimensional finite difference model for soil vapor extraction. The effort currently centers on the formulation of the solution algorithm for the transport equation. After attempting new methods for solution of the five-banded matrix, we have returned to the conventional successive-overrelaxation method. Once this code is formulated and tested, it will be coupled with the previously developed vapor flow module.

We have also begun discussions with Engineering Environmental Management, Inc. (e2M), about their cooperation in a gaseous tracer test at the Treatability System east of Zone 12. Consortium researchers will work together in planning the logistics of this field work. Initial conversations with the Pantex staff confirm that at least 30 to 45 days will be necessary to get NEPA-checklist approval of the preliminary work plan.

Chromium Remediation at the Pantex Plant

Chromium remediation research has continued under six program areas:

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

Develop and validate analytical procedures and quality control programs: Internal quality control procedures continued to be applied to each laboratory. The Texas A&M laboratory experienced difficulty in obtaining equipment for speciateing chromium on an ICP/MS using ion chromatography. The device was delivered at the end of the quarter and will be installed during the next quarter.

Develop chemical models for chromium in the vadose zone and perched aquifer: Work continued during the quarter to refine the equilibrium model. The overall concept of chromium transformations possible at Pantex are shown in Figure 1.

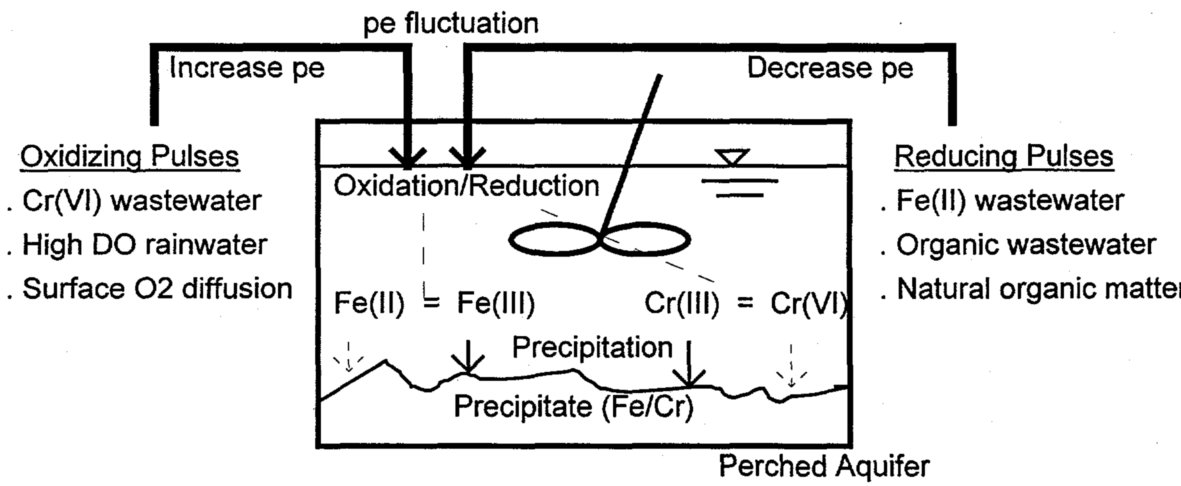


Figure 1. Schematic of Chemical Processsses Affecting Chromium.

Conduct ion exchange studies: Research on treating Pantex groundwater has focused on using ion exchange resins for hexavalent chromium removal. Hexavalent chromium is believed to exist primarily as chromate, CrO_4^{-2}, in this groundwater due to the concentration and pH conditions. Three column tests have been performed with groundwater from well PM-20 to determine the hexavalent chromium capacity of an ion exchange column. Breakthrough curves for each test were very gradual, spreading over thousands of bed volumes of throughput. Two possible reasons for this were determined, kinetics limitations and competition with other anions present in the groundwater.

An analysis of other anions which may compete with chromate was performed by using ion chromatography to analyze the samples collected from column test 3. Figure 2 below shows the breakthrough curves for these anions and for chromate. The strong base anion resin (SBA) begins in the chloride form; therefore, chloride initially elutes off the column in very high concentrations and decreases until equilibrium is achieved with the influent concentration. Explanations for other anion breakthrough curves are not as simple and are currently being investigated. Table 1 shows anion concentrations for the influent groundwater.

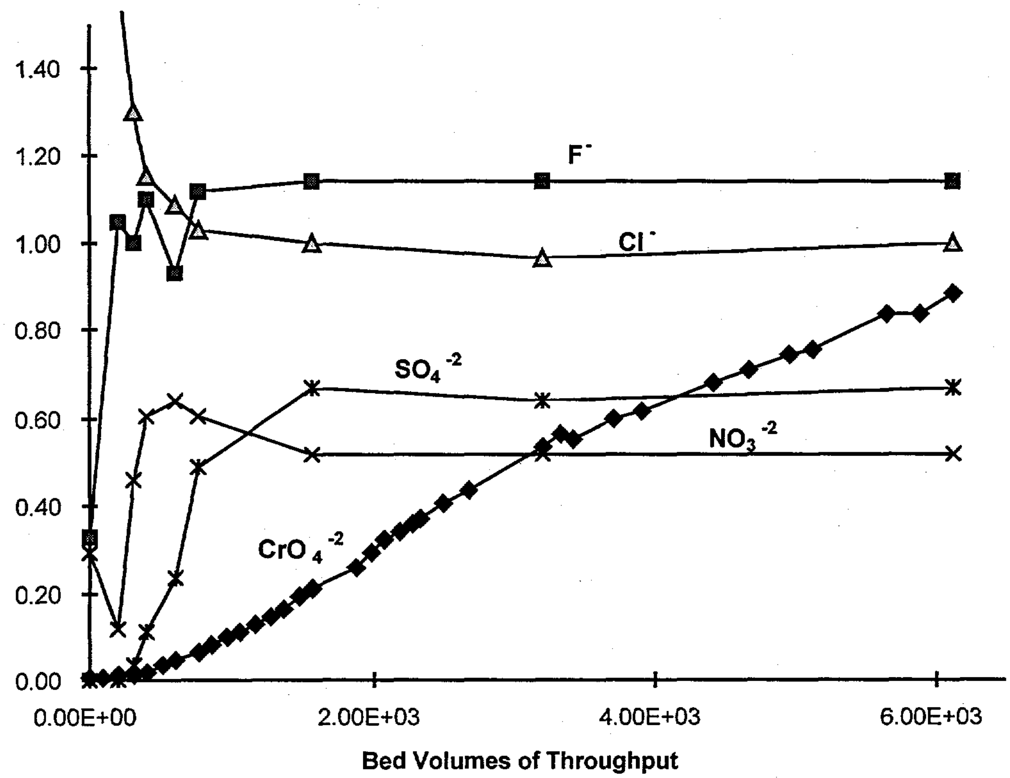


Figure 2. Anion Breakthrough Curves for Column Test 3

Table 1. Anion Influent Concentrations for Column Test 3		
Anion	Concentration (mg/L)	Concentration (moles/L)
CrO_4^{-2}	0.6	1.1 E -5
F^-	1.2	7.0 E -5
Cl^-	33	1.0 E -3
NO_3^-	15	2.4 E -4
SO_4^{-2}	21	2.0 E -4

Future work will include continuing to evaluate possible anion competition for ion exchange sites. A competitive equilibrium ion exchange model will also be used prior to further column tests to determine how competition between different anions should affect the effluent profiles.

Evaluate Redox chemistry of chromium: The experimental plan for chromium reduction studies was completed and supplies procured. Initiation of experiments has been delayed due to problems in establishing analytical procedures for chromium speciation. The analytical procedures should be established during the next quarter, allowing experiments to begin.

Identify sources and speciation of chromium: No progress on this task during this quarter.

Evaluate Sorption of Chromium on Soils: Equilibrium isotherm tests for eight core samples were completed. Linear isotherms were fitted to the plots of sorbed Cr (mg/kg) against dissolved Cr (mg/L). The test results are summarized below in form of distribution coefficients, K_d, in L/kg. The cause of the greater sorption in the PTX06-1014 soils is not yet known.

Table 2. Distribution Coefficients for Chromiium on Aquifer Materials

Sample	Depth (ft)	Kd (L/kg)
Aquitard		
PTX06-1012	285	0.36
PTX06-1013	265	0.79
PTX06-1014	287.5	4.45
PTX06-1016	285	0.35
Perched Aquifer		
PTX06-1012	272.5	0.40
PTX06-1013	250	0.21
PTX06-1014	277.5	2.48
PTX06-1016	245	0.33

Delivery of PM-20 Water: During November, six drums of Cr-contaminated water from monitor well PM-20 were collected with by the Battelle Environmental Monitoring group with TTU staff present. During the pumping of the 330 gal, a YSI 3500 flow-through cell with probes was used to monitor temperature, oxidation-reduction potential, and, pH. The drums were later delivered to the UT group for use in the ion exchange laboratory tests.

Planning of Future Sampling Events: During the collection of the PM-20 water, negotiation began for future cooperation for field sampling to assist in speciation work. In addition, the Battelle Environmental Monitoring group has recently proposed modification of the sampling schedule that should facilitate our cooperation. The new sampling schedule is being reviewed to plan the actual field sampling schedule.

2. Describe the most tangible accomplishments related to your research funding.

The research accomplishments have already been noted above. The other most tangible accomplishment during the last quarter was the ANRCP University Consortium Semiannual Environmental Meeting which was held at the Pantex Plant on January 11, 1996 in Building 16-12, Room 136-137. This meeting was attended by nearly 50 individuals from the Plant, the Consortium, and other interested parties. An outline of the meeting activities is presented below:

Welcome: Dan Ferguson, DOE/AAO, made introductions and a brief welcome. Meeting agendas were available to all participants, and an attendance log was circulated, copies of which were also made available.

Biodegradation of HE and In Situ Cometabolism of Chlorinated Solvents: Robin Autenrieth, TAMU, discussed the degradation of HMX and RDX using an acclimated culture and the methodology used in the initial research. Future work will include continuation of kinetic studies, RDX sorption studies and evaluation of the ability of facultative organisms to degrade RDX. Gerry Speitel, UT, discussed the ongoing work on biodegradation of TCE. The necessary organisms for degradation are present, and appear to be stimulated with the addition of nutrients. Work will continue on nutrient stimulation, and other bacteria will also be evaluated for their potential to degrade TCE. Details of these research projects are included in the 1995 annual report, and copies of the overheads used during the presentations have been distributed.

Vadose Zone Remediation: Ken Rainwater, TTU, discussed the permeability and hydraulic conductivity measurements as well as the VOC sorption evaluation studies that have been done in preparation for the development of a 2-D SVE model. Future work will include a field tracer test and completion of the SVE model. Details of this research project are included in the 1995 annual report, and copies of the overheads used during the presentation have been distributed.

Chromium Remediation: Bill Batchelor, TAMU, discussed the analytical procedures that have been developed and the plans for QA/QC of the analytical results, and ongoing ion exchange studies which have evaluated various resin removal efficiencies. Future research will include ion exchange column studies and sensitivity to pH, Cr reduction in soils, and Cr speciation and evaluation of potential sources. Details of this research project are included in the 1995 annual report, and copies of the overheads used during the presentation have been distributed.

Future Consortium Work: Randy Charbeneau, UT, stated that the ongoing research was designed to work with Pantex personnel in order to support environmental restoration and protection programs at the plant. The activities are organized in five general areas. The four areas which are a continuation of previous work include: 1) aquifer testing, tracer tests and produced water treatment, 2) bioremediation of soil and groundwater, 3) Vadose Zone Remediation and 4) Chromium Remediation. The fifth area is a new activity supporting the Biological Risk Assessment.

HE Biodegradation: Phillip Goodfellow, M&H, discussed the research ongoing in the Applied Technology Division to recycle or remove HE from the wastewater stream in support of waste reduction goals. The HE was removed from the wastewater stream using activated carbon. In order to recycle the carbon, the adsorbed HE was removed with solvents, and that waste stream was cycled through the biological treatment system, which completely degraded the HE. Copies of the overheads were available at the meeting.

Groundwater Monitoring Program: Ray Brady, BPX, discussed the changes in the groundwater sampling program. The program is now operated by EPD at Pantex, and the wells that were previously sampled monthly are now being sampled quarterly. Additional changes, pending approval by TNRCC, are to plug and abandon 10 wells, determine optimum sampling frequency based on location, sampling history and contaminant trends, and analyze only for contaminants of concern. However, at a minimum, it is recommended that all wells should be sampled annually for all analytes. Copies of the overheads were available at the meeting.

GIS Demonstration: Gary Thomas, BPX, showed the GIS database capabilities. He discussed the careful data validation performed before the data was input into the database, and showed some of the map making capabilities, including the ability to rotate 3-D structure maps and develop 3-D fence maps.

Off-Site Contamination: Johnny Weems, BPX, discussed the latest information on the groundwater contaminant plumes, which included the sample information from the wells drilled off the plant site to the east. The latest maps depicting the top of the fine-grained zone, top of the perched aquifer, and RDX, HMX, TNB, hexavalent chromium and TCE groundwater contaminant plumes were shown using the GIS system. Copies of the maps were available at the meeting.

Groundwater Treatability Study Tour: Darrell Brownlow, e2M, discussed the installation of the treatability system. Though not operational at the time due to problems of water disposal and freeze damage, a tour of the system was provided.

Biological Risk Assessment: Jim Rogers, BPX, discussed the requirements for the biological risk assessment and opportunities for research by the universities. Details of the process based on weight of evidence risk characterization were explained. Copies of the overheads were available at the meeting.

Roundtable Discussion: There was no time available for roundtable discussions. The meeting adjourned at 3:30.

Action Items: There were no action items assigned.

TASK 3

- **Phytoaccumulation of Heavy Metals**

QUARTERLY PROGRESS REPORT

November 1995 - January 1996

PROJECT UTA96-0043

PHYTOACCUMULATION OF SELECTED HEAVY METALS, URANIUM, AND PLUTONIUM IN PLANT SYSTEMS

Project Investigators

L.R. Hossner, Texas A&M University

R.H. Loeppert, Texas A&M University

D. R. Krieg, Texas Tech University

R.J. Newton, Texas A&M University

P.J. Szaniszlo, The University of Texas

Project Collaborator

Moses Attrep, Jr, Los Alamos National Laboratory

Submitted to

The University of Texas at Austin

February, 1996

TABLE OF CONTENTS

PROJECT SUMMARY

Project activity has concentrated on developing strategies to collect and acquire plant materials that have the potential for hyperaccumulation of chromium, uranium and plutonium. Initially, we will use chromium as an analog for plutonium and uranium. Chromium is similar to plutonium and uranium in that it is an important heavy metal contaminant in the environment, has multiple oxidation states and similar redox and chelation chemistry, tends to accumulate in the plant root, has comparable soil chemistry, and reacts similarly with organic acids within the plant. It is possible that plants that have the ability to hyperaccumulate chromium will also have the ability to hyperaccumulate plutonium or uranium. Plant selection, screening procedures, and laboratory techniques have been developed with chromium as the analog element.

An extensive literature review of metal hyperaccumulation in plants, and specifically as it relates to chromium, plutonium and uranium, has been completed and condensed as a part of this report. A list of plant species, identified as hyperaccumulators for other elements in the scientific literature, has been developed and seed acquisition efforts have been initiated. Plants from the same family and taxa that have been documented as metal accumulators and are present in Texas are being identified and will be collected when seeds are available.

Methods to be used in the selection, screening and testing of plants for hyperaccumulation have been developed and are outlined as a part of this report. Methods are preliminary and will change as the project develops. It is our intention to screen plants in both hydroponic and soil media. Selection of potential accumulator species will be determined by the concentration of metal in the plant tissue and biomass production.

INTRODUCTION

Phytoremediation is an integrated multidisciplinary approach which combines plant physiology, soil chemistry, and soil microbiology. Metal hyperaccumulator plants are attracting increasing attention because of their potential application in decontamination of metal-polluted soils. Soils are commonly contaminated by human activities and present clean-up technology may be too expensive for some sites. Removal of metals from these soils using accumulator plants is the goal of phytoremediation.

All vascular plants absorb heavy metals through their roots to varying degrees. Some plants may have an exclusion mechanism where there may be reduced uptake or restricted transport of the metal from root to shoot while others may exhibit passive uptake where metal concentrations in aerial plant tissues reflect soil concentration (indicator behavior). Accumulator plants concentrate metals in both roots and shoots (Baker, 1981). Some plant species endemic to metalliferous soils accumulate metals in % concentrations in the leaf dry matter (Brooks, 1987).

The term 'hyperaccumulator' was introduced by Brooks et al. (1977) for plants growing on serpentine sites that were capable of concentrating nickel (Ni) to more than 1000 µg/g (0.1%) in their leaves on dry matter basis. A concentration of 1000 µg/g has also been used to delineate exceptional uptake of copper (Cu), cobalt (Co), lead (Pb). The limit is raised to 10,000 µg/g (1.0%) for zinc (Zn) and manganese (Mn) because of greater background concentrations of these metals in the soil.

Chaney et al. (1995) proposed that a viable phytoremediation technology will require breeding improved cultivars of hyperaccumulators and development of improved agronomic practices or, for species like Thlaspi (yield is too low to support phytoremediation), bioengineering may be necessary to develop high biomass hyperaccumulating plants. They concluded that hyperaccumulator plants could be developed to remediate soils contaminated with heavy metals, and before the year 2000, commercial phytoremediation will compete with engineering approaches for remediation of contaminated soils.

Phytoremediation requires that the target metal 1) must be available to the plant root, 2) be absorb by the roots, and 3) must be translocated from the root to the shoot. Metal is removed from the site by harvesting plant material. After harvesting, the biomass is processed to either recover the metal or further concentrate the metal to facilitate disposal.

The concept of using hyperaccumulator plants to decontaminate industrially-contaminated soil was first tested at a farm managed by Rothamsted (McGrath et al., 1993). Ten species or populations were tested over four seasons. These were: *Thlaspi careulescens*, *Thlaspi achroleucum*, *Cadominopsis halleri*, *Reynoutria sachalinense*, *Cochlearia pyrenaica*, *Alyssum lesbiacum*, *Alyssum murale*, *Raphanus sativus* (radish), and *Brassica napus* (spring rape). The field was polluted with Zn. The greatest Zn yield was accomplished by *Thlaspi careulescens*, which had the potential to remove the equivalent of over 40 kg Zn/ha/yr. Similarly, Baker et al. (1991) conducted a pot study using soils from long-term field plots that had metal tolerant (including hyperaccumulators) and normal plants. They concluded that phytoremediation, using certain species, could offer a low cost, low technology alternative to current clean up technologies. Ernst (1988) harvested plants from natural stands on several contaminated sites and came to a different conclusion. He measured the relative abundance and metal uptake of various species and concluded that phytoremediation was not a viable remediation technology. Although hyperaccumulator plants were present on contaminated sites, they were not harvested because of their low growing, rosette characteristics. Ernst (1988) felt that it would be impractical to harvest rosette type plants with mechanical equipment.

Hyperaccumulation is often associated with relatively slow growth rates. Plants that employ other tolerance mechanisms generally have lower shoot concentrations of metals but greater biomass production. For example, the natural growth pattern of *Thlaspi* are is problematic for mechanical harvesting. But *Silene*, which accumulates metals less than *Thlaspi*, grows more rapidly and vigorously. *Silene* is also more capable of colonizing a contaminated site because of seed production and rhizomes. These factors would facilitate the establishment and harvesting of *Silene* over *Thlaspi* (Baker et al., 1995).

Fundamental to the environmental and economic success of phytoremediation is the existence of plant genotypes which hyperaccumulate metals. To maximize the metal concentration in the biomass ash, it will be necessary to use a combination of improved soil management inputs (optimized pH, application of the proper form and amount of nutrient, minimizing interfering elements, and introduction of agents which increase diffusion of metals), improved genotypes (optimize metal uptake, translocation, and tolerance), and improved biomass yield (e.g., > 20 t/ha).

This report reviews the current knowledge concerning the selection and physiology of different plants to accumulate metals, with emphasis on Cr and Ni. Chromium was chosen because it mimics to some extend the reactions of Pu (Andrew and Baker, 1982), and both Cr and Ni are present in high concentrations in serpentine soils. Serpentine soils are developed from serpentine rocks rich both in Cr (10-300 mmol/kg) and Ni (10-70 mmol/kg) (Gasser et al., 1995) and are a natural habitat for the natural selection of Cr and Ni hyperaccumulator plants. Plants that are adapted to serpentine soils are mostly Ni hyperaccumulators.

DISTRIBUTION OF HYPERACCUMULATOR PLANTS

Hyperaccumulator plants are geographically distributed and are found throughout the plant kingdom. The approximately 400 taxa shown in Table 1 include representatives of many families, ranging in growth habit from annual herbs to perennial shrubs and trees. They have been discovered in all continents in temperate and tropical environments. Centers of distribution have been defined for Ni (New Caledonia, Cuba, South East Asia, Brazil, Southern Europe and Asia Minor), Zn and Pb (Northwest Europe), Cu and Co (South-central Africa). Some families and genera are particularly well documented for Ni [*Brassicaceae* (*Alyssum* and *Thlaspi*), *Euphorbiaceae* (*Phyllanthus*, *Leucocroton*) and *Asterceae* (*Seeio*, *Pentacalia*)], Zn [*Brassicaceae* (*Thlaspi*)], Cu and Co (*Lamiaceae*, *Scrophulariaceae*) (Baker et al., 1992; Baker and Brooks, 1989) (Table 1).

There are not many Cr hyperaccumulators in nature, but there are numerous Ni hyperaccumulators (Table 1). Not many Cr hyperaccumulators have been identified partly because Cr in nature is in the Cr (III) form, is very insoluble and ,therefore, largely unavailable for plant uptake. The logical alternative would be to select Ni hyperaccumulators as target plants since both Ni and Cr are concentrated in serpentine soils where most of the Ni hyperaccumulators have developed

MULTIMETAL ACCUMULATORS

The ability of a plant to hyperaccumulate any one metal may confer some ability to accumulate other metals that are not found in elevated concentration in the parent soils (Reeves and Baker, 1984; Baker et al., 1994). Some metals may interact competitively for accumulation (e.g., Zn and Ni in calamine and serpentine soils).

Alyssum betolonii, which is endemic to serpentine soils, is known for its high concentration of Ni (> 10,000 ppm in leaves). The fact that serpentine (ultramafic) soils also contain other elements such as Cr has led to the assumption that the preferential accumulation of Ni in many species of *Alyssum* is due to a selective uptake mechanism. Gabbrielli et al. (1991) showed that in controlled experiments, excised roots of *Alyssum bertolonii* seedlings did not show selectivity to metal uptake. The plant roots tend to accumulate Ni, Co, and Zn without discriminating between them and with the same saturation trend, demonstrating a competitive action between these three elements and an common uptake mechanism. Clones of *Salix viminalis* were also found with high concentration of heavy metals (Cd, Cu and Zn) in their shoots.

Baker et al. (1994) suggest common mechanisms of absorption and transport of several metals by *Thlaspi* species. They observed high uptake of all metals studied. Zinc (Zn), cadmium (Cd), Co, Mn and Ni were readily transported to the shoot whereas aluminum (Al), Cr, Copper (Cu), iron (Fe) and Pb were predominantly immobilized in the roots.

Reeves and Baker, (1984) showed that hyperaccumulator plants growing in calcareous soils are able to tolerate serpentine soil and to take up elements other than Ni. It was observed when a population-type of *Thlaspi goesingense* Halacsy taken from calcareous soil was grown on serpentine soil extremely high concentrations of Ni, Zn, Co, and Mn were accumulated in the above-ground dry matter. The concentrations were similar to *Thlaspi.* growing in serpentine soils.

POTENTIAL ACCUMULATORS WITH HIGH BIOMASS PRODUCTION

Indian mustard (*Brassica juncea*) is a high biomass, rapidly growing crop plant which has an ability to accumulate Ni and Cd within its shoots (Kumar et al., 1995). It is an ideal plant with respect to phytoremediation and is suitable for genetic transformation (Terry et al., 1992).

Huang and Cunningham (1995) investigated phytoextraction of Pb from contaminated soils. They used two Zn hyperaccumulators and a single-gene Fe accumulating pea mutant (E107). Zinc hyperaccumulators accumulated Pb mainly in their roots while the pea mutant accumulated Pb in its shoots. They suggest that mutation techniques may help to understand Pb hyperaccumulation as well as to develop Pb hyperaccumulators. They also found that, since soil applied P fertilizer binds Pb, foliar P application increased shoot dry weight by 5 fold and increased total Pb accumulated in shoots by 115%.

Dushenkov et al. (1995) observed that roots of many hydroponically grown terrestrial plants such as Indian mustard (*Brassica juncea* (L.) Czem) and sunflower (*Helianthus annuus* L.) effectively removed the potentially toxic metals, Cu^{+2}, Cd^{+2}, Cr^{+6}, Ni^{+2}, Pb^{+2}, and Zn^{+2}, from aqueous solutions.

Streptanthus polygaloides Gray (Brassicaceae) is a Ni hyperaccumulator native to serpentine soils in northern California. This species tolerates 500 μM Ni without developing toxicity symptoms, and actually grows better with Ni than without. It accumulates Ni in both roots and shoots to concentrations as high as 2% on a dry weight basis. One function of Ni hyperaccumulation in S. polygaloides is as a defense against pathogens (Boyd et al., 1994). Preliminary data demonstrate that at least two Ni-binding proteins are unique to plants grown with Ni.

MECHANISMS FOR METAL TOLERANCE

An important part of this research program involves investigation of the processes involved in heavy metal absorption, translocation, and accumulation in metal hyperaccumulator species.

Plant species that are naturally high in heavy metals have developed a strategy to tolerate the heavy metals by unrestricted absorption and, as a result, accumulate high concentrations of the heavy metal in the plant tissue. Since heavy metals are damaging to most plants at relatively low tissue concentrations, this strategy requires some mechanism(s) to detoxify the metals. Although several detoxification mechanisms have been proposed, none has been described in detail.

It is widely accepted that detoxification of metal ions within plant tissues must depend on chelation by appropriate ligands. There has been considerable interest in determining the chemical nature of these ligands. Organic-acid anions such as citrate, malate, and malonate are commonly found at high concentrations in the leaves of *Alyssum* spp. Reeves (1992) has pointed out that, these anions tend to be present constitutively in these plants in substantial amounts and cannot account for the metal-specificity or species-specificity of Ni hyperaccumulators. Andrew et al. (1995) suggested that the Ni hyperaccumulation trait in *Alyssum* is associated with the ability of the root system to produce substantial amounts of histidine as a Ni complexing ligand.

Metals are required for a variety of metabolic processes in all organisms. However, because many metals can be toxic, plants have evolved systems to regulate the uptake and distribution of metals. For plants, uptake of metals occurs primarily through the roots so this is the primary site for regulating their accumulation. Once metals have crossed the root membrane, there are a variety of mechanisms to prevent metal toxicity, including compartmentation and binding to intercellular ligands. Plants are equipped with at least two ligands which are able to bind heavy metals such as Cu, Zn and Cd: phytochelatins (PCs) and metallothioneins (MTs).

Phytochelatins are a family of peptides with the general structure [∂-GluCys]n-Gly, where n>1 (Rauser, 1990). Metallothioneins (MTs) are similar to PCs in being Cys-rich, metal ligands. Metallothioneins, however, are proteins synthesized by mRNA translation.

vessels, it must first move symplastically to avoid the casparian strip. Cadmium appears to be translocated within the xylem chelated by oxygen atoms, probably within organic acids (Salt and Raskin, 1995).

CHROMIUM AS AN ANALOG FOR PLUTONIUM AND URANIUM

Mechanisms of Chromium Hyperaccumulation by Plants

Chromium (Cr) is an important industrial metal in the manufacture of many diverse products including alloys, chemicals, and refractories (Palmer and Wittbrodt, 1991). Chromium can enter the environment by several natural processes as well as from human activities. Several sites in the U.S. have been found to be contaminated by high levels of Cr (Palmer and Wittbrodt), which is toxic to humans and other living organisms. At the early stage of the current project, we have proposed to use Cr as an analog to plutonium (Pu) and uranium (U). After we find Cr hyperaccumulator plants and understand the mechanisms of Cr hyperaccumulation by plants, we will extend our knowledge of Cr to Pu and U. The reasons for the selection of Cr as an analog to Pu and U are that 1) Cr itself is an important heavy metal contaminant in the environment ,2) both Cr and Pu and other actinides have multiple oxidation states, e.g., III, IV, V and VI, and similar redox and chelation chemistry, 3) like Pu and U, once absorbed by plant roots, Cr is mainly accumulated in the roots (Shewry and Peterson, 1974; Cary et al., 1977a), and 4) within plants, soluble Cr is complexed by organic acids, similarly to Pu (Garland et al. 1983). It is conceivable that Cr hyperaccumulator plants will have the ability to hyperaccumulate Pu or U. In this report, we summarize the soil chemistry and plant uptake of Cr, based on the literature, and present our plans to study the mechanisms of hyperaccumulation of Cr by plants.

Soil Chemistry of Chromium

Chromium is widespread in the environment with small amounts usually being present in most rocks and soils as chromic oxides. Total Cr in igneous and sedimentary rocks may range from 11 to 100 ppm. Soils high in Cr (III) will be found in nature where parent materials are derived from serpentine rocks. They may have concentrations of Cr greater than 100,000 ppm.

As a mineral it is mostly found as chromite ($FeO-Cr_2O_3$). Uses of Cr in plating, tanning, paints, corrosion inhibitors, and fungicides all contribute to its dissemination in the environment. Soils of the United States may contain from 1 to 1,500 ppm of Cr. Serpentine soils are higher in Cr. There are deposits and serpentine rich soils in North America (California, Pennsylvania, Maryland) that contain several % Cr, however, there is no mining for Cr. Chromium produced in North America comes from Africa and Asia. Chromium is used for chromate, dichromate, and chromic acid formation, and in tanneries and other industries. Chromium (VI) exhibits chemical properties similar to phosphorus (P), and Cr(III) reactions are similar to Al. Environmental damages are largely a result of Cr (VI). The rate at which Cr (VI) converts to Cr (III) is a critical factor in determining its environmental pollution. The permissible limit is 50 ppb in potable water and 1.7 ppm in effluent water for Cr (VI).

A number of soil processes and factors may affect the form and fate of Cr. It is important to understand the chemistry of Cr in the soil, because soil is the medium from which plants absorb available Cr. Chromium usually enters into the environment from industry in the form of CrVI. However, CrVI is a strong oxidant, and can be easily reduced to CrIII and other intermediate states between CrVI and CrIII (Cary et al., 1977b). The transformation of CrVI to CrIII within soils is likely to occur as a result of reduction by ferrous Fe in solution and in minerals, reduced sulfur compounds, or soil organic matter. The amount of reduction of dichromate by soil is often used as a measure of soil organic matter (Nelson and Sommers, 1982). The reduction of CrVI to CrIII by organic matter is more rapid in acid than in alkaline soils (Cary et al., 1977b). ChromiumVI is generally considered to pose the greatest human health risk because it is more toxic, more soluble and more mobile than CrIII. Because CrVI can be so easily reduced to CrIII, under most soils conditions, CrIII can be expected to be the predominant form.

Chromium is present in soil as relatively unavailable, insoluble oxides. It also substitutes (as Cr^{3+}) for Al^{3+} in the [AlO_6] groups of aluminosilicates to become part of the mineral structure. Addition of chelated Cr to soils to promote plant absorption would be expected to rapidly transform to Cr oxide and the more stable iron chelate. Chromates would not be stable in soils except perhaps in an alkaline, oxidizing environment. Chromic ion (+6) does not exist in solution, but rather complexes with water and other anions under acid conditions. In an alkaline solution it forms polynucleated hydroxyl compounds. Soil Cr is sometimes mobilized when soils are flooded and then drained or incubated with organic matter, presumably by the production of soluble organic complexing agents, but no increase in the availability of Cr to plants on poorly drained soils has been reported. It should be noted that Cr is so tenaciously held by certain synthetic cation exchange resins that it can be removed only by ashing the resin (Lisk, 1972).

The solubility of CrIII in soil is dependent on pH (Palmer and Wittbrodt, 1991). At pH values less than 3, the predominant form of CrIII in a CrIII-H_2O system is Cr^{3+}. With increasing pH, CrIII will be hydrolyzed. The most important species are $CrOH^{2+}$, $[Cr(OH)_3]^0$, and $[Cr(OH)_4]^-$, with $[Cr(OH)_2]^{2-}$ occurring in the very narrow pH range between 6.27 and 6.84. ChromiumIII can form complexes with several organic ligands and polymers. ChromiumIII remains in solutions containing citric acid and DTPA at much higher pH than in water (James and Bartlett, 1983). Although oxidation of CrIII to CrVI is possible, it is restricted to oxidation by manganese oxides (Palmer and Wittbrodt, 1991). Oxidation only occurs under moist conditions, not in dry soils (Bartlett and James, 1979), and increases with decreasing pH (Eary and Rai, 1987).

Adsorption of CrIII by organic matter and other negatively-charged components is one of the factors limiting its availability for plant uptake (James and Bartlett, 1983), while CrVI, which exists in anionic form, can be adsorbed by positively-charged soil components such as Al and Fe oxides (Palmer and Wittbrodt, 1991). Generally, the adsorption of CrVI should be lower at neutral to alkaline pH than at more acidic pH values. The intensity of adsorption will depend on soil type and the type and quantity of soil components. Any factor which can change the chemistry of Cr will result in a change in its availability for plant uptake, e.g., adding citric acid (James and Bartlett, 1984) or synthetic chelators (Wallace et al., 1976) to soil or heating soil (Hafez et al., 1979) increased the solubility of soil Cr.

The Role of Chromium

Chromium is essential in humans and animals for glucose metabolism. Chromium (III) is bound almost entirely to a sidreophilin protein at unfilled iron-bonding sites. Chromium (VI) easily penetrates the cell wall. There is no evidence that Cr has any physiological function in plants. Chromium is toxic for agronomic plants at about 0.5 to 5.0 ppm in nutrient solution and 5 to 100 ppm of available Cr in soil .

Plant Uptake of Chromium

Chromium is not essential for plant growth and development, although some studies indicated that at low concentrations (1 μM), Cr stimulated plant growth (Bonet et al., 1991). Chromium is required for animal and human metabolism. At high concentrations (>1-2 μg/ml), Cr is toxic to plants. Under normal conditions, the concentration of Cr in the plant is <1 ppm. As a result, its uptake by plants should be mainly non-specific, probably as a result of plant uptake of essential nutrients and water. Plants can absorb both Cr^{6+} and Cr^{3+}. Chromate (VI) uptake is active whereas Cr^{3+} uptake is passive, demonstrating that the two forms do not share a common uptake mechanism. Evidently Cr (III) and Cr (VI) enter the vascular tissue with difficulty but once there can be readily transported. Once in the xylem, CrO_4^{2-} is more easily transported than Cr^{3+}, presumably because the latter is held up by ion exchange on the vessel walls. This would also explain why Cr-EDTA moves faster than Cr^{3+} into shoots. The only occurrence of Cr represented in xylem sap of *Leptospernum scoperium* was as a tri-oxalate Cr(III) complex.

Many studies have reported that plants absorb Cr^{6+} better than Cr^{3+} based solely on plant concentration data and the observation that CrVI is more toxic to plants than CrIII (Hara and Sonoda, 1979; Lee et al., 1981; Peterson and Girling, 1981).. Chromate (VI) was reported to be more toxic to the growth of barley in solution culture than chromic chloride (Skeffington et al., 1976). The evidence for these conclusions is not completely convincing, because the solubility of CrVI and CrIII is not comparable under the same conditions (McGrath, 1982). In a study of Cr uptake by oat, McGrath (1982) used a flowing culture technique which maintained equal concentrations of soluble Cr^{6+} and Cr^{3+}, and found that the plants absorbed Cr^{6+} and Cr^{3+}

equally well. Using metabolic inhibitors, Shewry and Peterson (1974) and Skeffington et al. (1976) demonstrated that plant uptake of Cr^{6+} was an active process, while uptake of Cr^{3+} was a passive process, that is, no energy was required. If this is the case, it is logical to conclude that plants should be able to continuously absorb CrIII, if it is soluble in the medium.

Plant species differ greatly in Cr uptake capacity and distribution. In an attempt to find approaches to increase Cr content of food crops, Cary et al. (1977a) compared Cr uptake by various dicot and monocot food crops and found that, in general, dicots such as buckwheat and rutabaga took up more Cr in both root and shoots than monocots such as corn and barley. The reason for this difference between dicots and monocots is unknown, however, the differences in root properties, transpiration rate and metabolism between the two groups of plants could be among the reasons. This phenomenon may suggest to us that we should look at dicots for Cr hyperaccumulator plants. Interestingly, several previously identified Cr hyperaccumulator plants are dicots. Although most plants can not hyperaccumulate Cr, a few plant species have evolved to hyperaccumulate Cr when grown on high Cr sites. Wild (1974) has reported extraordinary high concentrations of Cr in leaves of *Dicoma niccolifera* (1,500 µg/g dry weight) and *Sutera fodina* (2,400 µg/g) (Baker and Brooks, 1989) (both species were located in Zimbabwe), while *Lepertospermum scoparium* from an abandoned chromite mine in New Zealand contained up to 1% Cr (Lyon et al., 1971). Another species from Zimbabwe, *Pearsonia metallifera*, was also reported to contain high concentrations of Cr (Wild, 1974).

Phytotoxicity of Chromium

Chromium has a direct toxic effect on roots and an indirect effect on leaves. Chromium (VI) seems to act principally on plant roots, causing intense growth inhibition. Chlorosis, which appears in the upper leaves of Cr-toxic plants, has been proposed as an indirect effect of Cr, probably on Fe and Zn translocation. The primary toxic effect seemed to be membrane damage due to the high oxidation power of Cr (VI). It was suggested that Cr is retained in vacuoles and cell walls of roots and that the Cr reaching the leaves may be principally from Cr (III) retained in the cell wall (Vazquez et al., 1987).

Chromium and Ni are trace elements which are potentially toxic to higher plants at total tissue concentrations of >=0.1 mmol/kg dry weight (Mengel and Kirkby 1982). Natural soil concentrations of total Cr and Ni are generally <2mmol/kg (Gasser et al., 1995). Anthropogenic input (e.g. from tanneries, smelters or sewage sludge application) can increase the total concentrations of these metals in soils to >50 mmol/kg, which may be toxic to plants (Adriano 1986).

Mechanisms of Chromium Hyperaccumulation by Plants

Few Cr hyperaccumulator species have been identified to date, which is in contrast with Ni, for which numerous hyperaccumulators have been identified (Baker and Brooks, 1989). The species found to accumulate Cr are largely exotic. Research into the mechanisms of Cr hyperaccumulation is surprisingly scarce. For plants to be able to hyperaccumulate Cr from soil, where most Cr exists as insoluble CrIII, the plants have to be efficient in a series of processes including solubilization of Cr in soil, absorption of soluble Cr, and translocation, compartmentation, and detoxification of absorbed Cr within plant. The failure of any of these processes will prevent the plants from hyperaccumulating Cr from soils. Given the chemistry of Cr in the soil, solubilization of Cr could be a limiting process. Several studies have reported that plant uptake of Cr increased with increased soluble Cr in the media (Cary et al., 1977a; McGrath, 1982). If the plant releases a Cr chelator or decreases the rhizosphere pH, both of which both can increase the solubility of CrIII in the soil, the plant could have the potential to hyperaccumulate Cr.

The plant species *Leptospermum scoparium* J.R. et G. Forst (Myrtaceae) is an accumulator of Cr and there is a highly significant correlation between plant and soil concentration (Lyon et al., 1968). This species can accumulate up to 20,000 ppm Cr in the foliage ash when grown on serpentine soils. Despite the low solubility of Cr there are other species that contain large amounts Cr (Table 2). Peterson (1975) reported 48,000, and 30,000 ppm of Cr in the ash of *Sutera fodina*, and *Dicoma niccolofera*, respectively.

Factors Which Influence Chromium Toxicity

Redox potential and pH. James and Bartlett (1983a,b) investigated Cr reactions in soil. Chromate (CrO_4^{2-}) reduction is likely to occur in soil environments having a substantial organic matter level and an acidic reaction. Chromate adsorption was significant in soil environments exhibiting spodic horizons, noncrystalline clays or sesquioxides. Phosphate ($H_2PO_4^-$) was shown to inhibit CrO_4^{2-} adsorption in equilibrated soil suspensions, especially when phosphate addition was prior to chromate addition. A buffered phosphate solution was able to displace a portion of the adsorbed chromate. The extend of chromate displacement was dependent on pH and the nature of adsorbing surface. Thus, phosphate and chromate are potentially competitive species for surface sites.

Heating enhanced the solubility of soil Cr by at least two oxidative reactions: 1) the destruction of relatively heat-stable, probably organic, complexes with the release of Cr (III), and 2) the oxidation of free Cr (III) to Cr (VI) (Hafez et al., 1979).

Chromate is in pH-dependent equilibrium with other forms of Cr(VI) such as $HCrO_4^-$ and dichromate ($Cr_2O_7^{2-}$), with CrO_4^{2-} being the predominant form at pH>6. Dichromate in soil will tend to be reduced to Cr^{3+} by organic matter, making interconversion between the various forms of soil Cr a possibility.

Movement of Cr from soil to plant depends on the oxidation state of Cr and specific Cr compounds or complexes. Chromium (III) can be oxidized to Cr (VI) in natural systems by Mn oxides or organic chelating agents, and Cr (VI) reduction to Cr (III) can be accomplished by organic matter, Fe, and sulfides (equation 1).

$$Cr_2O_7^{2-} + 14H^+ + 6e = 2Cr^{3+} + 7H_2O \qquad (1)$$

Coprecipitation of Fe (III) and Cr (III) will stabilize and immobilize Cr.

Organic chelates. Chromium (VI) is more soluble and mobile than Cr (III). Chromium (III) in citric acid (1:1) remained soluble up to pH 7.0 to 7.5. Chromium (III) in citric acid (1:10) remained soluble above pH 7.5. Chromium (III) in water (no organic ligand added) was precipitated between pH 4.5 and 5.5. Chromium (VI) is reduced to Cr (III) under most soil conditions. There are no naturally occurring minerals containing Cr (VI). Minerals containing Cr (III) are mixed oxides of Cr (III) and Fe, for example, olivine in serpentine soils.

Concentrations of Cr in fescue increased only slightly or not all when grown with chrome tannery waste (Stomberg et al., 1984). Tannery wastes contain large amounts of Cr (10,000 ppm). Chromium in tannery waste is in the Cr (III) form. Applied Cr at 100 mg/kg soil had no adverse effect on cotton grown on a Yolo loam soil (Rehab and Wallace, 1978). The Cr source was $Cr_2(SO_4)_3$.

Calcium. Calcium (Ca) can modify the effects of excess heavy metals on plants and in some cases largely overcome the effect of the heavy metal. Excess heavy metal can also decrease uptake and translocation of Ca in plants. Alleviation of Ni toxicity at high Ni concentrations was shown in the presence of high background concentrations of Ca (Heikal et al. 1989).

High Pb-constitutional tolerance is associated with Ca-deficit tolerance and a high Ca status of a plant (Antosiewicz, 1993). *Silene inflata* populations were more Pb-tolerant than *Biscutella lavigata.* The high lead tolerance of the *Silene* populations was accompanied by their high Ca status and tolerance to Ca deficit (Antosiewicz, 1995). Chromic ion toxicity is alleviated by Ca ions and Cr toxicity was less likely in calcareous soils. *Leptospernum scoparium* can tolerates very high Cr and also has a high Ca concentration in the plant tissue.

Interactions with other elements. Chromium (VI) application significantly increased the available Fe in soil. The reduction of Cr(VI) and a decrease in soil pH may have contributed to higher Fe availability (Jaiswal and Misra, 1984). Cary et al. (1977) observed a positive relationship between Cr and Fe concentration in different organs of different plants grown on adjacent fields. They concluded that the plants which accumulate Fe will also accumulate Cr.

The absorption of Fe by spinach increased with low levels of application of Cr (VI), however, at higher Cr concentrations the translocation of Fe to seeds decreased (Misra and Jaiswal, 1982). Plants that accumulate Fe and Ni may also accumulate Cr. Chromium and Ni toxicity was not observed when the Ni/Fe ratio was <1. Chromium also caused necrosis and chlorosis similar to Fe deficiency.

There is a mutually antagonistic effect between Cr and Si or Phosphate. Silicon and P increased Cr uptake. Chromate application in an acid soil increased pH and CEC (similar to the phosphate self liming effect).

Plant uptake and transformations. Tri-and hexa-valent Cr were both absorbed by oat and were equally toxic when supplied at 2 to 200 μM in nutrient solution. The proportion of Cr translocated to the shoots was similar, regardless of the form supplied to roots. Adding 750 ug of hexavalent Cr per g of either acid or alkaline soil resulted in high, toxic concentrations of Cr in soil solution. The same amount of trivalent Cr gave a lower concentration in the soil solution, with higher soil solution Cr present in acid compared to alkaline soils (McGrath, 1982). Chromium toxicity can occur when soil is contaminated with Cr (VI) and the pH is high or when soil is contaminated with Cr (III) or Cr (VI) and the pH is low. In this case Cr (VI) will be reduced to Cr (III) which will equilibrate with the soil solution. Chromium is precipitated at higher pH values as the Cr (III) hydroxide and is unavailable to plants.

The transformation of applied Cr (III) and Cr (VI) was influenced by Fe^{2+}, Fe^{3+}, Mn^{2+}, and Mn^{4+}, with or without glucose addition under varying periods of flooding in three soils, an inceptisol, an ultisol and a vertisol (Das et al, 1991). The results showed a significant reduction of Cr (VI) conversion to Cr (III) that was further enhanced by the presence of Fe and glucose. The ability of these soils to convert soluble Cr to an unavailable form was in the order: vertisols>inceptisols>ultisols.

Although Cr (III) is not a significant hazard in itself, the potential for oxidation to Cr (VI) can make its risk tantamount to that of the hexavalent form. In natural systems, manganese oxides have proven to be the only compound capable of oxidizing Cr (III) to Cr (VI). Manganese oxides appear to be capable of oxidizing Cr(III) to Cr (VI), while organic material, sulfides, and ferrous species appear to be the dominant reductants (Fendorf, 1995). The low solubility of Cr(III) coupled with its strong retention on soil surfaces limits its bioavailability and mobility in soils and waters.

Plants must have the ability to translocate the Cr from the root to the shoot or to compartment it, in order for the plant to continue absorption of Cr from the medium, because a high concentration of Cr is toxic to plants. There are at least two advantages to the plant for translocation: 1) it can reduce Cr concentration and thus avoid toxicity to the root, and 2) translocation to the shoot is one of the mechanisms of resistance to high Cr, because for some plants the high concentration of Cr will be lost when leaves fall in the autumn. Unfortunately, most research using non-hyperaccumulator plants has shown that Cr is mainly accumulated in the roots and much less of the total Cr in a plant is in the leaves (Shewry and Peterson, 1974; Cary et al., 1977a). The distribution of Cr between root and shoot in hyperaccumulator plants, however, indicated that the leaves also contained a much higher Cr concentration than that of non-hyperaccumulator plants, suggesting better translocation of Cr from root to shoot for hyperaccumulator plants. Although the detailed mechanisms of Cr translocation are not understood, there are reports that Fe-deficient and P-deficient plants can better translocate Cr from roots to shoots (Cary et al., 1977a; Bonet et al., 1991). These results lead to the hypothesis that Fe- and P-deficiency induced accumulation of organic acids, e.g., citric acid (Landsberg, 1981; Ric De Vos et al., 1986; Johnson et al., 1994), may play an important role in Cr translocation. Using a hyperaccumulator plant *Leptospermum scoparium*, Lyon et al. (1969a,b) found that soluble Cr in leaf tissue was present as the trioxalatochromate (III) ion, $[Cr(C_2O_4)_3]^{3-}$. It is known that even when taken up as Cr^{6+}, Cr will soon be reduced in the plant to Cr(V), Cr(IV) and finally Cr(III) (Micera and Dessi, 1988). Chromium(III) should be insoluble at the physiological pH so organic acids must increase the solubility of Cr(III) within the plant, thus enhancing Cr translocation. James and Bartlett (1983) proved that the solubility of Cr^{3+} in citric acid can be maintained up to pH 7.5. These data suggest that hyperaccumulator plants which translocate more Cr than non-hyperaccumulator plants probably have a different metabolism from that of non-hyperaccumulator plants. More organic acids or other organic compounds are produced to increase Cr translocation from root to shoot

Iron is translocated as an Fe(III)-citrate complex (Tiffin, 1966) while Ni is readily complexed by organic acids and is very mobile in the plant. A majority of the Ni in the plant is present in leaves rather than in the roots (Baker and Brooks, 1989). Soluble Cr concentration is positively correlated with Fe (Cary et al., 1977a) and Ni (Shewry and Peterson, 1976) in plant leaves and roots. The positive correlation indicates that some Fe or Ni hyperaccumulator plants may also be Cr hyperaccumulators, and implies that Cr may have similar translocation and compartmentation mechanisms to those of Fe and Ni.

There is no information in the literature about Cr compartmentation in plants The vacuole is considered to be the major storage site for most other heavy metals (e.g., Cd, Zn, Mn, Ni), (Wagner et al., 1995). We know little about the form and fate of Cr in plants and how plants detoxify Cr so it will be very important to determine where Cr is compartmented. After finding that much of the soluble Cr in leaf tissue of *Lyptospermum scoparium* existed was present in a complexed form with organic acids, Lyon et al. (1969a,b) assumed the function of the Cr-organic acid complex was to reduce the cytoplasmic toxicity of Cr. There is no concluding evidence for this assumption.

RESEARCH PLAN

Compared with other heavy metals, our knowledge of Cr in plants is surprisingly limited. There are many areas in which research is needed. Research is needed using hyperaccumulator and non-hyperaccumulator plants. Unfortunately, few hyperaccumulator plants have been discovered and many of these plant species are exotic. Therefore, our task is to find hyperaccumulator plants from our own screening. After we identify hyperaccumulator plants, we will use these plants and non-accumulator plants to study the mechanisms that are responsible for hyperaccumulation.

Experimental approach for selecting hyperaccumulators. Chromium is not an essential element for plants and, since it is present as insoluble (Cr III), it is difficult for plant roots to extract Cr from soils. In addition, it appears to react with plant nutrients once inside the roots, reducing the amount translocated from the roots to the shoots. Based on the literature review and the above information we have initiated laboratory, growth chamber and pot experiments to identify Cr hyperaccumulator plants. Phase 1 of this investigation is a program to test plant species (Table 2) that can accumulate more than 500 ppm Cr in their shoots. We will screen hyperaccumulator plants previously identified by others and also screen other species which are chosen because of plant characteristics believed to be important in Cr hyperaccumulation. A partial list of the species we intend to screen are presented In Table 2. Screening experiments will be conducted in hydroponic systems and in soil. Soils will be conditioned to increase Cr solubility and its availability for plant uptake. Organic chelates have been used extensively to increase the activity of heavy metals in soil solution. Ethylenediaminetetraacetic acid (EDTA) greatly increased Ni and Fe concentrations in bush beans and in barley grown in a Yolo loam soil (Wallace et al, 1977).

Screening for hyperaccumuator plants. For screening, we will use a 1/2 strength Hoagland hydroponic culture. Considering that CrIII is the major form of Cr in the soil, Cr(III) ($CrCl_3$) will be used as a Cr source. However, to differentiate the processes to be screened, two different CrIII sources will be employed. One is soluble Cr(III) which will be retained in a soluble form throughout the experiment. This will require an in-depth chemical equilibrium evaluation to determine pH and chelate buffering conditions that are required to keep CrIII in solution. This system can be used to screen plants for absorption, translocation, compartmentation, and resistance. The other Cr source is freshly precipitated Cr(III) hydroxide. The solubility of the hydroxide will be dependent on the conditions of the nutrient solution. Plant roots can have a significant effect on solution chemistry so this system will be used to screen for Cr solubilization and mobilization.

After plants are grown to the desired growth stage, they will be harvested. Plant size and dry matter production are important criteria since phytoremediation depends on total metal harvest (metal concentration times plant biomass) by a metal accumulating plant. The biomass of both roots and shoots will be recorded. Chromium concentrations in shoots and roots will be determined using wet digestion and atomic absorption spectrophotometry. Alternatively, a radioactive Cr source will be used to evaluate Cr uptake. All plants will be ranked and hyperaccumulator plants will be identified. For some species, fresh samples will also be taken to determine the distribution of Cr in the root apoplast and symplast.

Studies on mechanisms of hyperaccumulation by plants. Hyperaccumulation can be limited by any of a series of processes from mobilization to absorption to translocation and compartmentation. The plant plays a decisive role in each of these processes. The difference in Cr accumulation between plant species is due to differences in these processes. The purpose of this part of the project is to identify the plant processes or components that lead to hyperaccumulation of Cr by plants

Plant chemistry of hyperaccumulator plants. Under a given soil condition where Cr is not soluble, plants that can hyperaccumulate Cr from soil must be able to solubilize Cr. This part of the research deals with Cr solubilization and translocation related plant factors such as root exudates or excretion and organic composition in the root and in the xylem. By comparing hyperaccumulator and non-hyperaccumulator plants, it can be determined if any of these factors are critical for Cr hyperaccumulation. Proton release from the root and root reducing or oxidizing capacity will be measured along with organic acids and other compounds released from the root, e.g., phytosiderophores, using HPLC and mass spectroscopy. Chromium exposure induced changes in these aspects for both hyperaccumulator and non-hyperaccumulator plants will be monitored. After a significant component is identified, its will be confirmed by comparing Cr accumulation by plants with and without the component. The metabolism of the component in the plant will be studied by examining related biochemical pathways and important enzymes involved.

Kinetics of metal uptake by plants. To hyperaccumulate Cr, the plant must absorb soluble Cr from the medium into the cell. This experiment will evaluate absorption related characteristics of both hyperaccumulator and non-hyperaccumulator plants by determining Cr uptake by whole plants and with excised roots and shoots over a range of Cr concentrations. From this experiment, we can determine whether the process of Cr absorption, that is, passing of Cr through the root plasma membrane, is a limiting factor for Cr hyperaccumulation. If absorption is found to be a limiting factor in hyperaccumulation, isolated plasma membrane will be used to perform influx analysis and the relative importance of biochemical components of the plasma membrane will be determined using reconstituted plasma membrane.

Subcellular chemistry of Cr in hyperaccumulator plants. How a plant stores the absorbed Cr, that is, where and in what form Cr is stored within cells, is important to detoxification of Cr and thus the success of hyperaccumulation. These experiments will localize the stored Cr in cells of roots and shoots by isolation of different organelles and determination of Cr concentration in each of the organelles. The chemical forms of Cr in the organelles will be determined by examining tissues of root, shoot and the isolated organelles using electron paramagnetic resonance (EPR) spectroscopy and x-ray absorption near-edge structure (XANES) spectroscopy.

Soil studies. Two groups of plants, three soils, and selected treatments will be tested in soil experiments. Agronomic non-hyperaccumulators crops and hyperaccumulating plants (Table 2) will be tested. Selection of plants will be depend on the results of hydroponic experiments for high Cr accumulations. Three groups of soils with varying Fe, Mn, and Ca will be collected in Texas. Treatments applied to these soils will include management practices that will maximize Cr availability. Parallel studies will also be conducted with Ni to simulate the serpentine soil solution. Sorption, desorption and kinetic studies will be conducted to determine which practices will maximize Cr mobilization in soils.

REFERENCES

Adriano, D.C. 1986. Trace elements in the terrestrial environment. Springer Verlag, Berlin, Germany. 533 pp.

Andrew, J., C. Smith, U. Kramer, and J.M. Baker. 1995. Role of metal transport and chelation in nickel hyperaccumulation in the genus Alyssum. Fourteenth Annual Symposium, University of Missouri-Columbia. Current topics in plant biochemistry, physiology and molecular biology, April 19-22, 1995. pp 9-10.

Antosiewicz D.M. 1993. Mineral status of dicotyledonous crop plants in relation to their constitutional tolerance to lead. Env. Exp. Bot. 33:575-589.

Antosiewicz D.M. 1995. Higher Pb tolerance of a plant is accompanied by higher tolerance to Ca deficit. Uni. of Colombia

Baker, A.J.M. 1981. Accumulators and excluders-strategies in the response of plants to heavy metals. Journal of Plant Nutrition. 3:643-654.

Baker A. J. M. and R. R. Brooks. 1989. Terrestrial higher plants which hyperaccumulate metallic elements -- A review of their distribution, ecology and phytochemistry. Biorecovery 1:81-126.

Baker, A.J.M., R.D. Reeves, and A.S. M. Hajar. 1994. Heavy metal accumulation and tolerance in British populations of the metallophyte *Thlaspi careulescens* J.&C. Presl (Brasssicaceae). New Phytol. 127:61-68.

Baker, A.J.M. R.D. Reeves, and S.P. McGrath. 1991. In situ decontamination of heavy metal polluted soils using crops of metal accumulating plants? A feasibility study. In In situ Bioreclamation; Hinchee, R.L., Olfenbuttel, R.F., Eds.; Butter-worth-heinemann: Boston.

Bartlett R. and B. James. 1979. Behavior of chromium in soils: III. Oxidation. J. Environ. Qual. 8:31-35.

James B. R. and R. J. Bartlett. 1983. Behavior of chromium in soils. V. Fate of organically complexed Cr(III) added to soil. J. Environ. Qual. 12:169-172.

James, B.R. and R.J. Bartlett. 1983a. Behavior of chromium in soils. VI. Interactions between oxidation-reduction and organic complexation. J. Environ. Qual. 12:173-176.

James, B.R. and R.J. Bartlett. 1983b. Behavior of chromium in soils. VII. Adsorption and reduction of hexavalent forms. J. Environ. Qual. 12:177-181.

James B. R. and R. J. Bartlett. 1984. Plant-soil interactions of chromium. J. Environ. Qual. 13:67-70.

Johnson J. F., D. L. Allan and C. P. Vance. 1994. Phosphorus stress-induced proteoid roots show altered metabolism in *Lupinus albus*. Plant Physiol. 104:657-665.

Landsberg E-C. 1981. Organic acid synthesis and release of hydrogen ions in response to Fe deficiency of mono- and dicotyledonous plant species. J. Plant Nutr. 3:579-591.

Lee C. R., T. C. Sturgis and M. C. Landin. 1981. Heavy metal uptake by marsh plants in hydroponic solution cultures. J. Plant Nutr. 3:139-151.

Lisk, D.J. 1972. Trace metals in soils, plants, and animals. Advance in Agron. 24:267-325.

Lyon, G.L., R.R. Brooks, P.J. Peterson, and G.W. Butler. 1967. Trace elements in a New Zealand serpentine Flora. Plant and Soil. 29:225-240.

Lyon G. L., P. J. Peterson, R. R. Brooks. 1969a. Chromium-51 distribution in tissues and extracts of *Leptospermum scoparium*. Planta 88:282-287.

Lyon G. L., P. J. Peterson, R. R. Brooks. 1969b. Chromium-51 transport in the xylem sap of *Leptospermum scoparium* (Manuka). N.Z. J. Sci. 12:541-545.

Lyon G. L., P. J. Peterson, R. R. Brooks and G. W. Butler. 1971. Calcium, magnesium and trace elements in a New Zealand serpentine flora. J. Ecol. 59:421-429.

McGrath S. P. 1982. The uptake and translocation of tri- and hexa-valent chromium and effects on the growth of oat in flowing nutrient solution and in soil. New Phytol. 92:381-390.

McGrath, P.S., C.M.D. Sidoli, A.J.M. Baker and R.D. Reeves. 1993. The potential for the use of metal-accumulating plants for the *in situ* decontamination of metal-polluted soils. p. 673-

676 *In* Integrated Soil and Sediment Research: A Basis for Proper Protection, H.J.P Eijsackers and T. Hamers (eds.), Kluwer Academic Publishers, Dordrecht.

Mengel, K. and E.A. Kirkby. 1982. Principals of plant nutrition. International Potash Institute, Bern, Switzerland. 655 pp.

Micera G. and A. Dessi. 1988. Chromium adsorption by plant roots and formation of long-lived Cr(V) species: An ecological hazard? J. Inorg. Biochem. 34:157-166.

Misra, S.G. and P.C. Jaiswal. 1982. Absorption of Fe by spinach on chromium (VI) treated soil. J. Plant Nutr. 5:755-760.

Morrey, D.R. and M.J. Balkwill. 1989. Studies on serpentine flora: Preliminary analyses of soils and vegetation associated with serpentine rock formations in the south-eastern Transvaal. S. Afr. J. Bot. 55:171-177.

Nelson D. W. and L. E. Sommers. 1982. Total carbon, organic carbon, and organic matter. *In* Methods Of Soil Analysis, Part 2. R. C. Dinauer (ed.). American Society of Agronomy, Inc. and Soil Science Society of America, Inc., Madison, WI. pp. 539-580.

Palmer C. D. and P. R. Wittbrodt. 1991. Processes affecting the remediation of chromium-contaminated sites. Environmental Health Perspectives 92:25-40.

Peterson P. J. and C. A. Girling. 1981. Other trace metals: Chromium. In: Effect of Heavy Metal Pollution on Plants. Vol. 1, N. W. Lepp (ed.), Applied Science Publishers, pp. 222-229.

Rehab, F.I., and A. Wallace. 1978. Excess trace metal effects on cotton: 4. Chromium and lithium in Yolo loam soil. Commun. Soil Sci. Plant Anal. 9:645-651.

Rauser, W.E. 1990. Phytochelatins. Annu. Rev. Biochem. 59:61-86.

Reeves, R.D. and A.J.M. Baker. 1984. Studies on metal uptake by plants from serpentine and non-serpentine populations of *Thlaspi goesingense* Halacsy (Cruciferae). New Phytologist. 98:191-204.

Ric De Vos C., H.J. Lubberding and H. F. Bienfait. 1986. Rhizosphere acidification as a response to iron deficiency in bean plants. Plant Physiol. 81:842-846.

Salt, D.E., I.Raskin. 1995. Cadmium transport and accumulation in plants. pp. 23-24.

Sauerbeck, D.R., and A. Hein. 1991. Nickel uptake from different soils and its predictions by chemical extractions. Water, Air, and Soil Pollution. 57:861-871.

Shewry P. R. and P. J. Peterson. 1974. The uptake and translocation of chromium by barley seedlings (Hordeum vulgare L.). J. Exp. Bot. 25:785-707.

Shewry P. R. and P. J. Peterson. 1976. Distribution of chromium and nickel in plants and soil from serpentine and other sites. J. Ecol. 64:195-212.

Skeffington R. A., P. R. Shewry and P. J. Peterson. 1976. Chromium uptake and transport in barley seedlings (*Hordeum vulgare* L.). Planta 132:209-214.

Soane, B.D., and D.H. Saunder. 1959. Nickel and chromium toxicity of serpentine soils in southern Rhodesia. soil Sci. 84:322-329.

Stmoberg, A.L., D.D. Hemphill, V.V. Volk, and C. Wickliff. 1984. Tall fescue response and soil properties following soil amendment with tannery wastes. Agron. J. 76:719-723.

Terry, N., C. Carlson, T.K. Raab, and A. Zayed. 1992. Rates of Se volatilization among crop species. J. Environ. Qual. 21:341-344.

Tiffin L. O. 1966. Iron translocation. I. Plant culture, exudate sampling, iron-citrate analysis. Plant Physiol. 41:510-514.

Vazquez, M.D., CH. Poschenrieder, and J. Barcelo. 1987. Chromium VI induced structural and ultrastructural changes in bush bean plants (*Phaseolus vulgaris* L.). Annals of Botany. 59:427-438.

Wagner G. J., D. Salt, G. Gries, K. Donachie, R. Wang and X. Yan. 1995. Biochemical studies of heavy metal transport in plants. p. 21-22. *In* Proceedings/Abstracts of the Fourteenth Annual Symposium, Current Topics in Plant Biochemistry, Physiology and Molecular Biology. University of Missouri, Columbia.

Wallace, A., E.M. Romney, J.W. Cha, S.M. Soufi and F.M. Chaudhry. 1977. Nickel phytotoxicity in relationship to soil pH manipulation and chelating agents. Commun. Soil Sci. Plant Anal. 8:757-764.

Wallace, A., E.M. Romney, J.W. Cha, S.M. Soufi and F.M. Chaudhry. 1977. Nickel phytotoxicity in relationship to soil pH manipulation and chelating agents. Commun. Soil Sci. Plant Anal. 8:757-764.

Wallace A., S. N. Soufi and J. W. Cha. 1976. Some effects of chromium toxicity on bush bean plants grown in soil. Plant Soil 44:471-473.

Wild H. 1974. Indigenous plants and chromium in Rhodesia. Kiekia 9:233-241.

Table 1. Numbers of metal hyperaccumulators plants based on all records available as of March, 1995

Metal	Concentration (% in leaf dry matter)	No. of taxa	No. of families
Cd	>0.01	1	1
Co	>0.1	26	12
Cu	>0.1	24	11
Pb	>0.1	5	3
Ni	>0.1	>300	35
Mn	>1.0	8	5
Zn	>1.0	18	5

Number of Ni hyperaccumulator taxa > 300 in 35 families and that commonly have 3-4% Ni in leaves dry matter but may range to as high as 25%.

Table 2. Preliminary list of plant species to be collected for metal hyperaccumulation studies.

Nickel Hyperaccumulators

Brassica juncea L. Indian Mustard.

Streptanthus polygaloides Gray (Brassicaceae).

Silene spp.(S.*vulgaris, S. burchelli, S.cobaltica, S.nflata, S. diocia*). (Caryophyllaceae) (>10,000 ppm Ni). Select varieties with the highest dry matter production

Thlaspi s pp. (*T.caerulescens,T. montanum,T. ochroleucum*) (Brassicaceae)

Alyssum spp. (BRASICACEAE) (*A.argentum, A. corsicum, A. euboeum, A. helderechii, A. murale, A. enium, A. troodii*)

Chromium hyperaccumulators

Leptospermum scoparium J.R &G. Frost. (Myrtaceae) (20,000 ash weight) (2,470 ppm) (small bush, common in New Zealand) Lyon et al. 1967)

Berkheya coddii (238 ppm dry weight) (Morrey et al. 1989)

Sutera sp. (Scophulariaceae) aff. *S. silenoides* (Morey et al. 1989; Wild,1974)

Sporbolus pectinatus Hack. (Graminae) (Morey et al., 1989)

Pimelea suteri Kirk (small endemic plants confined entirely to serpentine area)

Sutera fodina (Fabaceae) (48,000 ppm Cr in ash weight), (Lyon et al., 1968; Wild, 1974)

Andropogn gayanus (Poaceae) (690 ppm Cr in ash weight) (Wild, 1974)

Dicoma niccolifera (30,000 ppm Cr in ash weight) (Lyon et al., 1968)

Cassinia vauvilliersii (Homb et JacQ.) Hook. f.var serpentina (small bush, common in New Zealand) (Lyon et al., 1968)

Hebe odora (Hook. f.) (small bush, common in New Zealand) (Lyon et al. 1968)

Agronomic Plants

Lolium perenne L., Perennial Ryegrass

TASK 4

Executive Summary

PROGRESS REPORT
Communication, Education, and Training Program Management
Period Covered: November 1, 1995 through January 31, 1996

Organization: Amarillo National Resource Center for Plutonium

Assistant Director for Communication, Education, and Training: Elda D. Zounar, Ph.D.

Executive Summary

During the reporting period, the Communication, Education, and Training Program was instrumental in accomplishing the following:

1. Sponsored a poster session on the ANRCP, the contributors of which were the investigators in this program;
2. Published the ANRCP brochure (included) and distributed 1500 internationally;
3. Published Issue III of the quarterly ANRCP newsletter dated January 1996 (included) and distributed 1500 internationally;
4. Published Request for Proposals (RFP) at 54 Texas Offices of Special Projects for FY '96 continuing and new projects (included);
5. Established a display presence for the ANRCP Science Information and Resource Center at the Don Harrington Regional Discovery Center (which includes 100 of each of three ANRCP newsletters and the brochure);
6. Initiated partnership agreements and drafted the partnership plan for the Science Information and Resource Center program with the Don Harrington Regional Discovery Center and with the Pantex Plant which therefore, gave guidance to the investigators on the Science Information and Resource Center task;
7. Contributed an article to the Pantex Plant Environmental Impact Statement (EIS) newsletter and initiated contributions to the Amarillo Globe News;
8. Coordinated presentations to the ANRCP Governing Board on the Electronic Resource Library (November 1995, Dr. Ruddy from Amarillo College), on-going environmental research at Pantex (December 1995, Dr. Charbeneau from the University of Texas), and light-water reactors (January 1996, Dr. Adams from Texas A&M);
9. Initiated the PU Text and Training partnership with Mason and Hanger (Pantex);
10. Recruited and subsequently, hired the Education Program Coordinator; and
11. Recorded 107 visitors to the ANRCP office in Amarillo, Texas.

Further, ANRCP personnel worked routinely and closely with the Principle Investigator Mr. Phillip T. Nash and investigators on the funded projects as their work progressed. Two subprojects were renamed to more accurately reflect the objectives of the ANRCP. One new subproject was approved by the Governing Board for which funding is imminent.

FINANCIAL REPORT

Expenditure histories are provided for each task. The expenditure histories show only expenditures by Texas Tech University through December 1995 and do not reflect expenditures by the subcontractors Amarillo College (except for the Academic Intervention task) and West Texas A&M University. Recently received billings from Amarillo College (approximately $90,000) and West Texas A&M (approximately $128,000) are currently being processed for payment. Several researchers will be paid salary during the spring semester and summer. These salary allocations do not appear on expenditures through December 1995.

Request for Proposals - Communication, Education, and Training Programs

January 1996

The Amarillo National Resource Center for Plutonium has entered into an agreement with the State of Texas to engage in specific activities in support of the Panhandle of Texas, the state of Texas, and the U. S. Department of Energy (DOE). To that end, the mission of the Center is to serve as a scientific and technical resource for information relating to the handling, storage, disposition, potential utilization, and transportation of plutonium, high explosives, and other materials generated from weapons assembly and disassembly.

This is a solicitation of proposals for communication, education, and training programs deemed essential for the Center to inform, educate, and train a wide and diverse audience about the quality work the Center undertakes through the nuclear and environmental programs (to carry out the agreement). The programs of interest here are not bound by geographic area but could focus on the Pantex Plant, the city of Amarillo and the Panhandle of Texas, the state of Texas, or the United States.

Governance and Eligibility

The Amarillo National Resource Center for Plutonium is governed by a Higher Education Consortium composed of The Texas A&M University System, Texas Tech University, and The University of Texas System. A lead institution from within one of these three entities will be designated for each of the technical programs to which proposals will be submitted, and a collaborative proposal from this institution will be invited. At least two University systems that are members of the governing consortium must be represented by a principal or co-investigator on this and every proposal submitted. Collaborative proposals, in addition to the invited collaborative proposal, also will be reviewed. Subgrantees or subcontractors from other academic institutions, laboratories, or for-profit entities are allowable provided their contribution is an integral part of the proposed work and/or they contribute to the cost sharing required for these programs. No single institution or organization proposal will be accepted.

Continuing and New Proposals

A collaborative continuing proposal for the subcontract period January 16, 1996 to January 15, 1997 has been invited from Texas Tech University. New proposals also will be accepted. Mr. Phil Nash is the coordinator for the continuing and new proposals. His mailing address at Texas Tech University is Department of Civil Engineering, P. O. Box 41023, Lubbock, Texas 79409-1023. He also can be reached by telephone at 806/742-2783, by facsimile at 806/742-3488, or electronically at pnash@coe1.coe.ttu.edu.

Collaborative new proposals for the subcontract period June 1, 1996 to January 15, 1997 must be preceded by a Letter of Intent addressed to Mr. Nash. The Letter of Intent must be received by February 13, 1996. It should not exceed two double-spaced pages. It must include: (a) a description of the proposed research or applied-research program; (b) clear statement of need for or value to a communication, education, or training program; (c) identification of the team of investigators who will work on the proposed program and the designated contact person; (d) the approximate cost of the program; and (e) an estimate of the percent of effort or resources that will be expended in Amarillo, Texas. Principal Investigators of accepted Letters of Intent will be asked to submit full proposals and draft task plans by March 15, 1996. An external peer review will be performed and Principal Investigators will be notified of award by May 10, 1996. Grants and subgrants will be in place to begin work by June 1, 1996.

General Considerations

Comprehensive and seamless communication, education, and training programs are required to fulfill the obligations of the Center. Proposals that interface with the nuclear and environmental programs are encouraged. Proposals that include matching funds from another source or that can document a high potential to receive such matching at the end of a demonstration period are strongly encouraged. Proposals that enable a grantee to provide matching funds required by another program will be considered only if it can be clearly demonstrated that the tasks performed therein will enhance the ability of the Center to accomplish its mission.

Communication, education, and training programs are objective-driven by a verifiable need to strengthen and elevate the American knowledge-base in science and mathematics with applications in associated career fields and implications for economic development. Research methods and program processes to attain the objectives must be clearly articulated. Results must be measureable and defensible. Outcomes of formative and summative program evaluation must result in logical conclusions drawn from the work and meaningful recommendations for future work.

Areas of Emphasis

Communication Program

The objective of this program is to continuously and accurately inform the various publics about handling, storage, disposition, potential utilization, and transportation of plutonium, high explosives, and other materials generated from weapons assembly and disassembly. Different technologies and methods of external communications and outreach will be considered but they must be grounded in communications theory.

(A) Electronic Resource Library is a continuing program. The broad spectrum of published materials on plutonium will be retrievable for a wide range of users from the casual browser to the serious student to the scientist.

(B) Science Information and Resource Center is a continuing program. This Center is both a source of information in which data that contribute to the latest knowledge-base are generated and a place to find and interact with that information. Center displays, exhibits, technologies, and activities must appeal to a wide audience that ranges from the casual observer to the most serious student and teacher of scientific data.

Education Program

The objectives of this program are to foster interest and contribute to higher levels of academic achievement in science and mathematics curricula at all grade and degree levels; promote the professional growth and development of primary and secondary teachers and professors in higher education; and further career opportunity in fields such as mathematics, environmental health and safety, and engineering in the Panhandle of Texas.

(A) Delivery methods of Distance Education is a continuing program. Audiences, purposes of distance education, and intended program outcomes apply not only across the Panhandle of Texas but also throughout the United States. Distance Education is focused on community outreach, K-16 and graduate education, and career-related training.

(B) K-16 Science and Mathematics Education is a continuing program. A repertoire of programs and projects are needed to support the national science and mathematics education initiative as stated in Goals 2000.

(C) Academic Intervention is project-based and competitive. Interventions that fit within the scope of the Center and satisfy needs, reduce discrepancies, or solve problems are encouraged. Projects that address curricular deficiencies and inequitable student opportunities are two examples of academic intervention projects.

Training Program

The objective of this program is to support the DOE.

(A) Plutonium-related training focuses on results of organizational needs assessment conducted at plutonium-handling site(s).

Additional Information

Contact the Center staff at the telephone, facsimili, and address as shown on the letterhead. Contact Dr. Elda D. Zounar, Assistant Director for Communication, Education, and Training at zounar@pu.org for program information.

TASK 4

Project Management

WORK PLAN PROGRESS REPORT
Communication, Education, and Training Project Management
Period Covered: November 1, 1995 through January 31, 1996

Institution:	Texas Tech University
Principal Investigator:	Phillip T. Nash
Sub-Contract Number:	UTA95-0206
Award Period:	June 1, 1995 to May 31, 1996

1. Summary of research activities during reporting period.

With guidance from the ANRCP, the following project and subprojects were renamed:

Original title	New title
Education and Public Outreach	Communication, Education, and Training
Program Management	Project Management
Information Center	Science Information and Resource Center

A proposal for the Science Information and Resource Center was submitted to the ANRCP Governing Board August 23, 1995 and was signed by Wayne Kuenstler January 29, 1996. Total subproject funding is $171,102 with effective dates from September 1, 1995 through May 31, 1996.

The ANRCP issued a request for continuance and new proposals for FY 96. Communication and Education project personnel met in Plainview, Texas January 26, 1996 to discuss project and subproject plans. Integration of subproject objectives and approaches was emphasized.

2. Tangible accomplishments.

One new project for FY 96 was initiated. Several individual subproject goals were accomplished and they will be discussed under their respective subprojects.

3. Approach changes. None

4. Performance variances. None

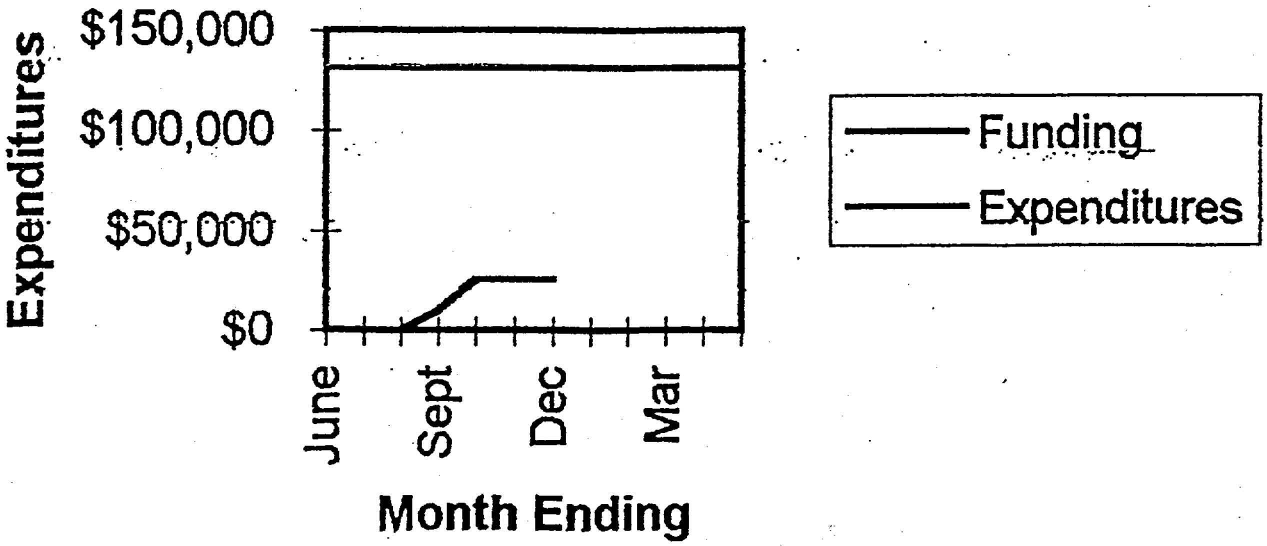
5. Open items.

No additional proposal was received for the Assess Public Knowledge subproject. The subproject is being dropped until the researcher decides to initiate action.

6. Status assessment and forecast.

Continuance proposals and new proposals for FY 96 funding are being developed.

Expenditures for Project Management



TASK 4

Academic Intervention

WORK PLAN PROGRESS REPORT
Academic Intervention
Period Covered: November 1, 1995 through January 31, 1996

1. Summary of research activities during reporting period.

Copies of the final report for AmarilloPREP '95 were sent to ANRCP, all major contributors, and to the TexPREP office at the University of Texas at San Antonio (UTSA).

Preparations for AmarilloPREP '96 were intensified in late November. Letters of solicitation were sent to the contributors list. Brochures, application packets, and information sheets were updated and printed.

Letters were sent to all school districts requesting updates on contact persons and informing the school administrators of the imminence of PREP materials. Information and application packets were sent to all area middle and high school contact persons.

A meeting of representatives of professional organizations interested in the PREP concept was held in Orlando, Florida January 12, 1996. The meeting was in conjunction with the Strengthening Under represented Minorities in Mathematics Achievement (SUMMA) and the Mathematics Association of America (MAA) Conferences which were held back-to-back in Orlando. SUMMA is part of MAA. Representatives of eight of the primary professional math and engineering minority organizations of the nation attended the meeting (see participant list in the Attachments). Strategies to introduce the PREP concept across the country, particularly in the community colleges, were discussed. A Board of Directors to forward the initiative is to be formed this spring.

2. Tangible accomplishments.

Materials and information procedures are on schedule for AmarilloPREP '96.

The study of the feasibility of National Initiative for PREP is organized and proceeding as planned.

3. Important recommendations regarding the ANRCP Competitive Grants Program.

None. We do appreciate the lead time for this report as well as the well-organized Request for Proposals.

4. Approach changes.

None. The last report cycle included the implementation of the program; this report cycle is the time of planning and recruitment.

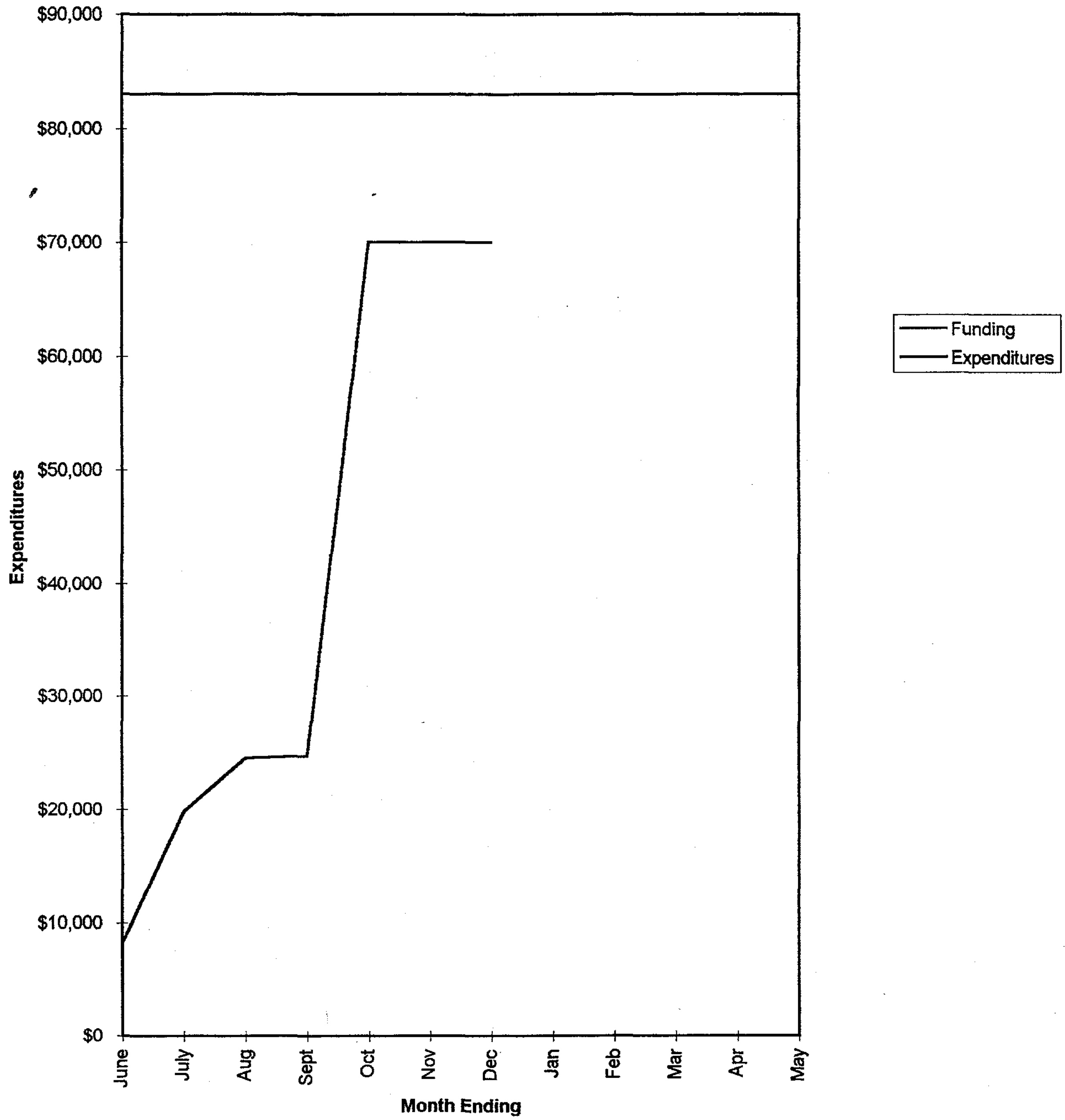
5. Performance variances. None

6. Open items. None.

7. Status assessment and forecast

Project is as scheduled. A continuance proposal will be submitted. Closer ties to other projects in the Communication, Education, and Training Program will be explored.

Expenditures for Academic Intervention



TASK 4

Academic Intervention

Attachment:
List of Attendees
National Initiative for PREP

NATIONAL INITIATIVE FOR PREP

Jack Alexander, PhD
Program Officer, National Academy of Sciences
President, National Association of Mathematics (NAM)
Washington, DC

Dr. Manuel Berriozabal, Mathematics Professor
University of Texas at San Antonio
Coordinator of TexPREP
San Antonio, Texas

J. A. Donaldson, Mathematics Professor
Howard University
V P, Mathematical Association of America (MAA)
Washington, DC

Wanda Garner, President, AMATYC
Mathematics & Sciences, Division Chmn.
Cabrillo College
Aptos, California

Dr. Mary Hawkins, Director
Enhanced Skills & Training Program
Prairie View A&M University
National Association of Mathematics (NAM)
Prairie View, Texas

Therese Jones, AmarilloPREP Director
AMATYC
Division Chmn., Sciences & Engineering
Amarillo College
Amarillo, Texas

Dr. Marilyn F. Mays, Professor of Mathematics
North Lake Community College
Past President, AMATYC
Irving, Texas

Lynn Rodriquez Mullis, Assistant Director
MESA Engineering Program
College of Engineering
California State University, Long Beach
Long Beach, California

Betty Jean Valdez, Manager
Admittance & Retention
Graduate Education of Minorities (GEM)
Notre Dame, Indiana

Dr. Larry Belgarde, Dean of Instruction
Turtle Mountain Community College
American Indian Scientists & Engineers Society (AISES)
Belcourt, North Dakota

Rikki Blair, Mathematics Professor
Lakeland Community College
AMATYC, Executive Board
Kirkland, Ohio

Melissa Villegas Drake, President
Society of Hispanic Professional Engineers
Rockwell, Inc.
League City, Texas

Mr. Ralph Gonzales, President
Mexican American Engineering Society (MAES)
Manager, Space Shuttle/Space Station Integration
NASA
Houston, Texas

William A. Hawkins, Jr., PhD, SUMMA Director
Mathematical Association of America
Mathematics Professor
University of Washington, DC
Washington, DC

Sunil Karnawat
Engineering Program
Turtle Mountain Community College
Belcourt, North Dakota

Dr. Robert Megginson, Chairman
CMPC of Mathematical Association of America (MAA); American Indian Scientists & Engineers Society (AISES), American Mathematical Society (AMS), Mathematics Professor
University of Michigan
Ann Arbor, Michigan

Samuel A. Ramirez
Mexican American Engineering Society (MAES)
Engineering Office/Ford Motor Co.
ATNPC - Livonia
Livonia, Michigan

Charles E. Vela, Executive Director (CEO)
Center for the Advancement of Hispanics in Science & Engineering Education (CAHSEE)
Bethesda, Maryland

TASK 4

Academic Intervention

Attachment:
TexPREP-Lubbock 1995

TexPREP-Lubbock 1995

June 5, 1995 - July 28, 1995

conducted at

TEXAS TECH UNIVERSITY

FINAL REPORT

Prepared and Submitted by

Dr. Charles N. Kellogg

Department of Mathematics
Texas Tech University
Lubbock, Texas 79409-1042

October 1, 1995

SUMMARY

TexPREP-Lubbock 1995 was conducted on the campus of Texas Tech University from 05 June 1995 to 28 July 1995. This program was sponsored by the Department of Mathematics at Texas Tech University, the Amarillo National Resource Center for Plutonium, Amoco Oil Company, the State of Texas, NASA and the United States Department of Energy. Additional funds were provided by the Texas Higher Education Coordinating Board Dwight D. Eisenhower Mathematics and Sciences Grants Program, the University of Texas at San Antonio TexPREP, the GTE Foundation, and the Colleges of Engineering and Arts and Sciences at Texas Tech University. The program provided an intense eight week academic experience for precollege students who have explicit potential for a career in engineering, mathematics, or one of the sciences. The program is a three year summer program consisting of a first year (PREP I), a second year (PREP II), and a third year (PREP III).

One hundred seventeen students applied to attend, 100 met the qualifications and were accepted; 47 in PREP I, 31 in PREP II, and 22 in PREP III. One hundred started; 47 in PREP I, 31 in PREP II, and 22 in PREP III.

Twenty-five PREP I students, 23 PREP II students and 18 PREP III students successfully completed the program with a passing grade (70).

From 1986 to now, 443 students have successfully completed at least one year of TexPREP-Lubbock (237 females and 209 males; 188 Anglos, 45 Blacks, 140 Hispanics, 3 American Indians, and 70 Others). Of these 443 students, 228 have gone on to complete PREP II and 130 of these 228 graduates have completed PREP III.

ALPHABETICAL LIST OF 1995 CONTRIBUTORS

1.	Amarillo National Resource Center for Plutonium	$ 37,697.00	(F)
2.	AMOCO	10,000.00	(F)
3.	Howard Hughes Medical Institute	5,000.00	(I)
4.	NASA	2,961.00	(F)
5.	State of Texas (TexPREP)	11,000.00	(F)
6.	SYETP	5,010.75	(I)
7.	Texas Instruments (Lubbock Plant)	2,000.00	(F)
8.	Texas Instruments Foundation	2,000.00	(F)
9.	Texas Tech University	13,427.00	(I)
10.	Texas Tech University College of Arts & Sciences	500.00	(F)
11.	Texas Tech University College of Engineering	750.00	(F)
12.	THECB Eisenhower Grants Program	10,842.00	(F)

Total Financial Support $77,750.00

Total Inkind Support 23,437.75

Total 1995 Support $101,187.75

FACULTY AND STAFF - 1995

01. Dr. Charles N. Kellogg, Associate Professor of Mathematics, Texas Tech University, Director
02. Dr. Shelby Hildebrand, Professor of Mathematics, Texas Tech University, Assoc. Director, PREP Instructor
03. Ms. Dana Byerly, Student, Texas Tech University, Administrative Assistant
04. Mr. Sam Black, Graduate Student, Mathematics, Texas Tech University, PREP Instructor
05. Ms. Virginia Gause, Graduate Student, Mathematics, Texas Tech University, PREP Instructor
06. Ms. Elvia Gomez, Graduate Student, Mathematics, Texas Tech University, PREP Instructor
07. Mr. Jose Ortiz, Graduate Student, Engineering, Texas Tech University, PREP Instructor
08. Mr. Tony David Potter, Graduate Student, Mathematics, Texas Tech University, PREP Instructor
09. Mr. Brian Yearwood, Assistant Principal, Cavazos Jr. High School, LISD, PREP Instructor
10. Ms. Leticia De Larrosa, Student, Mathematics, Texas Tech University, PREP Assistant
11. Ms. Jennifer Klenclo, Student, Lubbock High School, PREP Assistant
12. Ms. Mindy Mooney, Student, Family Studies, Texas Tech University, PREP Assistant

PROGRAM

INTRODUCTION

TexPREP-Lubbock 1995 provided an intense eight-week academic experience for one hundred precollege students who had been identified as having the ability to pursue a career in one of the following areas: engineering, mathematics, or one of the sciences.

PROGRAM GOALS

To increase the number of competently prepared precollege students who will ultimately pursue careers in engineering, mathematics, or science.

To reinforce the mathematics and computer science preparation of the participants at the precollege level.

To increase the retention rate of the participants after they enroll in colleges or universities.

To acquaint the participants with the professional opportunities in engineering, mathematics, and science.

RECRUITMENT

Recruitment of PREP I students is handled through the area middle and junior high schools' mathematics teachers. Additionally, principals and counselors of those schools with a high percentage of minority students assist in the recruitment. This recruitment process has worked well over the ten years of the program.

THE 1995 PROGRAM

TexPREP-Lubbock 1995 was sponsored by the Department of Mathematics at Texas Tech University, the Amarillo National Resource Center for Plutonium, Amoco Oil Company, the State of Texas, NASA and the United States Department of Energy. Additional funds were provided by the Texas Higher Education Coordinating Board Dwight D. Eisenhower Mathematics and Sciences Grants Program, the University of Texas at San Antonio TexPREP, the GTE Foundation, and the Colleges of Engineering and Arts and Sciences at Texas Tech University. The program provided an intense eight-week academic experience for precollege students who have explicit potential for a career in engineering, mathematics, or one of the sciences. The program is a three-year summer program consisting of a first year (PREP I), a second year (PREP II), and a third year (PREP III).

TexPREP-Lubbock 1995 was conducted on the campus of Texas Tech University from 05 June 1995 to 28 July 1995. Participants lived off campus, but spent the hours between 9:00 a.m. and 3:00 p.m. each Monday through Friday between June 5 and July 28 on the campus of Texas Tech University. No tuition or fees were charged. Schedules varied according to the level of the participant. For a listing of the participants, see Appendix A. For a listing of the program components and the various daily schedules, see Appendix F.

Throughout the program, a mini-college experience was provided the participants. Exams were given on a regular basis and the students presented both written and oral reports. Students not only attended classes, but had the opportunity to hear a variety of university professors explain their research and discuss various careers in their disciplines. Additionally, other opportunities were given to the students to learn about Texas Tech University and colleges in general. For a listing of the speakers and other benefactors, see Appendix G.

One hundred seventeen students applied to attend, 100 met the qualifications and were accepted; 47 in PREP I, 31 in PREP II, and 22 in PREP III. One hundred started; 47 in PREP I, 31 in PREP II, and 22 in PREP III.

Twenty-five PREP I students, 23 PREP II students and 18 PREP III students successfully completed the program with a passing grade (70).

For a follow up study of former students, please see Appendix B. For an evaluation of the 1995 program as provided by the students, please see Appendix C.

THE GTE MINORITY SCHOLARSHIP PROGRAM

In 1989, the GTE Service Corporation provided Texas Tech University $300,000 to be used to award twenty-five $12,000 scholarships to Texas Tech University for Blacks or Hispanics who complete at least two years of TexPREP-Lubbock, and who meet certain other requirements established by Texas Tech University, TexPREP-Lubbock, and GTE. While all twenty-five of these scholarships were initially awarded, some of the potential awardees have declined their scholarships. The remaining scholarships will be awarded in the next several years with prospective candidates being drawn from current and past TexPREP students.

Two of the GTE Minority Scholarship recipients, Jeremiah Aguilar and Elvia Gomez, have graduated from Texas Tech University. Michael McKelvy and Antroy Arreola, who declined their scholarships to attend other universities, have graduated from Notre Dame and Rice Universities, respectively. Fourteen of the students receiving scholarships are currently attending Texas Tech University. Appendix E provides a complete listing of all scholarship recipients.

CASH AWARDS

Fifteen hundred dollars provided by the Dean of the College of Arts and Sciences and the Dean of the College of Engineering were used to provide cash awards for the top students in each of the five programs. The most improved PREP II and PREP III students also received cash awards. Appendix E provides a listing of the winners.

JOB TRAINING PROGRAMS

Five students qualified for financial support provided by the Job Training Partnership Act (JTPA), and distributed by the Private Industry Council (PIC) under its JobSource+ (Lubbock County) program. Each of these students had the opportunity to earn up to $930.75 while attending the program.

FINAL COMMENTS - DIRECTOR

The summer of 1995 Program marks the tenth year that the program has been in existence. During these ten years the program showed consistent growth through 1992 with a decline in 1993, 1994 and 1995. This decline coincides with the loss of additional GTE funding. This summer, PREP III was offered for the fifth time and eighteen students completed this phase of the program. Some of the PREP III students indicated an interest for a fourth year, however, there are no plans for a fourth year at this time.

There was a decrease in the number of students taking PREP I from the summer of 1993 to the summer of 1995. The difference in preparation in mathematics of seventh and eighth graders justifies considering having sections consisting of only seventh graders or eighth graders. Efforts will be made to continually update and expand notes.

Fewer students (100) were accepted for the 1995 program than for the 1994 program (119). Also, the number of students (66) who successfully completed the 1995 program was lower than the number (87) who successfully completed the 1994 program. The 1995 program was as successful as those from previous summers, although some participants felt there were more restrictions/rules in 1995 than in previous years. One can expect for the program to carry about 100-120 participants in the summer of 1996.

During these last ten years 443 students have successfully completed at least one year of TexPREP-Lubbock (237 females and 209 males; 188 Anglos, 45 Blacks, 140 Hispanics, 3 American Indians, and 70 Others). Of these 443 students, 228 have gone on to complete PREP II and 130 of these 228 graduates have completed PREP III.

PROGRAM EVALUATION

Seven of the components in the eight-week summer PREP curriculum were selected for evaluation utilizing a Pre-Post test approach. The components selected were Mathematical Thought (Logic), Science I, and Computer Science I in PREP I, Problem Solving and Science II in PREP II, and Calculus and Statistics in PREP III. The pre-test was given during the first day of class on June 5, 1995 The pre-test was designed to determine the students' prerequisite knowledge for the courses as well as knowledge on the basic concepts to be covered in the course.

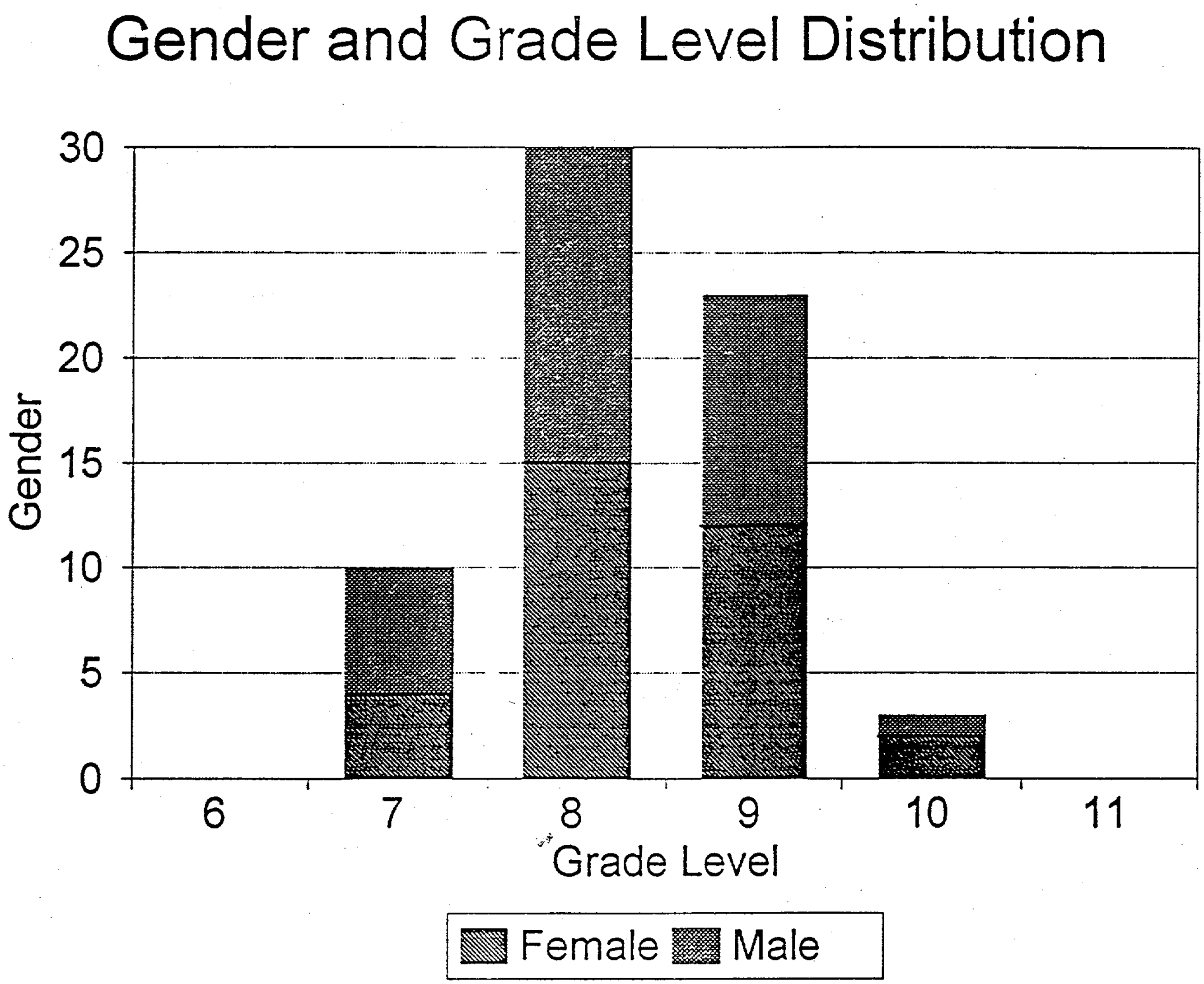
During the last week of the program the students were given a post-test in the components listed above. The courses taken in the PREP program have content that the students have not had in their respective schools. However, since the participants are high-ability students, some of them do better on a pre-test of this type than would students selected at large from the student population. Nevertheless, the participants would be expected to do better on the post-test than they did on the pre-test. The results of the testing confirm this expectation without the need of having to carry out any elaborate statistical tests. However, the following table summarizes the results of the results obtained in the pre-post tests. There were two sections of students in PREP I, two sections in PREP II, and one section of PREP III students.

1995 SURVEY OF FORMER TexPREP PARTICIPANTS CURRENTLY IN COLLEGE

LUBBOCK

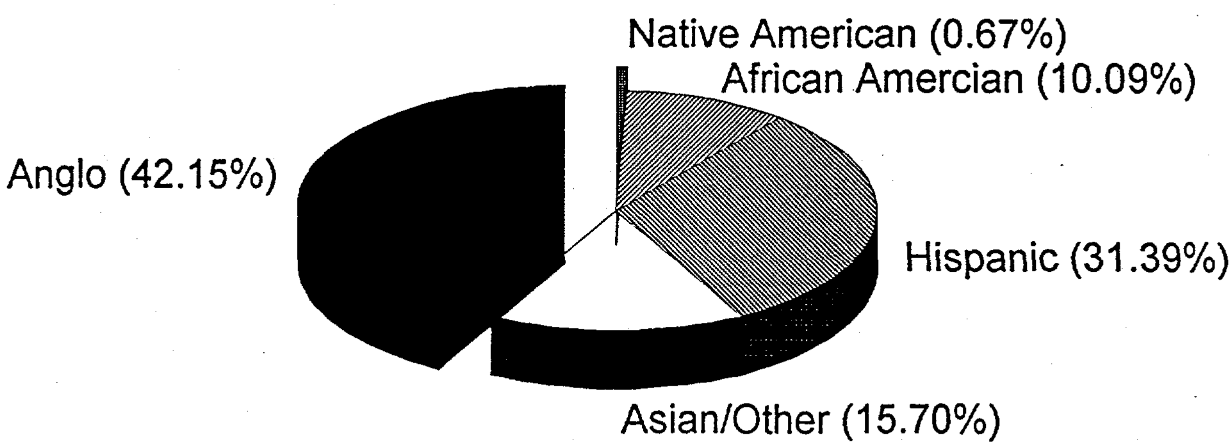
INSTITUTION	ENGINEERING	SCIENCE	OTHER	UNDECIDED	TOTAL
Abilene Christian University			1		1
Arizona State University	1				1
Baylor Medical School		1			1
California Institute of Technology		1			1
Cambridge University	1				1
Colorado School of Mines				1	1
Duke University			1		1
Harding University			1		1
Harvard University			1		1
Jarvis Christian College			1		1
Lubbock Christian University			1		1
Massachusetts Institute of Technology	1				1
McMurry University		1			1
National Education Center		1			1
Ohio State University	1				1
Rice University		2			2
Royal Melbourne Institute of Technology	1				1
South Plains College-Levelland		2	1		3
South Plains College-Reese AFB				1	1
Southern Methodist University		1			1
Southwestern Christian College		1		1	2
Southwestern University			1		1
Stanford University	1				1
Texas A&M University		5			5
Texas Christian University				1	1
Texas Tech University	8	13	11	2	34
University of Dallas			1		1
University of North Texas-TAMS		1			1
University of Texas - Austin	1	2	1		4
West Texas A&M		1			1
TOTALS	15	32	21	6	74

GRC 9/8/95

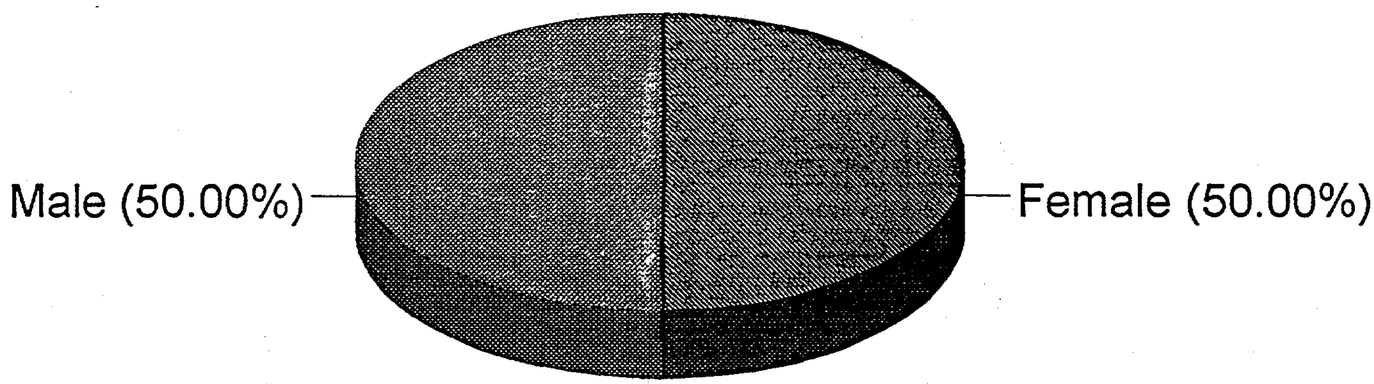

Gender and Grade Level Distribution
30
25
20
15
10
5
0
Gender
6
7
8
9
10
11
Grade Level
Female
Male

TEXPREP ETHNIC DISTRIBUTION

(LUBBOCK 1986-1995)

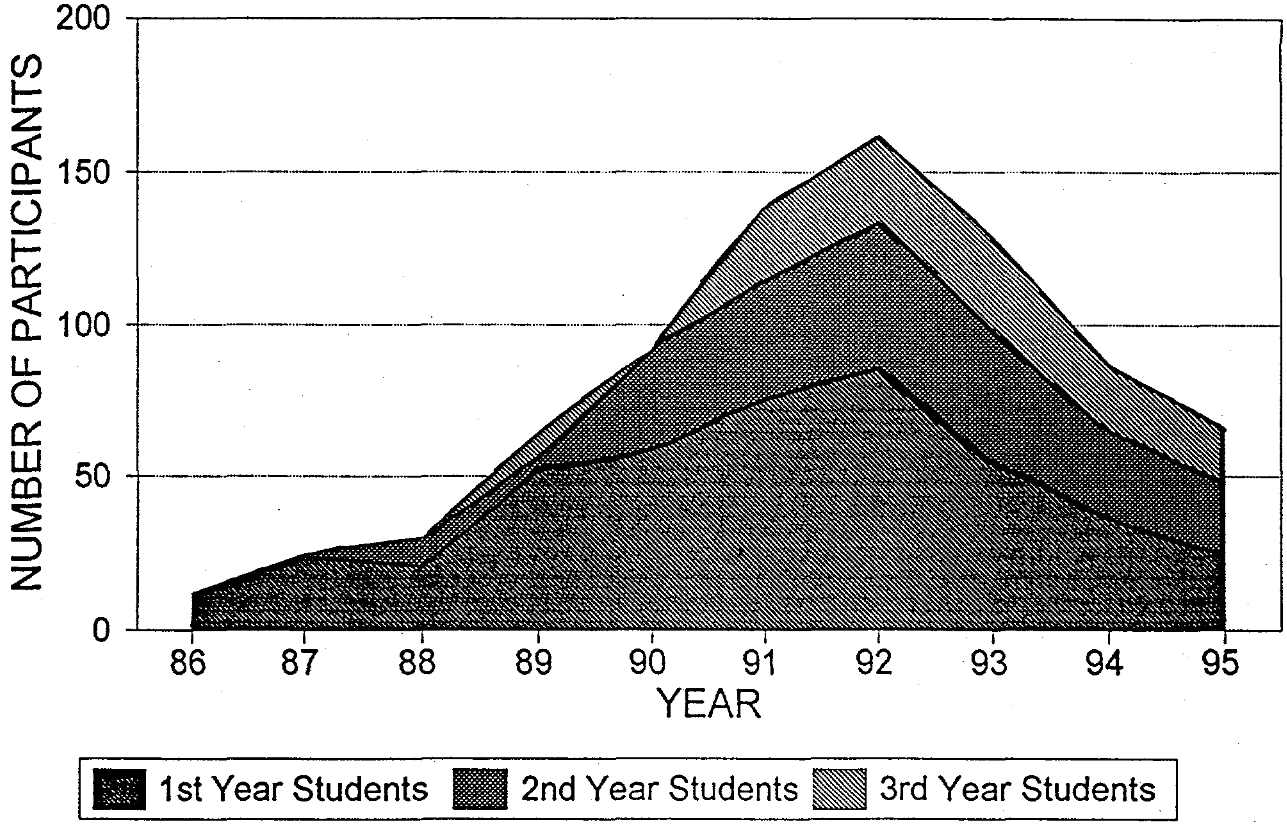


Gender Distribution



TEXPREP GROWTH RATE

(LUBBOCK 1986-1995)



TASK 4

K-16 Mathematics & Science Education

WORK PLAN PROGRESS REPORT
K-16 Mathematics and Science Education
Period Covered: November 1, 1995 through January 31, 1996

1. Summary of research activities during reporting period.

To educate is the purpose of the K-16 Mathematics and Science Education project. It identified stakeholders in science and mathematics education in the Texas Panhandle and created a forum for them to unite to assess educational needs, inventory existing resources, identify potential resources, formulate goals, and develop short- and long-term strategies for sharing information, combining resources, and seeking additional funding to meet the identified needs. From June through October 1995, the following activities took place.

(a) A steering committee that represented the diverse group of stakeholders in science and mathematics education in the Texas Panhandle was formed under the name Panhandle Science and Mathematics Education Network.

(b) Strengths and weaknesses of science and mathematics education in the Texas Panhandle, potential problems and obstacles for science and mathematics in the Texas Panhandle, and strategies for designing and administering needs assessment instruments and inventories of resources were all identified.

(c) Collaborative efforts between the subproject director and Region XVI Education Service Center personnel in charge of a grant proposal to the NSF funded Texas Statewide Systemic Initiative were initiated.

(d) The Region XVI Mathematics Task Force, whose major objective it is to develop a framework for K-12 schools in the Texas Panhandle for use in professional development of mathematics teachers was formed.

On November 3, the Second Annual Student Research Conference was held at West Texas A&M University. The Amarillo National Resource Center for Plutonium joined Southwestern Bell Telephone Foundation and West Texas A&M University Kilgore Research Center as sponsors of the conference. Support of the conference was officially added to the K-16 Mathematics and Science Education subproject tasks and budget in September. The conference attracted over 120 student papers presented by undergraduate and graduate students representing 34 colleges and universities from four states. A copy of the conference program and report of the conference is included with the progress report. On November 21, the subproject director made a presentation to the Region XVI Mathematics Task Force addressing the National Mathematics Standards and provided information about the Amarillo National Resource Center for Plutonium and the work of the Panhandle Science and Mathematics Education Network. A discussion of how the needs assessment data collected through the project will be utilized by the Task Force was also conducted.

On December 12, the subproject director provided a poster presentation at the Holiday Reception of the ANRCP. The focus of the posters was the Student Research Conference and the Steering Committee of the Panhandle Science and Mathematics Education Network.

Three needs assessment surveys have been developed and reviewed by both the Steering Committee and the Region XVI Mathematics Task Force. One survey targets elementary science and mathematics teachers, another targets secondary science teachers, and a third targets secondary mathematics teachers. Upon recommendation of Region XVI Education Service Center Personnel, actual collection of data will take place in February. Copies of the three surveys are attached.

Collection of information about science and mathematics education resources in the Texas Panhandle has begun. Information about state and national resources for science and mathematics education also is being collected. Identification of model sites for steering committee members to visit is continuing.

2. Tangible accomplishments.

A significant accomplishment of the subproject was the number of states and universities represented at the Student Research Conference. Funds from the ANRCP impacted research of both undergraduate and graduate students from four states (Texas, New Mexico, Oklahoma, and Kansas) and from 34 universities. The conference provided a unique opportunity for these students to participate in the pursuit of scholarly achievement and to share the results of those pursuits with fellow academicians.

Another significant accomplishment is the opening of communication between stakeholders in science and mathematics across the Texas Panhandle. This communication is providing opportunities for sharing information and for minimizing duplication of efforts which result in more efficient use of time and money.

3. Important recommendations regarding the ANRCP Competitive Grants Program.

The guideline for preparation of continuing proposals has been helpful in providing a format for the subproject directors to follow in development of proposals.

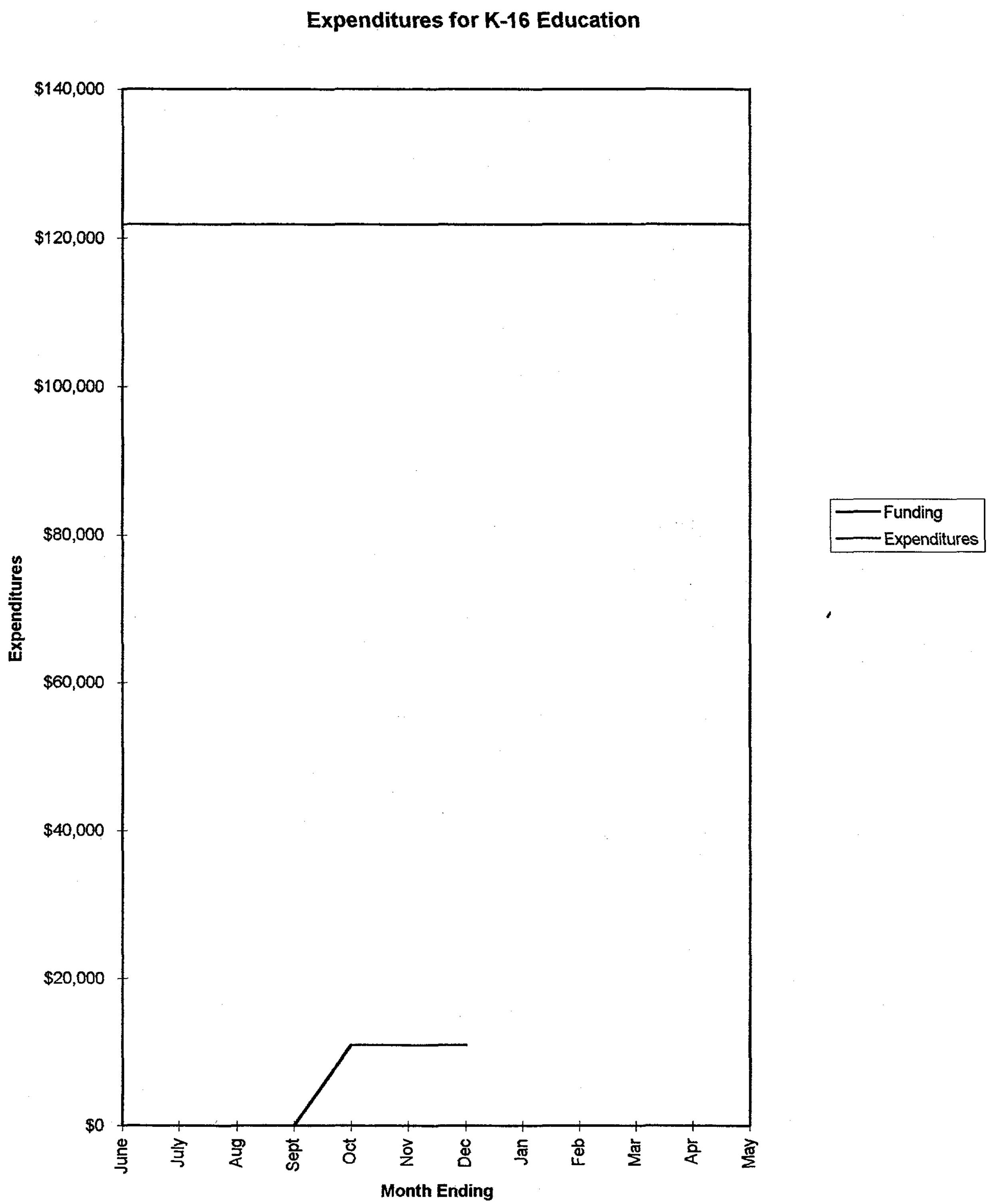
4. Approach changes. None

5. Performance variances. None

6. Open items. None

7. Status assessment and forecast

Continue with current plan.


Expenditures for K-16 Education
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Expenditures
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Month Ending
Funding
Expenditures

TASK 4

K-16 Mathematics & Science Education

Attachment:
Report on Student Research Conference
West Texas AM University

REPORT
STUDENT RESEARCH CONFERENCE
WEST TEXAS A&M UNIVERSITY

The Second Annual Student Research Conference was held Friday, November 3, 1995, at West Texas A&M University. Sponsors of the conference were Southwestern Bell Telephone Foundation, Amarillo National Resource Center for Plutonium, and West Texas A&M University Killgore Research Center. This year's conference attracted undergraduate and graduate students from 34 colleges and universities in four different states. Over 120 student papers were presented in the day-long event. Last year's conference attracted 67 students from 21 colleges and universities.

The conference provides a unique opportunity for college and university students to participate in the pursuit of scholarly achievement and to share the results of their pursuits with fellow academicians. Students prepared original abstracts or proposals and then delivered a 15-20 minute presentation before judges and colleagues. First, second, and third prizes totaling $3500 were awarded in the following categories: agriculture; business; communications; computer science, mathematics, and engineering technology; education; history, humanities, and philosophy; literature; music and art; natural sciences; and social and behavioral sciences. Winners were announced and recognized Friday night at the Student Research Conference awards banquet. Gerald Johnson, United States Department of Energy Area Manager, delivered the keynote address, "Roots of American Anti-Nuclear Activism."

Work will begin soon for the Third Annual Student Research Conference. The date for the 1996 conference is Friday, November 1. The Student Research Conference chairman is Dr. Shearle Furnish. For more information, contact Dr. Furnish at 806-656-2476 or by e-mail at FURNISH@WTAMU.EDU.

PARTICIPANTS
SECOND ANNUAL STUDENT RESEARCH CONFERENCE
WEST TEXAS A&M UNIVERSITY

Participants in the Second Annual Student Research Conference at West Texas A&M University on November 3, 1995 represented the following universities:

TEXAS

Angelo State University, San Angelo
East Texas Baptist University, Marshall
Incarnate Word College, San Antonio
Our Lady of the Lake University, San Antonio
Southwest Texas State University, San Marcos
St. Edward's University, Austin
Stephen F. Austin State University, Nacogdoches
Tarleton State University, Stephenville
Texas A&M University, College Station
Texas A&M University at Corpus Christi
Texas Tech University, Lubbock
Texas Tech University Health Sciences Center, Amarillo
University of Dallas
University of North Texas, Denton
University of Houston
University of Houston - Clear Lake
University of Texas at Arlington
University of Texas at Brownsville
University of Texas - Pan American, Edinburg
University of Texas - Permian Basin, Odessa
University of Texas at Tyler
West Texas A&M University, Canyon

OKLAHOMA

Cameron University, Lawton
Langston University, Langston
Oklahoma Panhandle State University, Goodwell
Oral Roberts University, Tulsa
University of Oklahoma, Norman

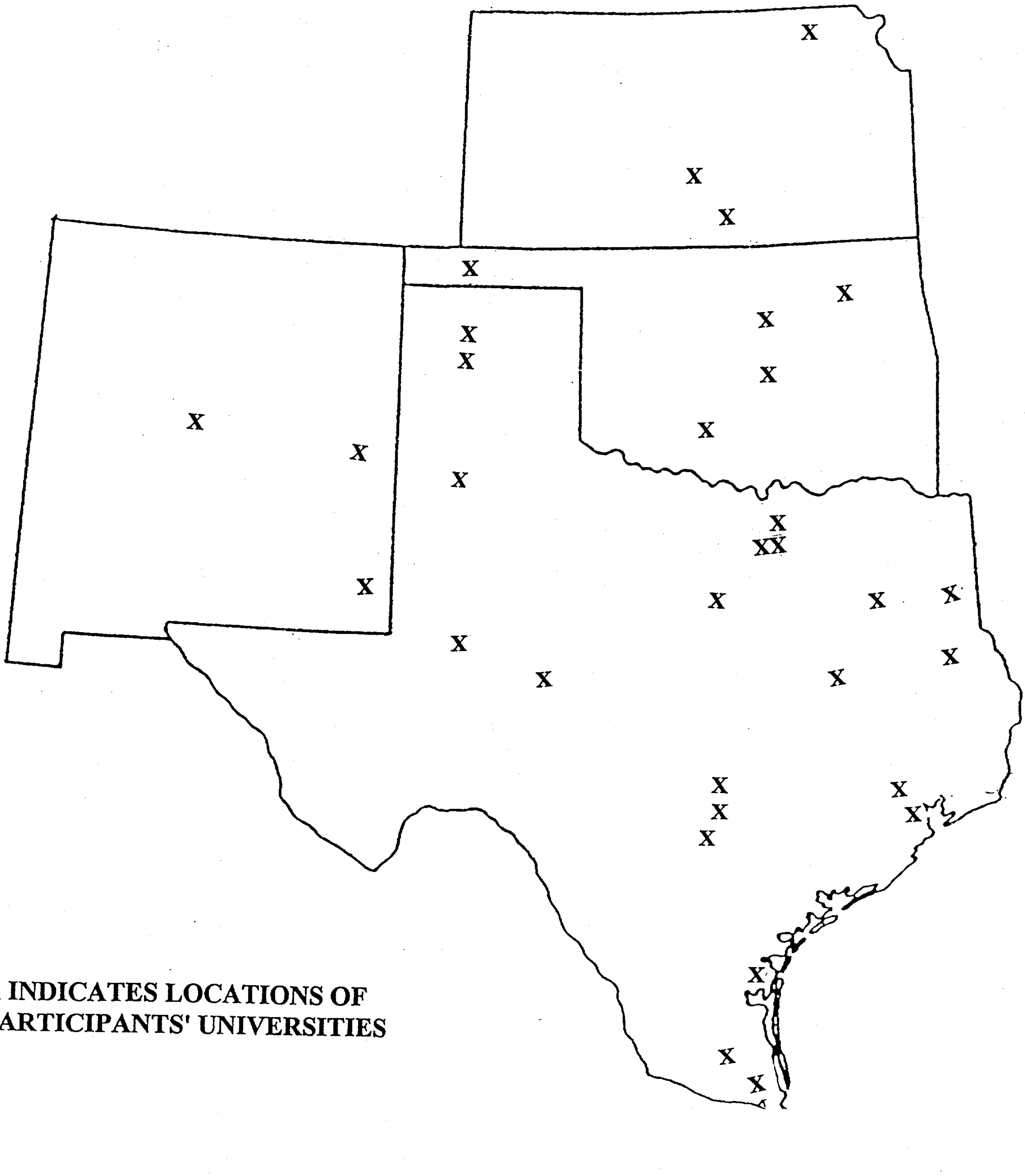
KANSAS

Fort Hayes State University, Fort Hayes
Southwestern College, Winfield
Washburn University, Topeka
Wichita State University, Wichita

NEW MEXICO

College of the Southwest, Hobbs
Eastern New Mexico University, Portales
University of New Mexico, Albuquerque

PARTICIPANTS
STUDENT RESEARCH CONFERENCE
WEST TEXAS A&M UNIVERSITY
NOVEMBER 3, 1995



X INDICATES LOCATIONS OF
PARTICIPANTS' UNIVERSITIES

TASK 4

K-16 Mathematics & Science Education

Attachment:
Secondary Science Teachers Survey

SECONDARY SCIENCE TEACHERS SURVEY

West Texas A&M University received funding from the Amarillo National Resource Center for Plutonium for a planning grant. As part of that grant, science and mathematics teachers across the Panhandle will receive survey instruments such as this. The data collected will be used to help develop an action plan for science and mathematics education and as a basis for seeking funding to provide opportunities for science and mathematics teachers. Thank you for your help in supplying information needed to develop this plan. When you complete the survey, please return it to the person who asked you to provide the information or to Judy Kelley, WT Box 217, Canyon, TX 79016.

For each of the following questions, please circle only one response.

1. Age: (a) 20-29 (b) 30-39 (c) 40-49 (d) 50-59 (e) 60 and over.

2. Sex: (a) female (b) male

3. Ethnic background: (a) African American (b) Asian (c) Caucasian (d) Hispanic (e) Native American

4. Degree Status: (a) bachelor's (b) bachelor's plus hours (c) master's (d) master's plus hours (e) doctorate

5. Number of years teaching experience, including this year: (a) 1-4 (b) 5-9 (c) 10-14 (d) 15-19 (e) 20 or more

6. Number of schools where you held full-time teaching positions: (a) 1 (b) 2 (c) 3 (d) 4 (e) 5 or more

7. Number of years in your present school, including this year: (a) 1 (b) 2 (c) 3-5 (d) 6-10 (e) 11 or more

8. Present School District: ______________________________

9. Classification of high school your students will or do attend: (a) A (b) AA (c) AAA (d) AAAA (e) AAAAA

10. Current school: (a) public school (b) private school

11. Current assignment: (a) junior high (b) middle school (c) high school (d) combination of junior high/high school

12. Teaching certificate: (a) elementary with science concentration (b) elementary with non-science concentration (c) composite science (d) two science fields (e) one science field and one non-science field (f) no certification in science

13. Are you certified to teach all the subjects you have been assigned to teach this year and last year? (a) yes (b) no

14. Your principal teaching assignment this year is (a) biology/life science (b) chemistry (c) earth science (d) physics (e) physical science (f) other__________________

Approximately how many college courses have you completed in each of the following:

15. Geology: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

16. Astronomy: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

17. Meteorology: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

18. Oceanography: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

19. Chemistry: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

20. Physics: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

21. Biology: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

22. Botany: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

23. Zoology: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

24. Environmental Science: (a) 0 (b) 1 (c) 2 (d) 3-5 (e) 6 or more

25. Number of years since your last college science class (approximately): (a) 0-2 (b) 3-5 (c) 6-8 (d) 9-11 (e) 12 or more

26. Frequency that you personally use computers: (a) less than once a month (b) once a month (c) every 2 weeks (d) weekly (e) daily

27. If you use computers for schoolwork, primary purpose: (a) word processing (b) record management (c) instruction (d) other ________________________________

28. If you don't use computers for schoolwork, primary reason: (a) lack of access to computers (b) lack of training (c) lack of time (d) lack of software (e) other____

29. Computers available for class use: (a) every period (b) once a day (c) once a week (d) once a month (e) less than once a month

30. Computer available for class demonstrations: (a) every period (b) once a day (c) once a week (d) once a month (e) less than once a month

31. Internet access available: (a) in my classroom (b) in my school (c) in my district (d) none of these

32. Physics offered at your high school: (a) every year (b) every other year (c) never (d) do not know

33. Chemistry offered at your high school: (a) every year (b) every other year (c) never (d) do not know

34. Approximate percentage of students in your high school that complete 3 science courses: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

35. Approximate percentage of students in your high school that complete 4 science courses: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

Approximate percentage of students in your high school that complete a course in

36. chemistry: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

37. physics: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

38. biology: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

39. physical science: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

40. Number of elective science courses other than Chemistry I and Physics I available in your high school: (a) 0 (b) 1 (c) 2 (d) 3 (e) 4 or more

41. Adequacy of equipment and supplies for conducting science labs in your school: (a) none available (b) barely adequate (c) adequate (d) more than adequate (e) not sure

42. Approximate percentage of time you are unable to do a laboratory activity because equipment and/or materials are not available: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

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% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

44. Approximate percentage of time laboratory activities must be planned for a specific day because equipment and materials are shared: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

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 (b) 1-4 (c) 5-9 (d) 10-14 (e) over 15

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 (b) somewhat important (c) not important

47. **when** it will be held: (a) very important (b) somewhat important (c) not important

48. **how long** it will last: (a) very important (b) somewhat important (c) not important

49. **cost** to attend: (a) very important (b) somewhat important (c) not important

50. **topic** addressed: (a) very important (b) somewhat important (c) not important

51. **who** is presenting it: (a) very important (b) somewhat important (c) not important

52. **how much time** you will be out of classroom: (a) very important (b) somewhat important (c) not important

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 (b) probably yes (c) probably no (d) definitely no

54. at cluster sites near your district: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

55. at an Education Service Center: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

56. at a university (graduate credit): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

57. at a community college (undergraduate credit): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

58. at a science center or museum: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

59. after school: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

60. at night: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

61. on Saturdays: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

62. for one or two days: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

63. once a month (week-days) during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

64. once a month (Saturdays) during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

65. on one week-day in the summer: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

66. for one week in the summer: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

67. for 1 week in the summer and follow-up during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

68. for 3 weeks in the summer and follow-up during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

How many **SCIENCE** teacher organizations do you have membership in at the

69. local/state level (STAT, TABT, etc.): (a) 0 (b) 1 (c) 2 or more

70. national level (NSTA, NABT, etc.): (a) 0 (b) 1 (c) 2 or more

Have you attended a convention or conference for **SCIENCE** teachers in the last 3 years

71. in the Panhandle: (a) yes (b) no

72. in Texas but not in the Panhandle: (a) yes (b) no

73. in another state: (a) yes (b) no

74. Does your district provide funds for individuals or groups of teachers to attend **non-required** professional development for **science** teachers? (a) yes (b) no

75. In the last three years have you attended **district-required** professional development addressing methodology used to teach science concepts? (a) yes (b) no

76. In the last three years have you attended **district-required** professional development addressing knowledge about science concepts? (a) yes (b) no

77. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach science concepts: (a) every year (b) every other year (c) every 3-5 years (d) never

78. Frequency you **choose** to attend **non-required** professional development addressing knowledge about science concepts: (a) every year (b) every other year (c) every 3-5 years (d) never

79. Average distance you usually travel to attend **non-required** professional development: (a) less than 5 miles (b) 5-30 miles (c) 31-60 miles (d) 61-120 miles (e) more than 120 miles

80. Which of the following best describes your knowledge about the publication National Science Education Standards: (a) I have not heard of it. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

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. (b) I have heard of it before this survey but have no idea about its purpose. (c) I have general ideas about its purpose. (d) I understand its purpose.

How often do you use the following in science instruction

82. Laboratory activities: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

83. Teacher demonstrations: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

84. Collaborative or cooperative learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

85. Computer activities: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

86. Teacher lecture: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

87. Discovery/Inquiry learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

88. Alternative assessment: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

89. Field trips: (a) weekly (b) monthly (c) once a semester (d) once a year (e) never

Indicate the extent you need assistance with each of the following in your science teaching.

90. New teaching methods: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

91. Instructional materials: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

92. Resources available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

93. Programs available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

94. Speakers available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

95. Field trips available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

96. Uses of Internet in science classes: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

97. Discovery/Inquiry learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

98. Collaborative or cooperative learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

99. Computers in science classrooms: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

100. Process skills: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

101. Laboratory set-ups: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

102. Laboratory safety: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

103. Alternative assessment: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

104. Maintaining live organisms for science instruction: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

105. Botany: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

106. Zoology: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

107. Chemistry: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

108. Physics: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

109. Astronomy: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

110. Geology: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

111. Environmental science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

112. Meteorology: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

113. Oceanography: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

114. Integration of mathematics and science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

115. Applications of science concepts in society: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

116. Science related societal issues: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

117. Science related career opportunities for students: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

118. Describe the most beneficial professional development that you have attended in the last five years:

119. What are the major obstacles you face in participating in professional development?

120. Other comments:

TASK 4

K-16 Mathematics & Science Education

Attachment:
Secondary Mathematics Teachers Survey

SECONDARY MATHEMATICS TEACHERS SURVEY

West Texas A&M University received funding from the Amarillo National Resource Center for Plutonium for a planning grant. As part of that grant, science and mathematics teachers across the Panhandle will receive survey instruments such as this. The data collected will be used to help develop an action plan for science and mathematics education and as a basis for seeking funding to provide opportunities for science and mathematics teachers. Thank you for your help in supplying information needed to develop this plan. When you complete the survey, please return it to the person who asked you to provide the information or to Judy Kelley, WT Box 217, Canyon, TX 79106.

For each of the following questions, please circle only one response.

1. Age: (a) 20-29 (b) 30-39 (c) 40-49 (d) 50-59 (e) 60 and over

2. Sex: (a) female (b) male

3. Ethnic background: (a) African American (b) Asian (c) Caucasian (d) Hispanic (e) Native American

4. Degree Status: (a) bachelor's (b) bachelor's plus hours (c) master's (d) master's plus hours (e) doctorate

5. Number of years teaching experience, including this year: (a) 1-4 (b) 5-9 (c) 10-14 (d) 15-19 (e) 20 or more

6. Number of schools where you held full-time teaching positions: (a) 1 (b) 2 (c) 3 (d) 4 (e) 5 or more

7. Number of years in your present school, including this year: (a) 1 (b) 2 (c) 3-5 (d) 6-10 (e) 11 or more

8. Present school district ______________________________

9. Classification of high school your students will or do attend: (a) A (b) AA (c) AAA (d) AAAA (e) AAAAA

10. Current school: (a) public school (b) private school

11. Current assignment: (a) junior high (b) middle school (c) high school (d) combination of junior high/high school

12. Teaching certificate: (a) elementary with math concentration (b) elementary with non-math concentration (c) secondary with math as 1st teaching field (d) secondary with math as 2nd teaching field (e) secondary with math as only teaching field (f) other (please describe) ______________________________

13. Number of years since your last college mathematics class (approximately): (a) 0-2 (b) 3-5 (c) 6-8 (d) 9-11 (e) 12 or more

14. Frequency that you personally use computers: (a) less than once a month (b) once a month (c) every 2 weeks (d) weekly (e) daily

15. If you use computers for schoolwork, primary purpose: (a) word processing (b) record management (c) instruction (d) other ______________________________

16. If you don't use computers for schoolwork, primary reason: (a) lack of access to computers (b) lack of training (c) lack of time (d) lack of software (e) other ______________________________

17. Computers available for class use: (a) every period (b) once a day (c) once a week (d) once a month (e) less than once a month

18. Computer available for class demonstrations: (a) every period (b) once a day (c) once a week (d) once a month (e) less than once a month

19. Internet access available: (a) in my classroom (b) in my school (c) in my district (d) none of these

20. Kinds of class sets of calculators available: (a) 4-function (b) fraction (c) scientific (d) graphing (e) none available

21. Approximate percentage of students in your high school that complete 3 years of mathematics: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

22. Approximate percentage of students in your high school that complete 4 years of mathematics: (a) 0-10% (b) 11-25% (c) 26-50% (d) 51-75% (e) over 75%

How important do you consider the following when deciding whether or not to attend professional development:

23. **where** it will be held: (a) very important (b) somewhat important (c) not important

24. **when** it will be held: (a) very important (b) somewhat important (c) not important

25. **how long** it will last: (a) very important (b) somewhat important (c) not important

26. **cost** to attend: (a) very important (b) somewhat important (c) not important

27. **topic** addressed: (a) very important (b) somewhat important (c) not important

28. **who** is presenting it: (a) very important (b) somewhat important (c) not important

29. **how much time** you will be out of classroom: (a) very important (b) somewhat important (c) not important

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 (b) probably yes (c) probably no (d) definitely no

31. at cluster sites near your district: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

32. at an Education Service Center: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

33. at a university (graduate credit): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

34. at a community college (undergraduate credit): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

35. after school: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

36. at night: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

37. on Saturdays: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

38. for one or two days: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

39. once a month (week-days) during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

40. once a month (Saturdays) during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

41. on one week-day in the summer: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

42. for one week in the summer: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

43. for 1 week in the summer and follow-up during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

44. for 3 weeks in the summer and follow-up during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

How many **MATHEMATICS** teacher organizations do you have membership in at the

45. local/state level (PACTM, TCTM, etc.): (a) 0 (b) 1 (c) 2 or more

46. national level (NCTM, etc.): (a) 0 (b) 1 (c) 2 or more

Have you attended a convention or conference for **MATHEMATICS** teachers in the last 3 years

47. in the Panhandle: (a) yes (b) no

48. in Texas but not in the Panhandle: (a) yes (b) no

49. in another state: (a) yes (b) no

50. Does your district provide funds for individuals or groups of teachers to attend **non-required** professional development for **mathematics** teachers? (a) yes (b) no

51. In the last three years have you attended **district-required** professional development addressing methodology used to teach mathematics concepts? (a) yes (b) no

52. In the last three years have you attended **district-required** professional development addressing knowledge about mathematics concepts? (a) yes (b) no

53. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach mathematics concepts: (a) every year (b) every other year (c) every 3-5 years (d) never

54. Frequency you **choose** to attend **non-required** professional development addressing knowledge about mathematics concepts: (a) every year (b) every other year (c) every 3-5 years (d) never

55. Average distance you usually travel to attend **non-required** professional development: (a) less than 5 miles (b) 5-30 miles (c) 31-60 miles (d) 61-120 miles (e) more than 120 miles

56. Which of the following best describes your knowledge about the publication Curriculum and Evaluation Standards for School Mathematics: (a) I have not heard of it. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

57. Which of the following best describes your knowledge about the publication Professional Standards for Teaching Mathematics: (a) I have not heard of it. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

58. Which of the following best describes your knowledge about the publication Assessment Standards for School Mathematics: (a) I have not heard of it. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

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. (b) I have heard of it before this survey but have no idea about its purpose. (c) I have general ideas about its purpose. (d) I understand its purpose.

How often do you use the following in mathematics instruction

60. Hands-on activities in which students use manipulatives: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

61. Teacher demonstrations using manipulatives: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

62. Collaborative or cooperative learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

63. Computers for tutorials: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

64. Computers for drill and practice: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

65. Computers for instructional activities: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

66. Calculators for graphing: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

67. Calculators for computation: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

68. Calculators for instructional activities (not graphing): (a) daily (b) weekly (c) monthly (d) once a semester (e) never

69. Problem-solving activities: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

70. Teacher lecture: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

71. Discovery/Inquiry learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

72. Alternative assessment: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

Indicate the extent you need assistance with each of the following in your mathematics teaching.

73. New teaching methods: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

74. Instructional materials: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

75. Resources available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

76. Programs available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

77. Speakers available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

78. Field trips available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

79. Uses of Internet: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

80. Discovery/Inquiry learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

81. Collaborative or cooperative learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

82. Manipulatives to model mathematics concepts: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

83. Computers in mathematics classrooms: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

84. Graphing calculators: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

85. Calculators as instructional tools: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

86. Problem-solving: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

87. Alternative assessment: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

88. Patterns, relations and functions: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

89. Number sense (not the competition, but comfort and ability to use numbers): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

90. Euclidean Geometry: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

91. Non-Euclidean Geometry: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

92. Trigonometry: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

93. Statistics: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

94. Probability: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

95. Proportions: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

96. Reasonableness: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

97. Estimation: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

98. Matrices: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

99. Calculus: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

100. Mathematics of money/finance: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

101. Integration of mathematics and science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

102. Applications of mathematics in today's world: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

103. Mathematics related career opportunities for students: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

104. Describe the most beneficial professional development that you have attended in the last five years:

105. What are the major obstacles you face in participating in professional development?

106. Other comments:

TASK 4

K-16 Mathematics & Science Education

Attachment:
Elementary Science and/or Mathematics Teachers Survey

ELEMENTARY SCIENCE AND/OR MATHEMATICS TEACHERS SURVEY

West Texas A&M University received funding from the Amarillo National Resource Center for Plutonium for a planning grant. As part of that grant, science and mathematics teachers across the Panhandle will receive survey instruments such as this. The data collected will be used to help develop an action plan for science and mathematics education and as a basis for seeking funding to provide opportunities for science and mathematics teachers. Thank you for your help in supplying information needed to develop this plan. When you complete the survey, please return it to the person who asked you to provide the information or to Judy Kelley, WT Box 217, Canyon, TX 79016.

For each question, please circle only one response.

A. General Information:

1. Age: (a) 20-29 (b) 30-39 (c) 40-49 (d) 50-59 (e) 60 and over.

2. Sex: (a) female (b) male

3. Ethnic background: (a) African American (b) Asian (c) Caucasian (d) Hispanic (e) Native American (f) Other

4. Degree Status: (a) bachelor's (b) bachelor's plus hours (c) master's (d) master's plus hours (e) doctorate

5. Number of years teaching experience, including this year: (a) 1-4 (b) 5-9 (c) 10-14 (d) 15-19 (e) 20 or more

6. Number of schools where you held full-time teaching positions: (a) 1 (b) 2 (c) 3 (d) 4 (e) 5 or more

7. Number of years in your present school, including this year: (a) 1 (b) 2 (c) 3-5 (d) 6-10 (e) 11 or more

8. Present school district: ______________________________

9. Usual number of classes (sections) for each grade level in your school: (a) 1 (b) 2 (c) 3 (d) 4 (e) more than 4

10. Classification of high school your students will eventually attend: (a) A (b) AA (c) AAA (d) AAAA (e) AAAAA

11. Current school: (a) public school (b) private school

12. Current grade-level teaching assignment: (a) PK (b) K (c) 1 (d) 2 (e) 3 (f) 4 (g) 5 (h) 6 (i) combination of grade levels

13. Certification concentration area: (a) science (b) mathematics (c) reading (d) social studies (e) language arts (f) other

14. Currently teaching science: (a) yes (b) no

15. Currently teaching mathematics: (a) yes (b) no

16. Number of college science content (not education) classes completed (approximately): (a) 2 or fewer (b) 3 (c) 4 (d) more than 4

17. Number of college mathematics content (not education) classes completed (approximately): (a) 0 (b) 1 (c) 2 (d) 3-4 (e) more than 4

18. Number of years since your last college science content class (approximately): (a) 0-2 (b) 3-5 (c) 6-8 (d) 9-11 (e) 12 or more

19. Number of years since your last college mathematics content class (approximately): (a) 0-2 (b) 3-5 (c) 6-8 (d) 9-11 (e) 12 or more

20. Frequency that you personally use computers: (a) less than once a month (b) once a month (c) every 2 weeks (d) weekly (e) daily

21. If you use computers for schoolwork, primary purpose: (a) word processing (b) record management (c) instruction (d) other ______________________________

22. If you don't use computers for schoolwork, primary reason: (a) lack of access to computers (b) lack of training (c) lack of time (d) lack of software (e) other ______________________________

23. Computers available for class use: (a) daily (b) weekly (c) monthly (d) never

24. Computer available for class demonstrations: (a) daily (b) weekly (c) monthly (d) never

25. Internet access available: (a) in my classroom (b) in my school (c) in my district (d) none of these

26. Classroom sets of calculators available: (a) yes (b) no

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 (b) somewhat important (c) not important

28. **when** it will be held: (a) very important (b) somewhat important (c) not important

29. **how long** it will last: (a) very important (b) somewhat important (c) not important

30. **cost** to attend: (a) very important (b) somewhat important (c) not important

31. **topic** addressed: (a) very important (b) somewhat important (c) not important

32. **who** is presenting it: (a) very important (b) somewhat important (c) not important

33. **how much time** you will be out of the classroom: (a) very important (b) somewhat important (c) not important

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 (b) probably yes (c) probably no (d) definitely no

35. at cluster sites near your district: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

36. at an Education Service Center: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

37. at a university (graduate credit): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

38. at a community college (undergraduate credit): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

39. at a museum or science center: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

40. after school: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

41. at night: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

42. on Saturdays: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

43. for one or two days: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

44. once a month (week-days) during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

45. once a month (Saturdays) during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

46. on one week-day in the summer: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

47. for one week in the summer: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

48. for 1 week in the summer and follow-up during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

49. for 3 weeks in the summer and follow-up during the school year: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

50. Average distance you usually travel to attend **non-required** professional development: (a) less than 5 miles (b) 5-30 miles (c) 31-60 miles (d) 61-120 miles (e) more than 120 miles

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 (b) no

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. (b) I have heard of it before this survey but have no idea about its purpose.
(c) I have general ideas about its purpose. (d) I understand its purpose.

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 (b) no
54. zoology: (a) yes (b) no
55. botany: (a) yes (b) no
56. physics: (a) yes (b) no
57. chemistry: (a) yes (b) no
58. geology: (a) yes (b) no
59. astronomy: (a) yes (b) no
60. environmental science: (a) yes (b) no
61. integrated general science: (a) yes (b) no

How many **SCIENCE** teacher organizations do you have membership in at the

62. local/state level (STAT, etc.): (a) 0 (b) 1 (c) 2 or more
63. national level (NSTA, NABT, etc.): (a) 0 (b) 1 (c) 2 or more

Have you attended a convention or conference for **SCIENCE** teachers in the last 3 years

64. in the Panhandle: (a) yes (b) no
65. in Texas but not in the Panhandle: (a) yes (b) no
66. in another state: (a) yes (b) no

67. In the last 3 years have you attended **district-required** professional development addressing methodology used to teach science? (a) yes (b) no

68. In the last 3 years have you attended **district-required** professional development addressing knowledge of science concepts? (a) yes (b) no

69. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach science:
(a) every year (b) every other year (c) every 3-5 years (d) never

70. Frequency you **choose** to attend **non-required** professional development addressing knowledge of science concepts: (a) every year (b) every other year (c) every 3-5 years (d) never

71. Which of the following best describes your knowledge about the publication National Science Education Standards:
(a) I have not heard of it. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

How often do you use the following activities for science instruction:

72. Activities involving students in manipulating objects and/or equipment: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

73. Field trips to off-campus sites for science objectives: (a) weekly (b) monthly (c) every semester (d) every year (e) never

74. Collaborative or cooperative learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

75. Computer activities in science class or lab: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

76. Teacher demonstrations in science: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

77. Teacher lecture in science class: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

78. Discovery/Inquiry learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

79. Computers for tutorials: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

80. Alternative assessment: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

Indicate the extent you need assistance with each of the following in your science teaching:

81. New teaching methods: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

82. Instructional materials: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

83. Resources available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

84. Programs available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

85. Speakers available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

86. Field trips available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

87. Uses of Internet in science classes: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

88. Maintaining plants and animals: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

89. Discovery/Inquiry learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

90. Collaborative or cooperative learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

91. Hands-on activities: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

92. Classroom demonstrations: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

93. Alternative assessment: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

94. Technology in science classrooms: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

95. Process skills: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

96. Life science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

97. Physical science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

98. Earth science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

99. Environmental science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

100. Astronomy: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

101. Integration of mathematics and science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

102. Applications of science concepts in society: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

103. Science related societal issues: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

104. Science related career opportunities for students: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

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 (b) 1 (c) 2 or more

106. national level (NCTM, etc.): (a) 0 (b) 1 (c) 2 or more

Have you attended a convention or conference for **MATHEMATICS** teachers in the last 3 years

107. in the Panhandle: (a) yes (b) no

108. in Texas but not in the Panhandle: (a) yes (b) no

109. in another state: (a) yes (b) no

110. In the last three years have you attended **district-required** professional development addressing methodology used to teach mathematics concepts? (a) yes (b) no

111. In the last three years have you attended **district-required** professional development addressing knowledge of mathematics concepts? (a) yes (b) no

112. Frequency you **choose** to attend **non-required** professional development addressing methodology used to teach mathematics concepts: (a) every year (b) every other year (c) every 3-5 years (d) never

113. Frequency you **choose** to attend **non-required** professional development addressing knowledge of mathematics concepts: (a) every year (b) every other year (c) every 3-5 years (d) never

114. Have you participated in training addressing the use of manipulatives? (a) yes (b) no

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. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

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. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

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. (b) I have heard of it but have no idea what it says. (c) I have general ideas about what it says. (d) I have begun implementation of ideas it presents.

How often do you use the following in mathematics instruction:

118. Hands-on activities in which students use manipulatives: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

119. Teacher demonstrations using manipulatives: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

120. Collaborative or cooperative learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

121. Computers for tutorials: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

122. Computers for drill and practice: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

123. Computers for instructional activities: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

124. Calculators for computation: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

125. Calculators for instructional activities: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

126. Problem-solving activities: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

127. Teacher lecture: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

128. Discovery/Inquiry learning: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

129. Alternative assessment: (a) daily (b) weekly (c) monthly (d) once a semester (e) never

Indicate the extent you need assistance with each of the following in your mathematics teaching:

130. New teaching methods: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

131. Instructional materials: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

132. Resources available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

133. Programs available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

134. Speakers available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

135. Field trips available in our region: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

136. Uses of Internet in mathematics classes: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

137. Discovery/Inquiry learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

138. Collaborative or cooperative learning: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

139. Manipulatives to model mathematics concepts: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

140. Computers in mathematics classrooms: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

141. Calculators in mathematics classrooms: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

142. Problem-solving: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

143. Alternative assessment: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

144. Patterns, relations and functions: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

145. Number sense (not the competition but the comfort with and ability to use numbers): (a) definitely yes (b) probably yes (c) probably no (d) definitely no

146. Geometry: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

147. Proportions: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

148. Statistics: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

149. Probability: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

150. Reasonableness: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

151. Estimation: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

152. Measurement: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

153. Fractions: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

154. Decimals: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

155. Integration of mathematics and science: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

156. Applications of mathematics in today's world: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

157. Mathematics related career opportunities for students: (a) definitely yes (b) probably yes (c) probably no (d) definitely no

D. All teachers please answer the following questions:

158. Describe the most beneficial professional development that you have attended in the last five years:

159. What are the major obstacles you face in participating in professional development?

160. Other comments:

TASK 4

Graduate Education

WORK PLAN PROGRESS REPORT
Graduate Education
Period Covered: November 1, 1995 through January 31, 1996

1. Summary of research activities during reporting period.

Continued developing a prototype delivery system on world wide web server. Interfaced with researchers from the Electronic Resource Library (ERL) subproject to ensure compatibility of the prototype delivery system with ERL systems. Began initial planning to include researchers with instructional technology background.

2. Tangible accomplishments.

Initial design of the prototype delivery system.

3. Important recommendations regarding the ANRCP Competitive Grants Program.

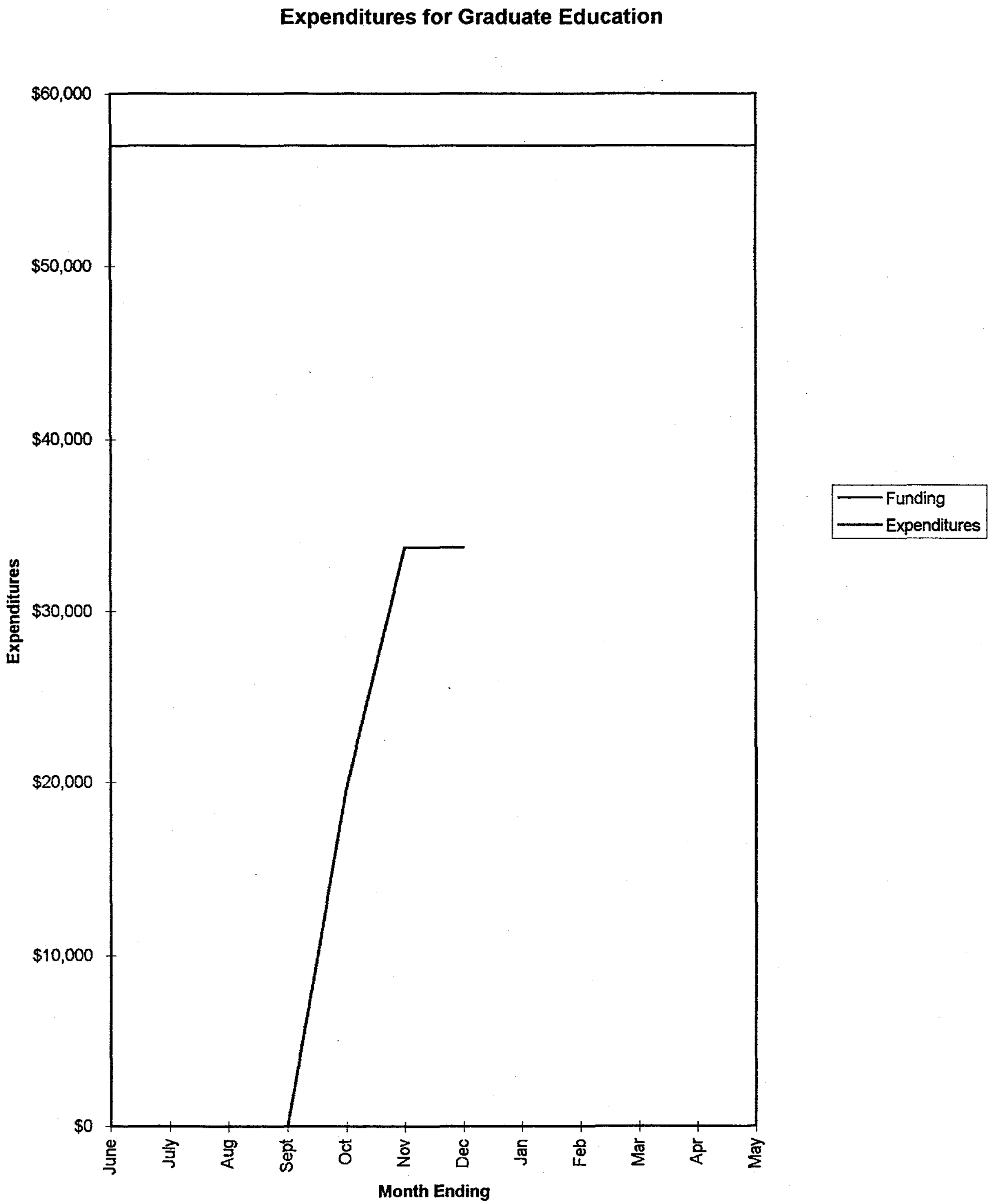
None

4. Approach changes. None

5. Performance variances. None

6. Open items. None

7. Status assessment and forecast. Continue with original project schedule.


Expenditures for Graduate Education
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
Expenditures
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Month Ending
Funding
Expenditures

TASK 4

Science Information and Resource Center

WORK PLAN PROGRESS REPORT
Science Information and Resource Center
Period Covered: November 1, 1995 through January 31, 1996

1. Summary of research activities during reporting period.

Since October 1, 1995, the investigators have initiated the pre-design process. The following activities are in progress:

a. Design programming has begun. Due to constraints that will be identified in part 5 of this report, the programming stage has been limited to: (1) visits to three science center/museums in the Texas Panhandle region; (2) interviews with the directors of the aforementioned facilities; (3) interview with the ANRCP Director; and (4) preliminary development of a review of literature, user needs analysis, and activities analysis.

b. Identification of science/information centers outside of the Panhandle which the investigators will visit and critically assess. Travel arrangements to Albuquerque and San Francisco are underway. The first visit to Albuquerque is scheduled for mid-February.

2. Tangible accomplishments.

To date, the principle product of the research is the collection of background information for the design program document. This has included information gathered from preliminary reviews of literature, interviews with museum directors, and assessments of three regional facilities: a science center and a museum. Additionally, a research office for the Science Information and Resource Center subproject has been established near the offices of the principal investigators.

3. Important recommendations regarding the ANRCP Competitive Grants Program.

As a result of lengthy funding delays, the project is significantly behind schedule. Consequently, there has been limited interaction with ANRCP except for the initial proposal review and subsequent requests for project clarification. The principle suggestion might be to increase the lead-time for submission of reports and subsequent proposals. The researchers recognize, however, that ANRCP may have little control over this.

4. Approach changes. None.

5. Performance variances.

The original research objectives and methodology were based on an award period to begin October 1, 1995. Although the Board of Directors of ANRCP approved the research proposal very promptly, the sub-contract was not received until the end of January 1996. The investigators were not permitted to establish even a temporary budget until mid-January 1996. Consequently, the project has not progressed to the intended level. For example, lack of funding has not permitted investigators to appoint graduate research assistants whose immediate functions would have included identification of appropriate data bases, a thorough review of literature, and preliminary development of a survey instrument. Furthermore, the principal investigators have been hesitant to seek out additional investigators from both Texas Tech and consortium member universities without a firm commitment. Additionally, the investigators had intended to visit and assess several science/information centers before October 31, 1995.

6. Open items. None.

7. Status assessment and forecast. Initiate work on project plan.

TASK 4

Public Outreach

WORK PLAN PROGRESS REPORT
Public Outreach
Period Covered: November 1, 1995 through January 31, 1996

1. Summary of research activities during reporting period.

Completed and submitted for review the final report on the ANRCP Awareness Study.

Scheduled interviews with key stakeholders to provide information for the development of the Communication Plan.

Producing the Pantex Documentary.

Developing the ANRCP Informational Video.

Developing print material to accompany the ANRCP Informational Video.

2. Tangible accomplishments.

Presented subproject information at the following meetings:

> November 1995 - Chicago, Midwest Association of Public Opinion Research.
>
> December 1995 - Texas Tech University Campus, Dr. Lee Peddicord, Texas A & M University.
>
> December 1995 - ANRCP, Amarillo, Poster session.

3. Important recommendations regarding the ANRCP Competitive Grants Program.

None.

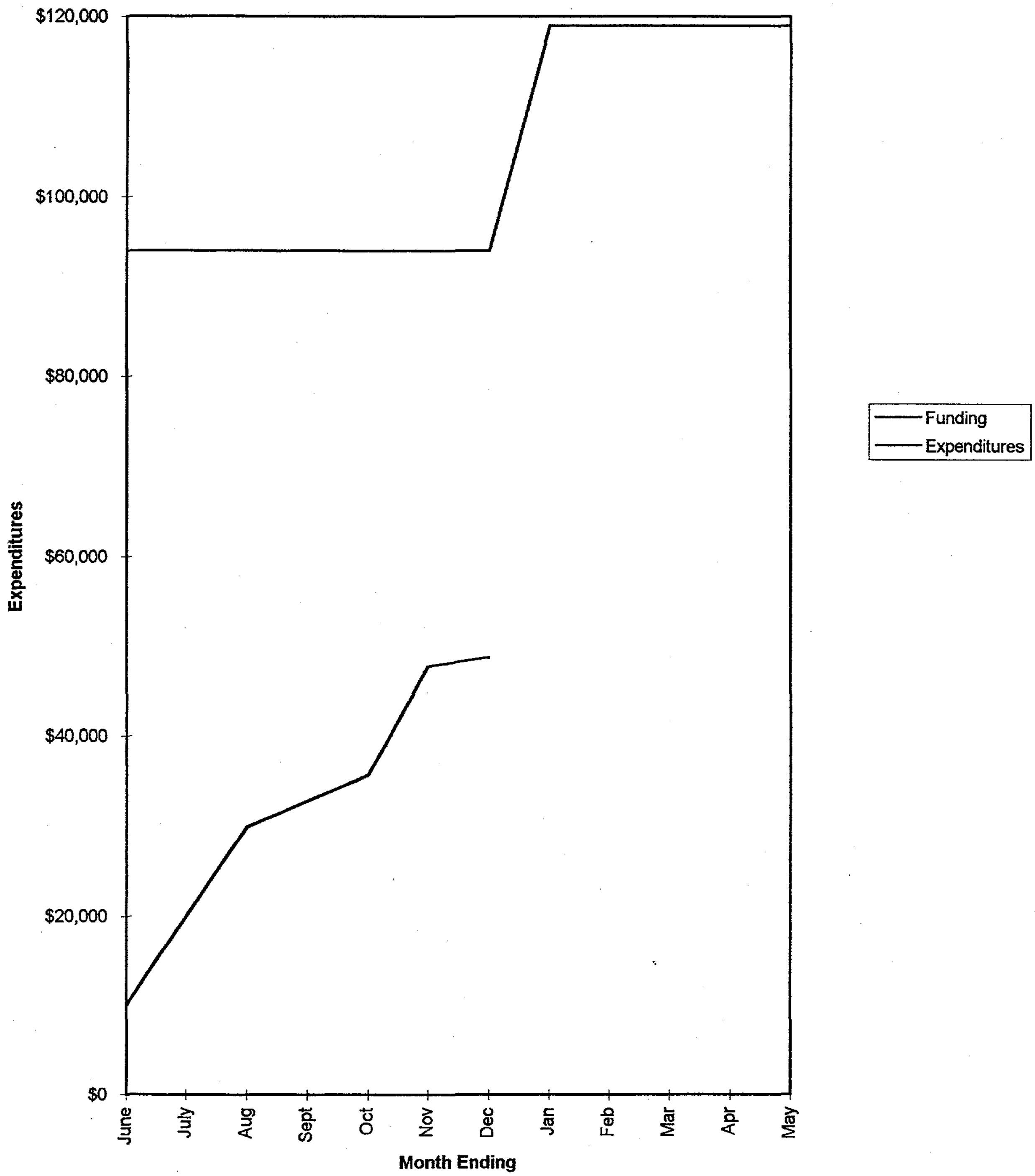
4. Approach changes. None.

5. Performance variances. None.

6. Open items. None.

7. Status assessment and forecast. Continue with project plan.

Expenditures for Public Outreach



Amarillo National Resource Center for Plutonium

A Higher Education Consortium consisting of the Texas A&M University System, Texas Tech University, and The University of Texas System

January 1996

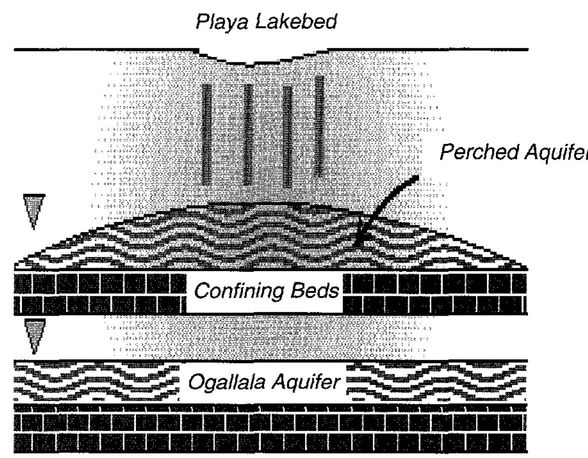
Environmental News

Bugs in the water?

Frequently, the Governing Board of the Amarillo National Resource Center for Plutonium is briefed on the progress of its various programs. In December 1995, Dr. Randall Charbeneau from the University of Texas at Austin reported on an Environmental Restoration project - but not to the members of the Governing Board only. Virakon Kongdara (also known as Kon), a junior at Palo Duro High School and student at Amarillo Area Center for Advanced Learning (AACAL), was accompanied by his AACAL teacher of environmental technology and attended the presentation. According to Kon, "The governing board meeting was very interesting. New ideas and evaluations of environmental works were discussed. It was a very positive experience of board meeting, organization and most of all, teamwork for the better(ment) of the community."

The Center researchers have an opportunity to work in a living laboratory at the Pantex Plant near Amarillo. Their research tasks are motivated by the Ogallala Aquifer. They include testing the perched aquifer and conducting treatability experiments as well as experiments associated with bioremediation of the groundwater.

In an earlier series of October 1995 reports, Charbeneau stated that site characterization investigations at the Pantex Plant have shown that the perched aquifer beneath Pantex is contaminated with concentrations of chromium, high explosives and chlorinated solvents. According to Charbeneau, research has identified an option for removal of chromium from groundwater which is pumped to the surface using the Pantex treatability system. For the organic contaminants, bioremediation is one option being investigated for subsurface restoration. Bioremediation of unsaturated soil and groundwater involves the use of microorganisms to convert contaminants to less harmful species in order to remediate contaminated sites. Charbeneau continued to say that bioremediation of organic contaminants in the saturated and unsaturated zones is an attractive remediation technology because of its low cost and high level of public acceptance.



Reported research results to date are not conclusive and indicate the need for continued research as issues arise out of research design and methodology. For example, the laboratory research on high explosives has shown that soil core samples will not yet yield the microorganisms capable of degrading nitroaromatic compounds. However, research on *in situ* cometabolism of chlorinated solvents has shown that slow growing organisms (phenol degraders and methanotrophs) are present in the perched aquifer.

Treated and remediated water at the Pantex Plant site is a valued water resource not only for Pantex but also for the surrounding agricultural community. Collaborative efforts that support research and community outreach on this research topic are important priorities of the Center.

5. recovery and disposition of residual amounts of weapons-grade materials that are remnants of the weapons production process; and
6. disposition by deep burial.

And here. After having spent several weeks delivering lectures at Texas A&M in College Station, Professor Vladimir Naumov of the Moscow Engineering Physics Institute spoke at a Panhandle 2000 luncheon in Amarillo, Texas on December 7 about Russia's approach for using plutonium as a fuel to generate electricity in fast reactors. Professor Naumov made it clear that Russia fully intends to use its excess weapons plutonium as a valuable fuel to generate electricity, and that waste generated from that process will not be significantly different than waste generated from the civilian nuclear power program. Dr. Naumov is an expert on Russian nuclear power plants and was in Amarillo on behalf of the Amarillo National Resource Center for Plutonium.

Off-Center News

- We recycle. It took only four days to convince the janitor not to empty the recycle bins.
- Holiday reception: ours was a time to champion the people who do the work and to share our progress with Amarillo civic leaders.
- For Nuclear Group news, contact igor@trinity.tamu.edu.
- Let us know who you think should receive this newsletter and contact derrick@pu.org.

Contributors

Dr. Randall Charbeneau is the Director of the Center for Research and Water Resources at the University of Texas at Austin
Judy Kelley is Associate Director of the Texas Engineering Experiment Station Regional Division at West Texas A&M University, Canyon.
Kim Bruce is a Public Information Specialist and Dana Olmstead is the Director of the Office of Communication Services at West Texas A&M University, Canyon
Dr. Shearle Furnish is Associate Professor of English at West Texas A&M University, Canyon
Dr. Karen Ruddy is at the Learning Resources Center at Amarillo College, Texas
Dr. Radha is Associate Professor and the Department Head of Civil Engineering at Prairie View A&M University
Dr. Huque is Assistant Professor in Mechanical Engineering at Prairie View A&M University

Amarillo National Resource Center for Plutonium
600 S. Tyler, Suite 800 - Mail Box 12098
Amarillo, Texas 79101

Printed on Recycled Paper

"This newsletter was prepared with the support of the U.S. Department of Energy, Cooperative Agreement No. DE-FCO4-95AL85832. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE."

Amarillo National Resource Center for Plutonium

Quarterly Progress Report
1 November 1995 - 31 January 1996

Nuclear Group

TABLE OF CONTENTS

COORDINATION AND TECHNICAL INFORMATION SUPPORT FOR NUCLEAR GROUP ACTIVITIES

Paul Nelson (PI), Gia Alexander, Department of Nuclear Engineering, Texas A&M University
Igor Carron, The Amarillo National Resource Center for Plutonium

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

Support Activities

Following are the specific tasks and activities that were proposed under this project, and progress on these that has occurred during the present period:

Tasks

1. Flow of Information to the Nuclear Group

***Subtask 1a: Develop a Nuclear Group Library at ANRCP Headquarters in Amarillo*:**

During this reporting period, one trip was made by Dr. Carron to Texas A&M University and University of Texas. This trip was made to present the possibilities offered by the Nuclear Group Library in terms of acquisitions. Most of the Principal Investigators (PIs) of the Nuclear Group at these institutions were visited. Another goal of the trip was to define the subjects which PIs were most interested in. This effort was aimed at optimally fulfilling their documentation and information needs. Those meetings were beneficial in terms of future interactions.

A web page was subsequently created which contained the holdings of the Nuclear Group Technical Library. This web site can be viewed from each of the universities participating to the Nuclear Group activities. It is updated every time new holdings are being acquired. Further collaboration with the Public Outreach program has led to include the holdings of the DOE public room located at Amarillo College, Amarillo, TX. The result of several searches made on electronic databases were also made available through another web page to the Nuclear Group Principal Investigators. This was aimed at enhancing their capabilities for finding documents relevant to their topics of investigations. A procedure was devised in order to continue updating the DOE Public room holdings on this web page by having monthly contact with Dr. Karen Ruddy and George Huffman at Amarillo College.

The following documents have been acquired from the open literature publications in order to form a nucleus for the planned Nuclear Group Library:

* Books:

Plutonium Handbook, A Guide to the Technology, Volume I and II. O.J. Wick Editor, American Nuclear Society, 1980.

Physics of Plutonium Recycling, Volume 1: Issues and Perspectives, OECD-Nuclear Energy Agency, 1995.

Physics of Plutonium Recycling, Volume 2: Plutonium Recycling in PWRs, OECD-Nuclear Energy Agency, 1995.

Physics of Plutonium Recycling, Volume 3: Void Reactivity Effects in PWRs, OECD-Nuclear Energy Agency, 1995.

Protection and Management of Plutonium, Special Panel Report, American Nuclear Society, August 1995.

* Technical Reports:

Each National Laboratories technical reports were provided by these same National Laboratories. The Russian technical reports were provided to the Nuclear group through contacts during US/Russia Joint Studies activities.

McKibben et al, 1993, Vitrification of Excess Plutonium, Predecisional Draft, Report No. WSRC-RP-93-755, Savannah River Site, Westinghouse Savannah River Company, May 1993.

Brough W.G., Boerigter S.T., 1995 Plutonium-bearing Materials Feed Report for the DOE Fissile Materials Disposition Program Alternatives, Report No. UCRL-ID-120749, Lawrence Livermore National Laboratory, April 6.

Omberg R.P., Walter C.E., 1993, Disposition of Plutonium from Dismantled Nuclear Weapons Fission Options and Comparisons, LLNL, Report No. UCRL-ID-113055.

Ramspott L.D., Choi J-S, Halsey W., Pasternak A., Cotton T., Burn J. McCabe A. Colglazier W., W.W.-L Lee, 1992, Impacts of New Developments in Partitioning and Transmutation on the Disposal of High-level Nuclear Waste in a Mined Geologic Repository, LLNL, Report No. UCRL-ID-109203.

GE Nuclear Energy Report NEDO-32351, Study of Pu Disposition Using the GE Advanced Boiling Water Reactor (ABWR), April 30, 1994 (Includes Errata and Addenda Revs. 1 & 2) ARM-3.

GE Nuclear Energy Report NEDO-32361, Study of Pu Disposition Using Existing GE Boiling Water Reactors, June 1, 1994 (Includes Errata and Addenda Revs. 1 & 2).

Arthur E., Buksa J., Davidson W., Poston D., 1995, Discriminators for the Accelerator-based Conversion (ABC) Concept Using a Subcritical, Molten Salt System, Report No. LA-12949-MS, UC-721, Los Alamos National Laboratory, May 1995.

Bowman C. D., Venneri F., 1994, Underground Supercriticality from Plutonium and Other Fissile Material LANL Report, LA-UR 94-4022A

Canavan G. H., 1995, Comments on "Nuclear Excursions" and Criticality Issues, LANL Report, LAUR:95:0851.

Rudneva V., Kagramanian V., Murgorov V. Poplavski V., Chaudat J.P., Faure C., Grouiller J.P., Zaetta A., Sicard B., The AIDA MOX Program: Strategic Approaches to Plutonium Utilization, Log. 281.

Mugorov V.M., Dubinin A.A., Ziabletsev D.N., Ilyunin V.G., Kagramanyan V.S., Kazantev G.N., Pivovarov V.A., Raskatch F.P., Smetanin E. Ya, Troyanov M.F., Tsikunov A.G., Chernov L.A., 1995, Uranium-Thorium Fuel Cycle - Its Advantages and Prospects of Nuclear Power Development on this Basis, Obninsk, IPPE - 2448.

Mugorov V.M., Kagramanian V.S., Troyanov M.F., Poplavski V.M., Matveev V.I., The Management of Plutonium in Russia, Obninsk, IPPE, Log. 129.

Mugorov V.M., Kagramanian V.S., Chebeskov A.N., Scenarios of Separated Plutonium Utilization in Russian Thermal and Fast Reactors, Presented at ICEM 5, Berlin, Germany, 3-5 September 1995.

Mugorov V.M., Troyanov M.F., Poplavsky V.M., Kagramanian V.S., Malenkov A.V., Kiryushin A.I., Sukhnev K.L., Yershov V.N., Is Construction of Fast Power Reactors More Expensive Than for Thermal Reactors in the Present-day Russian Nuclear Power Industry, Obninsk, Log. 018.

Mugorov V.M., Kagramanian V.S., Troyanov M.F., 1995, Nuclear Fuel Cycle Resistant to Proliferation with Using Plutonium in Russia, The Consultants Meeting IAEA, 26-30 June 1995, Vienna.

* Conference Proceedings:

Volga 95, Proceedings of 9th Topical Meeting on Problems of Nuclear Reactor Safety, September 4-8, 1995, Mephi, Volumes 1 and 2.

ICEM 95, Proceedings of the Fifth International Conference on Radioactive Waste Management and Environmental Remediation, Edited by Slate S., Feizollahi F., Creer J., Berlin, Germany. September 3-7 1995.

Global 95, International Conference on Evaluation of Emerging Nuclear Fuel Cycle Systems, Versailles, France, September 11-14, 1995.

Subtask 1b: Participate in DOE-MD meetings, particularly the monthly technical information status meetings.

Dr. Paul Nelson participated at the December and the January DOE-MD technical information status monthly meetings.

Subtask 1c: Promulgate electronically a monthly group newsletter to participate in the Nuclear Group.

A third Newsletter was sent electronically to the participants in the Nuclear Group. Dr. Carron helped in defining the relevant newsletters the Center should acquire so that information relevant to the DOE complex and the Weapons Dismantlement activities in Russia be made available to the Nuclear Group in the monthly Newsletter and to the Center.

Subtask 1d: Promulgate electronically, on a monthly basis, a conference calendar providing brief information regarding technical conferences and other public events that relate to the interests and activities of the Nuclear Group.

A third Calendar was sent electronically to the participants in the Nuclear Group.

2. Flow of Information from the Nuclear Group

Subtask 2a: Organize quarterly meetings of Nuclear Group participants.

No quarterly meetings were organized during this period.

Subtask 2b: Prepare quarterly progress reports describing activities of the Nuclear Group.

The second of these quarterly progress report consists of the present document.

Subtask 2c: Edit, print, assemble and distribute topical technical reports presenting results obtained by the various research projects operating within the Nuclear Group.

No topical technical reports were processed during this period.

Subtask 2d: Prepare an annual report describing activities of the Nuclear Group over the past year.

Not applicable.

3. Global Information Flow

Subtask 3a: Organize workshops devoted to specific technical issues of interest to the Center and DOE-MD.

Dr. Carron and Dr. Hassan (Texas A&M University) sent a call for papers for sessions to held at the ANS/ENS International Meeting on Transport Phenomena in the Disposal of Fissile Materials.

Subtask 3b: Organize major national and international conferences on broad topics of interest to the Center and DOE-MD.

No actions were taken during this period.

Most Tangible Accomplishments

Acquisition of Technical Reports and other documents from National Labs and other organizations. Constitution of a web page accessible to all Nuclear Group Participants for information on the status of the Technical Library. Electronically sent a Newsletter and a Calendar of Events for the Nuclear Group participants. Participation to DOE-MD monthly meetings.

SUPPORT OF JOINT US/RUSSIAN TECHNICAL WORKING GROUPS FOR THE STUDY OF ALTERNATIVES FOR THE DISPOSITION OF EXCESS WEAPONS-GRADE PLUTONIUM

Paul Nelson, Department of Nuclear Engineering, Texas A&M University (PI)
Igor Carron, Amarillo National Resource Center for Plutonium

PROGRESS REPORT
(1 November 1995 - 31 January 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 to travel to Russia in support of the study. Specific instances follow:

1. Professors Dale Klein, Paul Nelson and K. Lee Peddicord represented the Center at the first meeting of the Joint Co-chairs, which was held at the Institute of Physics and Power Engineering (Obninsk, Russia), November 2-4 .

2. The Center made all arrangements for the Russian participants in the second meeting of the Joint Co-chairs, including individual site visits to various DOE laboratories following the meeting itself. This meeting was held at the Oak Ridge National Laboratory (Oak Ridge, Tennessee), December 5-7, 1995. The Center was represented by Professors Klein and Peddicord, with administrative support from Ms. Brenda Mooney.

3. The Center made arrangements for Dr. A. Malenkov, Russian Co-chair of the newly formed Economics Study Team (see below), to visit the Oak Ridge National Laboratory from December 9-23, 1995. The purpose of this visit was to plan, jointly with the U.S. Co-chair (Dr. Kent Williams, ORNL), the efforts to be carried out within the framework of the Economics Study Team. Mr. Brad Rearden represented the Center during a portion of these discussions.

4. The Center made arrangements for the Russian participants in the second meeting of the Joint Steering Committee for this study. This meeting was held at the Lawrence Livermore National Laboratory (Livermore, California), January 17-19, 1996. The center was represented by Professor Peddicord.

5. The Center currently is coordinating with Dr. Cal Jaeger (Sandia National Laboratories - Albuquerque), who is Co-chair on the U.S. side, in making detailed arrangements for the Russian participants in the forthcoming meeting of the newly formed Nonproliferation Study Team. This meeting is scheduled for March 4-7, 1996, at the Roslyn (Virginia) office of Sandia. The Center will be represented by Professor Nelson and Dr. Igor Carron.
6. A contract has been issued to the Institute Physics and Power Engineering and the A. A. Bochvar Institute to provide the Protocol for a Joint U.S.-Russian Plutonium Disposition Study and Terms of Reference for this disposition studies. The U. S.-Russian Joint Studies

call for six working groups to evaluation the following plutonium disposition options: Water Reactors, Fast Reactors, Long -Term Storage, Burial in Geological Formations, Immobilization, and Stabilization of Solutions and Other Forms. ,

The primary other event during the present reporting period that impacted this effort was the mutual agreement, at the December Co-chairs meeting in Oak Ridge that was mentioned above, to form two additional study teams, on Economics and Nonproliferation.

WATER-REACTOR OPTIONS FOR DISPOSITION OF WEAPONS PLUTONIUM

Naeem M. Abdurrahman (Co-PI), Department of Mechanical Engineering, University of Texas
Marvin L. Adams (Co-PI), Department of Nuclear Engineering, Texas A&M University
D. Yu. Anistratov, Department of Nuclear Engineering, Texas A&M University
Yassin Hassan, Department of Nuclear Engineering, Texas A&M University
Ted A. Parish, Department of Nuclear Engineering, Texas A&M University
W. Wilson Pitt, Department of Nuclear Engineering, Texas A&M University
W. Dan Reece, Department of Nuclear Engineering, Texas A&M University

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

Research Activities

- MOX Data Repository

Database software for the on-line database was acquired and installed . Design of on-line interface and database structure was begun. Some data on MOX fuels was found; much more was found to be proprietary. Contact was established with key personnel at ORNL who know a great deal about existing data, both public and proprietary.

- Design of Within-Assembly Enrichment Distributions

A working meeting was held at the Westinghouse Energy Research Center in Monroeville, PA where the scope of this task was precisely defined. The Vogtle plant was chosen as a model and the first transition cycle was selected as the target in which the intra-assembly enrichments are to be optimized.

Methodology was assembled at Texas A&M for estimating peaking factors in each assembly throughout the cycle, and this was used to evaluate initial enrichment distributions. Preliminary designs will be completed in February, at which time a student researcher will go to Monroeville to perform final calculations and design refinements, using Westinghouse codes.

- Sol-gel Processes for MOX Fabrication

Completed survey of sol-gel processes. Found at least two gel processes that appear feasible for preparing MOX fuel; these would require minimal development before production use. Prepared to present results at AIChE meeting.

- 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. We began seeking approval and preparing for this design effort by assembling the necessary analysis tools (BRACC, CASMO-3, TABLES-3, SIMULATE-3).

- Design of Multipurpose Reactor

  Agreed to pursue collaboration with ABB-CE on design of multipurpose reactor. Agreed that Palo Verde is to be used for specific design, which will make tritium, irradiated weapons plutonium (as MOX fuel), and make electricity. Reports on previous work were collected, and work was begun on defining the scope of the study.

- Study of VVER Utilization of MOX Fuel

  Hosted Professor V. Naumov of MEPhI 4 weeks. Began report summarizing knowledge gained from visit.

- Characterization of Spent MOX Fuel

  ORIGEN2 was obtained, installed, and tested on simple MOX cores. SCALE was obtained and installed. A study of MOCUP (a link between MCNP and ORIGEN2) was begun to determine whether to acquire it.

- Evaluation of Analysis Tools

  Made progress toward evaluating reactor-analysis tools as applied to MOX cores. Obtained WIMS results similar to published results on MOX benchmark problems.

- Economic analysis

  Entered final stages of assembling methodology for evaluating economics of various MOX fuel-cycle scenarios.

- MOX Fuel Demonstration

  Began discussing weapons-MOX irradiation demonstrations, potentially to be performed in UT and/or Texas A&M reactors. Arranged meeting of OFMD, ORNL, LANL, and ANRCP, to be held in College Station in early February.

- Exploration of Gallim Removal

  Initiated search for feasible methods and processes for controlled removal of gallium during or before fuel fabrication.

- **Most Tangible Accomplishments**

  Made considerable progress toward recognition as a key player in the water-reactor disposition effort. Moved toward better coordination among the large number of entities involved: DOE/OFMD, ANRCP, ORNL, LANL, Westinghouse, GE, ABB-CE, AECL.

SUPPORT OF RUSSIAN JOINT STUDIES: IMMOBILIZATION STUDIES

Abraham Clearfield (Co-PI), Department of Chemistry, Texas A&M University
Richard Bartsch, Department of Chemistry, Texas Tech University
Mukul Sharma (Co-PI), Department of Chemical Engineering, The University of Texas

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

TASK 1: Immobilization and Disposal of PuO2 by Incorporation into Ceramic Media (Dr. A. Clearfield and Dr. R. Bartsch)

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, CaTiO3 (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 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 (O.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.

TASK 2: Disposition of Excess Weapons-grade Plutonium in Deep Boreholes (M. Sharma)

The progress made since November 1, 1995 is summarized below.

The experimental apparatus to measure diffusion rates of plutonium surrogates in bentonitic type materials was completed. The apparatus can measure transport rates of ions and other aqueous species at confining pressures of up to 5000 psi. Initial tests were completed to monitor the rates of transport of chloride 36 and calcium 40 in very fine grained bentonitic shales. Preliminary results indicate that the apparatus is functioning properly and diffusion rates measured for chloride 36 ions appear reasonable.

The review of the existing work on colloid mediated radionuclide transport in the geosphere continues. A detailed report summarizing past work is currently under preparation.

We still do not have a graduate student to conduct the research on geochemical modeling for plutonium transport. Initial contacts have been made with Professor Larry Lake and Professor Mary Wheeler who have been involved with past work on uranium transport using geochemical models. The feasibility of using these models has been evaluated. We expect that a new graduate student will start working on this project either in the Summer 1996 or by the Fall 1996.

SUPPORT OF FOR 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 November 1995 - 31 January 1996)

This report covers the recently redefined task originally aimed at supporting the Joint US/Russian Study of the HTGR. This task has been redefined to encompass: (a) coordinating ANRCP support of the national storage facility effort, and (b) generating a college-level academic program addressing weapon materials disposition topics.

Research Activities

1. Dr. Boyle developed a revised proposed task plan (as described in paragraph 1 above) in response to the demise of the former HTGR joint US/Russian study effort.

2. In mid-December, Dr. Boyle attended a meeting with LANL and Russian storage experts at Los Alamos. Post-meeting discussions with the LANL POC for storage issues produced a list of specific technical areas where ANRCP experts could conduct independent analyses to aid design of a national consolidated storage facility. Dr. Boyle summarized highlights from these meetings in writing and distributed them to the ANRCP PIs with technical expertise in the appropriate areas. Per recommendation of the LANL storage POC, Dr. Boyle has initiated action to re-activate the security clearances Dr. Boyle will need to participate in future design reviews of the proposed consolidated storage facility. Dr. Boyle hosted the weekend visit to Texas A&M by Russian storage expert, Gennady Kozko.

SUPPORT OF RUSSIAN JOINT STUDIES: ACCELERATOR DRIVEN TRANSMUTATION

R. Wigmans (PI), Physics Department,Texas Tech University
M. A. Frautschi, Physics Department, Texas Tech University

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

Introduction

We report our progress in investigation into the possibilities for accelerator catalyzed transmutation of spent nuclear fuel (high level waste). We also express several concerns related to the deselection of accelerator driven options for excess weapons grade plutonium

Activities

An undergraduate student, Mr. Khondoker M. S. Shahriar, has been added to the TTU group. Mr. Shahriar has assisted with the gathering of nuclear data through the world wide web.

Since our last (27 November 1995) progress report, we have concentrated our investigation on the possible benefits of accelerator driven transmutation (ADT) of high-level nuclear waste into less problematic substances. In particular, we have concentrated our efforts on the nuclide Tc-99, abundantly produced in nuclear fission of uranium and plutonium and, with a half-life of about 200,000 years, one of the longest-lived fission products. Tc-99 decays through emission of energetic electrons (beta-decay, endpoint 294 keV) to Ru-99, which is stable.

The conclusion of our studies is simple: ADT of Tc-99 is a non-viable option. On the other hand, we do see merit in exposing Tc-99 to an intense flux of thermal neutrons, as available near the core of a nuclear reactor.

Thermal neutrons captured by Tc-99 convert this nuclide in Tc-100, which rapidly (15 s) decays to Ru-100, a stable isotope. Subsequent capture of other neutrons by Ru-100 does not lead to the production of other long- lived radioactive substances. The initial Tc-99 (n,gamma) Tc-100 reaction has a large cross section, about 20 barns, and has no competition from other processes, so that the available thermal neutrons are very efficiently used in this way. In a separate study, we will address the practical aspects of this technique (conversion rates, costs, etc.).

The higher-energy neutrons available in the accelerator driven option allow for several additional reaction pathways, involving reactions of the types (n,2n), (n,p), (n,pn), (n,alpha), etc. Most prominent among these is the (n,2n) reaction, which, above a threshold of about 7 MeV, has a cross section of more than one barn for Tc-99. In this process, Tc-98 is produced, a nuclide with a half-life of 4.2 million years, decaying through the emission of energetic electrons and gamma's to Ru-98 (beta endpoint 1.8 MeV). Because of these properties, Tc-98 is much more problematic than Tc-99.

Tc-98 is not produced at significant levels in fission processes (more than 6 orders of magnitude less than Tc-99). This is because fission products with A=98 end up as Mo-98, which is slightly lighter than Tc-98.

Because of these reasons, ADT of Tc-99 will make the nuclear waste problem worse and should thus not be pursued.

SUPPORT OF RUSSIAN JOINT STUDIES: EVALUATION OF FAST REACTORS FOR THE UTILIZATION OF PLUTONIUM

W. D. Reece (PI), Department of Nuclear Engineering, Texas A&M University

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

Research Activities

One of the activities this quarter has been establishing links between the ORNL joint study investigators and the expertise available from the activities at the Fast Flux Text Facility (FFTF) at Hanford, Washington. While we have no current fast reactor program in this country, a consortium of private investors is seriously studying FFTF for use as a tritium production facility. If FFTF should restart, then the core could also serve as a test platform for joint reactor studies.

The Russians have submitted a draft of their material to be included in *the Joint US-Russian Report on the Fast Reactor Option for Pu Disposition in Russia*, and this draft was forwarded to the PI by David Moses at ORNL. The review of this report is still ongoing (both by the PI and ORNL), but several key features are of considerable interest. All of the MOX processes described in the Russian report start with the nitrate form. The US has taken the position that work in this country should work directly from the solid metal form. Whether this effort with the Russians will stymie joint studies is unclear. The Russian report gives an overview of several of the MOX production processes tried in their country, including mechanical mixing of individual oxides, sol-gel processes, ammoniac granulation, carbonate coprecipitation, and plasma-chemical production.

The reactor physics parameters for the BN-350 and BN-600 are given along with proposal and calculations fur using BN-800s. The Russians propose removing the radial (and maybe the axial) blanket from the core to lower the breeding ratio to increase the throughput. Several technical problems with this approach are discussed. No long term storage exists presently for the spent fuel that would be generated from the Pu disposition campaign. Finally, the Russian time line for Pu disposition extends to 2030 even if there is rapid completion of two BN-800 reactors in the Southern Urals by 2004.

TRANSPORTATION OF MIXED OXIDE FUELS

L Balasubramanian and R. Radha, Department of Civil Engineering
Ziaul Huque, Department of Mechanical Engineering
Prairie View A&M University

Y. A. Hassan, W. H. Marlow and Paul Nelson (PI)
Department of Nuclear Engineering
Texas A&M University

D. C. Wunsch, Department of Electrical Engineering
Texas Tech University

Hani Mahmasanni, Center for Transportation Research
The University of Texas at Austin

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

TASK 1: Transportation Modeling (R. Radha and Ziaul Huque, Prairie View A&M University)

Objectives

The main objective of the study is to develop an engineering modeling capability to optimize the transportation of mixed oxide fuels from a temporary storage site to a permanent storage location. This will be used in the future to support the transportation related aspects of the various alternatives for plutonium disposition.

Work in Progress During This Period

1. Information gathering.
2. Use of the TRANSNET software which is provided by the Sandia National Laboratory.
3. Coordination meeting at PVAMU.

Information Gathering

Library resources were used to understand the factors relating to the transportation of radioactive materials like accidents (due to fire, spills, etc.) and the objective risk of exposure in addition to the mode of transportation and routing. The elements that have to be considered in MOX fuel transportation are:

1. Environmental aspects
2. regulatory requirements
3. incident management
4. system, structure and responsibility
5. training, awareness and competence
6. global positioning and communication
7. control procedures
8. emergency preparedness
9. monitoring and measurement

Moreover the available literature on interactive model development has also been reviewed. A graduate student is working on collecting the regulations dealing with the transportation of MOX fuels.

Understanding of the TRANSNET Software

The TRANSNET software was provided by the Sandia National Laboratories as the outcome of the meeting. This is a compilation of risk, system analysis, routing and cost model as well as related data pertaining to radioactive materials transportation. It also has the most up-to-date transportation risk and system analysis codes and databases. Efforts are taken to utilize the software for the project. Hypothetical trial runs have been made using the software. Mr. Rick Orzel has been contacted for source codes, input and output formats to run the TRANSNET software.

Coordination Meeting at PVAMU

A coordination meeting was held at PVAMU on January 22, 1996. Dr. Paul Nelson, Dr. Hassan and Dr. Marlow attended the meeting along with the PVAMU team. Discussions were carried out regarding the proposals and one shot activities. Interaction between the groups were planned and information gathered by individual groups were shared with the other groups. It was decided that the PVAMU team will work in conjunction with Dr. Hani S. Mahmassani, UT Austin in the area of transportation and routing and the TAMU group in the area of fire modeling.

References

1. "The Next Nuclear Gamble: Transportation and Storage of Nuclear Waste", Resnikoff, Marvin, 1983.

2. "Hazardous Materials Transportation: Hearing Before the Subcommittee on Surface Transportation", Washington, DC, 1990.

3. From the Transportation research Record 1148, 1988.

- "Interactive Selection of Minimum Risk Routes for Dangerous Goods Shipments," Saccomanno, F., M. Van Aerde and D. Queen
- "Hazardous Materials Transportation Incident-Accident Information Systems," Abkowitz George List.

Task 1A: Routing Methodologies (H. Mahamasanni, University of Texas At Austin)

A. Summarize Work Accomplished this Quarter (relating progress to objectives describe in your work plan, and attach copies of papers produced)

The general objective of this task is the identification and study of transportation-related issues that arise under this alternative. The primary objective is the identification (as a first step toward ultimate resolution) of transportation-related issues that bear on the acceptability of this alternative.

The UT-Austin team provided a complementary advisory role to the efforts of the Prairie View A&M team in reviewing methodologies for routing hazardous substances, especially nuclear fuels, and created a lot of references which were passed on to the PVAMU team.

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. The methodology at this stage remains generic but may be customized to the specific needs of the project.

B. Briefly Describe Findings

Submitted list of references 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 multiobjective nature, and the dynamically varying stochastic nature of f the network.

C. Work Plan for Next Quarter

Develop conceptual framework for routing procedure, taking into account various sources of risk and characteristics of the network.

TASK 2: Modeling of Plutonium Dispersal (Yassin A. Hassan and William H. Marlow, Texas A&M University)

Research Activities

The primary objective of this task of the transportation project is to model the dispersion if MOX fuels due to transportation accidents. The following is a summary of the progress during this performance period.

Developing a computer program to deal with the accurate description of the fluid flow has started. A computer program PEGSUS from the Air Force has been ordered and received. This program describes techniques for proper modeling of complex configurations. PEGSUS will produce a file consisting of interpolation information that will be used by the flow solver. This program is being tested.

In January, we met with the investigators of Prairie View A&M University to coordinate our efforts in the transportation project.

TASK 3: Subnational Intervention (D.C. Wunsch, Texas Tech University)

Information for this activity was not available for technical reasons at the time this report was prepared.

TASK 4: Transportation Risk Assessment (Paul Nelson, Texas A&M University)

Since January 15, a search has been conducted to obtain documentation concerning some of the Department of Energy's transportation risk analysis codes. Manuals for RADTRAN 4, a transportation radiological risk computer code developed at Sandia, have been written, however only volumes 3 and 4 (the user's guide and the programmer's manual) are available through NTIS. Sandia Technical Library has been contacted and their staff is currently attempting to find volumes 1 and 2 (the executive summary and the technical manual) through contact with the authors. Other computer codes for which documentation has been requested include RISKIN (a transportation risk code developed at Argonne) and MRISKIN, a modified version of RISKIN.

Texas A&M has access to the NTIS database in the university library, however Prairie View does not. Literature searches have been done using this database to look for documents relevant to work being performed at Prairie View, including searching for reports on the following routing models: HIGHWAY, INTERSTAT, and StateGEN/StateNET. Data bases searched for included

RMIR (Radioactive Materials Incident Report Data Base) and RAMPOST (Radioactive Materials Postnotification Data Base). Information on documents available from NTIS has been forwarded to Lalli Balasubramanian at Prairie View.

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, has not yet been located. Since the original office which produced this report, the Office of New Production Reactors, no longer exists, the Office of Reconfiguration is currently investigating this matter.

DEVELOPMENT OF NONDESTRUCTIVE ASSAY METHODS FOR WEAPONS PLUTONIUM AND MOX FUEL SAFEGUARDS

Naeem M. Abdurrahman (PI), Department of Mechanical Engineering,
The University of Texas at Austin

Bernard W. Wehring, Department of Mechanical Engineering,
The University of Texas at Austin

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

PART 1

The primary objective of this project is to develop nondestructive fissile assay (NDA) methods capable of determining the fissile contents of plutonium pits and fresh as well as spent mixed-oxide (MOX) fuel for verification and safeguards purposes. The following is a summary of the main activities during the second quarter (November 1, 1995 to January 31, 1996) of the project.

We continued our effort to investigate the technological safeguards issues related to plutonium pits and mixed-oxide fuels and to conduct a thorough assessment of current measurement technologies for fissile assay and isotopic determination. This activity included continuing our literature survey and information gathering effort. A report on safeguards issues and technologies is currently being compiled.

We continued our investigation of the two proposed fissile assay devices, namely the delayed neutron gauge (DNG) for plutonium pit assay and the lead slowing down time spectrometer (LSDTS) for MOX fuel assay. 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. The DNG puts less restrictive requirements on the neutron source. We have started evaluating several accelerator and neutron generator options for neutron production that would constitute suitable neutron sources for the DNG and LSDTS. Part of our effort during this period included compiling information on the various options for neutron sources. A report on suitable neutron sources for these devices is currently being compiled.

Based on our preliminary assessment, it appears that the most feasible option is to upgrade the University of Texas Nuclear Engineering Teaching Laboratory (NETL) 14 MeV neutron generator (NG). Unfortunately, the NETLNG as is, as other commercially available neutron generators, is not capable of providing neutron pulses with the intensity and frequency required for the LSDTS. In order to obtain the required intensity we plan to develop a pulsing high voltage source to drive the NETL NG. Using "pulse-power" technology, this HV source will be capable of delivering to the NG target pulses of ions with particle energies of up to 140 keV, currents of up to 100 kA, durations of 1 μs, and repetition rates of 100 pps. Under such timing specifications, a peak current of 10 A would produce the same average heating of the NG target as exists for the NETL NG running in steady state mode. However, it would give an increase of 104 in pulse intensity.

Two neutron transport code packages, namely MCNP and DANTSYS (ONEDANT, TWODANT and THREEDANT), have been selected as the principal computational tools for carrying out the detailed neutronics analyses and engineering designs of the DNG and LSDTS. We have purchased an IBM RS/6000 Workstation, obtained and installed the above neutronics codes, and started our calculation program. This initial phase of the calculations is intended to determine the adequacy of the candidate neutron sources for the LSDTS.

We continued our effort to establish communication and collaboration with national labs and international organizations with programs in nuclear materials safeguards. At the national level we have established contacts with researchers at Sandia National Laboratory (SNL) and Los Alamos National Laboratory (LANL). At the international level, we have established communication with researchers at Moscow Engineering Physics Institute (MEPhI), Belgian Nuclear Energy Center (SCK/CEN), and the International Atomic Energy Agency (IAEA). To enhance communication and collaboration with researchers at MEPhI, we participated in a proposal submitted to NATO for a network equipment grant to improve the networking capabilities of MEPhI. If awarded, this grant, combined with the NATO linkage grant which we have already been awarded, will facilitate our collaboration with MEPhI researchers in nondestructive assay measurement techniques and other research on nuclear materials safeguards.

PART 2

In summary, the most tangible accomplishments thus far include purchasing and setting up a UNIX Workstation, obtaining and installing the main computational codes for our neutronics and design calculations, and starting neutronics calculations to determine the adequacy of the candidate neutron sources for the proposed lead slowing down time spectrometer. We continued our literature search on safeguards issues and technologies, and information gathering on neutron generators and other suitable neutron sources and system components for the proposed slowing down time spectrometer. We continued our effort to strengthen our national and international contacts in the area of safeguards. As part of the latter, we participated in submitting a network equipment grant to upgrade MEPhI networking capabilities. This, if awarded, will serve, in conjunction with the already awarded linkage grant, to facilitate our international collaboration in fissile measurements and safeguards technologies research. Two reports, one on safeguards issues and technologies and the other on suitable neutron sources are currently being prepared.

ROBOTICS, AUTOMATION, AND TELE-OPERATION PROGRAM FOR SAFE HANDLING AND LONG-TERM STORAGE OF NUCLEAR COMPONENTS

Alan Barhorst (PI), Department of Mechanical Engineering, Texas Tech University
Richard Volz, Department of Computer Science, Texas A&M University
George Kondraske, Human Performance Institute, The University of Texas at Arlington
Jose Macedo, Department of Industrial Engineering, Texas Tech University
Mica Endsley, Department of Industrial Engineering, Texas Tech University
William Kolarik, Department of Industrial Engineering, Texas Tech University
Michael Parten, Department of Electrical Engineering, Texas Tech University
Hua Li, Department of Computer Science, Texas Tech University
Jeff Trinkle, Department of Computer Science, Texas A&M University
Louis Everett, Department of Mechanical Engineering, Texas A&M University
S. John Poston, Department of Nuclear Engineering, Texas A&M University
David Kirkpatrick, Department of Engineering Technology, Prairie View AM University
S. Sreenivajan, Department of Mechanical Engineering, The University of Texas at Austin

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

Result Summary

The research project is composed of six areas of study. The research team is composed of members from five distinctive institutions. This section will be completed on a research task basis.

General Information

Since the last report the transients of start up have subsided considerably and the investigators are beginning to see results from themselves and task aware students. The final budgets have been received by the research offices and students have been hired at each site. In general, most of the commercial software required for the project has been obtained and training (TTU only) with these packages has been completed. The larger teams at TTU and TAMU have regular scheduled meetings to keep the respective groups informed. A larger inter-institutional meeting is in the planning stage for the next quarter. The task details are explained below.

Task 1: Storage Automation

System simulation is being approached from a number of different fronts. The Silicon Graphics simulation test bed (Telegrip, ModelGen, and Vega) and other PC-based systems (Working Model and MATLAB) are being investigated as platforms for simulation in this area. These include mobile platform models (at the controller level) and the robotic arms. Vision based path following algorithms for mobile platforms are being implemented for testing on the Staubli robot testbed at TTU.

Task 2: Simulation Testbed

The computers and software necessary for this task have been delivered and/or installed where appropriate. Training on the software has been completed (TTU) and the skills learned are being taught to the other members of the group. Contacts with SNL and LANL personnel have been successful and Telgrip models of the Consolidated Storage Facility (CSF) will be delivered in the next reporting period. The InterAgent software purchase is in progress. Initial study of network protocols such as UDP/IP and TCP/IP have been studied and or implemented on the SGI machine and MS Windows machines. Plans for next quarter include the initiation of the tele-link (via InterAgent) between TTU and TAMU.

Task 3: Human and Automation Integration

The Telgrip simulation software package was installed at TAMU, and various Virtual Reality devices are being added including the flock of birds and a VR head mount display. Intensive training has also been initiated to familiarize personnel with the new equipment.. Also, a method has been found to port existing geometric models, developed using SSM (Solid Surface Modular) in conjunction with NASA Johnson Space Center, to Telgrip. At the TTU site, Vega and ModelGen models are under development that will allow examination of interface concepts. Investigation into how to link ModelGen, Vega, and Telegrip have been initiated. Also see paragraph 2 under Task 5.

Task 4: Component and Material Handling

Algorithms have been developed outside the simulation testbed at present. These algorithms are used for component handling and for large scale contact/impact motion. Tools (workstations and software such as Mathematica and IMSL) available in-house have been utilized. Implementation of the algorithms into the Telegrip based testbed are in future plans.

Task 5: Safety/Reliability Studies

1. At TAMU, a document search has been completed on the gathering of information related to the "Study of Existing Robot Safety Systems." Based on information gathered from this search an analysis of existing automated systems can be implemented in regards to hazard and risk assessment and human-machine interfacing. This information can also be used to analyze activities which might be automated in the future (see Task 6 below).

2. A document search of DOE and NASA documents regarding automation in radioactive and hazardous environments, particularly at Pantex, has been initiated. Based on information obtained during this search a database is being compiled for recording exposure rates, time of task completion, and total worker exposure savings under newly automated procedures, particularly during transportation and storage activities. This information is also useful for Task 3 above.

3. At TTU, work is continuing on the identification and collection of reports and standards. Several documents have been identified and their acquisition is underway. Theoretical development of technology relative to the two Ph.D. research efforts (reported during the last quarter) is continuing. One effort is in the qualifying examination stage, with a research proposal approved. This research proposal deals with control of a dynamic system using neural network and evolutionary methods. The second effort is in the proposal stage, it deals with the collection and assimilation of reliability and time-series technology. Plans for the next quarter call for both of these Ph.D. efforts to clear the qualifying examination stage and enter the actual research phase. Both efforts will consist of theory and empirical demonstration of the theory.

Task 6: Automation Studies

See paragraph 1 under Task 5. This task will remain integrated with the other task as explained in the proposal.

Most Tangible Accomplishments

The most tangible results are the Software and Computer installation, the minor results that are in the genesis stage, and the fact that we have been given the CSF simulation completely from the SNL (Larry Shipers) and LANL (Warren Wood) personnel working on the CSF. They have also agreed to help the transition occur smoothly. With the large number of investigators on this project and considering the initial start up problems, major results will be abundant in the very near future.

AIR MONITORING FOR DETECTING RELEASES OF PLUTONIUM IN A FUTURE CONSOLIDATED STORAGE FACILITY

R. L. Corsi (PI), Department of Civil Engineering, University of Texas (Principal Investigator)
M. J. Andrews, Department of Mechanical Engineering, Texas A&M University
P. K. Dasgupta, Department of Chemistry, Texas Tech University
H. M. Liljestrand, Department of Civil Engineering, University of Texas
William H. Marlow, Department of Nuclear Engineering, Texas A&M University
A. R. McFarland, Department of Mechanical Engineering, Texas A&M University
J. C. Rodgers, ESH-4, Los Alamos National Laboratory.

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

INTRODUCTION

Under certain scenarios, it is possible that plutonium aerosol could be released into the indoor environment of a future Integrated Storage Facility (ISF) at the PANTEX facility. For example, a plutonium aerosol could occur if a storage container were to leak due to the effects of prolonged storage under conditions of fluctuating temperatures, which could induce moisture and suitable oxidizing conditions leading to corrosion and plutonium or uranium release. Because the ISF will not be constructed for several years, the intervening period provides an excellent opportunity for the design and development of monitoring systems that will allow detection of plutonium container leakage, identification of the leakage source, and quantitative determination of plutonium aerosol releases.

The purpose of this research effort is to develop an optimized system for detecting plutonium releases in the ISF. The system will ultimately provide meaningful data for alarm purposes, for determining the exact source of leakage, and a quantitative basis for indoor and outdoor exposure to such releases. The research program will be completed over a four year period, and will result in optimal design criteria for sampler sitting, as well as hardware systems for detection of leakage and measurement of plutonium aerosols. During the first year of the proposed study, the research team will conduct studies that will lay the foundation for the actual monitoring system. Subsequent years will focus on system development and testing.

The research program is divided into three primary areas and four primary tasks (see next section). These areas include (principal investigator(s) from each institution are noted in parentheses) (1) development of a method for detecting the occurrence and isolating the location of leakage from storage containers (R.L. Corsi and H.M. Liljestrand, The University of Texas at Austin), (2) development of a method for predicting the best sampling and monitoring locations (A. McFarland, Texas A&M University), and (3) development of a method(s) for accurate detection of plutonium aerosols (W. Marlow, Texas A&M University and P.K. Dasgupta, Texas Tech University).

PRIMARY TASKS

The research has been divided into three major areas and four primary tasks as described above. Each primary task has been divided into appropriate sub-tasks by the appropriate research team. Progress statements for each of the four primary tasks are provided below. Note that primary tasks 3 and 4 both fall within area (3) (development of a method(s) for accurate detection of plutonium aerosols).

Primary Task 1. Development of a Tracer-Based Fingerprinting System to Identify and Locate Pu Storage Container Leakage (R.L. Corsi and H.M. Liljestrand Department of Civil Engineering, The University of Texas at Austin)

As described above, it is plausible that plutonium storage containers could "fail" during long-term storage, with the potential release of plutonium aerosols. It would be desirable to identify container failure prior to significant losses of plutonium particles, such that remediation action may be taken to eliminate container leakage. This task involves the design and ultimate development of a tracer-based detection system that will allow both the identification of a container leakage, as well as determination of the specific location of leakage, i.e., which of the containers in the ISF is leaking. The latter is not a trivial exercise given the large number of storage containers (hundreds) that will ultimately be placed in the ISF, and the fact that a small crack in one container may be difficult to identify without a well-defined fingerprinting strategy.

Plutonium storage containers are typically pressurized with helium prior to being sealed. Thus, the detection of helium in ISF room or exhaust air would provide a signal that one or more containers have developed leaks. However, such detection would not allow for determination of the exact location(s) of the leaks. The premise behind a tracer-based fingerprinting system is that small quantities of other inert tracers, e.g., chlorofluorocarbons, could be added to helium in a container headspace. The use of multiple tracers at varying concentrations would allow for container-specific fingerprints. For example, if tracers X,Y, and Z were all detected simultaneously in a specific ratio it would be possible to immediately identify the specific container from which they were released. It would then be possible to rapidly isolate and remediate the specific failure on the target container. It is anticipated that the leak detection system could ultimately be linked to a robotics system consistent with another nuclear group project (see Robotics, Automation and Tele-Operation for Safe Handling and Long-Term Storage of Nuclear Components) for ultimate container remediation.

This primary task consists of six major sub-tasks. These include (a) the identification of a list of potential tracers, (b) a rigorous literature review on the effects of a-radiation on each of the tracers listed in (a) (future experiments may be required to facilitate this task), (c) selection of final "target" tracers, (d) design of a fingerprinting scheme, e.g., specific tracers, tracer combinations, and concentration variations to allow for container-specific identification, (e) selection and potential design of an appropriate on-line monitoring system to allow detection of target tracer with required sensitivity, (f) development of fingerprint feedback software to facilitate leakage notification and container identification, and (g) development and testing of a prototype detection/fingerprint system. Our goal is to complete sub-tasks a through d during the first year of research. Sub-tasks e through g will be completed during the second, third and fourth years of research.

Research tasks (a) through (c) have been completed. Based on the results of (a) and (b), the following tracers have been selected: sulfur hexaflouride, carbon tetrafluoride, perfluoroethane, perfluoropropane, and perfluorocyclobutane. Additional information has been obtained regarding the design specifications for plutonium storage containers. This information will be of great benefit with respect to the completion of subtask (d). We do not anticipate any problems with completion of subtask(d) by the end of the first year of research.

Primary Task 2. Development of Improved Sampling Systems for the Collection of Plutonium Aerosols (A.R. McFarland, N.K. Anand, W.E. Wente, and A. Muyshondt Department of Mechanical Engineering, Texas A&M University)

Two categories of studies on the sampling of simulated Pu aerosols are to be conducted during the current project year. First, there are basic data that are lacking in the technology of air sampling system design, including characteristics of acceptable bends in transport lines. Studies are currently underway to develop such design criteria. Second, the trend in continuous emission monitoring (CEM) in the nuclear industry is to use single point sampling in accordance with the Alternate Reference Methodology (ARM) that was approved by EPA in November, 1994 for use at all DOE facilities. To comply with the requirements of the ARM, samples for CEM must be withdrawn from a location in the stack or duct where the flow is well mixed. Although mixing criteria are specified in the ARM, there is no apprioate means for determining if a sampling location is suitable. During the current year, numerical modeling of flows in ducts will be carried out using Large Eddy Simulation (LES) techniques. The modeling will begin in December when Mr. Hongrui Gong joins our research group. At the present time, we have applied for, and received a grant for 2500 hours of computer time from Texas A&M University. Mr. Gong is currently developing a sub-grid model for use in LES, and he will apply that knowledge to modeling the flows in stacks and ducts.

With respect to research into aerosol transport components, we are investigating the effects of curvature ratio and tube flattening on losses in bends. The methodology for design of air sampling systems for the nuclear industry is provided by ANSI N13.1-1969, "Guide to Sampling

Airborne Radioactive Material in Nuclear Facilities." In that standard, it states the curvature ratio of bends shall be at least five, where the curvature ratio is the radius of curvature of the bend divided by the tube diameter. There does not appear to be a well-founded basis for this criterion, so we are conducting tests to either verify the criterion, or to offer a new value. It would be helpful to designers if value were less than five. Currently, there are no criteria for acceptable flattening of tube cross-section in bends.

Numerical studies on modeling of flow mixing in stacks and ducts have been initiated. We are continuing our studies on aerosol losses in transport system components.

Primary Task 3. Plutonium Aerosol Monitoring by Fluorescence Detection (W.H. Marlow Department of Nuclear Engineering, Texas A&M University)

During the start-up year of this project, the principle progress will occur in preparatory work including literature survey of methods, determination of facilities' needs and arrangements for their use, and initial experimental efforts.

Research on aerosol capture media to facilitate future optical detection methods for plutonium began with a survey of fabrication methodology for silica aerogels. During the Second Quarter, discussions were initiated with the Texas A&M Chemical Engineering Department regarding alternative methods for creating porous aerogels. These discussions indicated that creation of more highly porous aerogels and possibly xerogels than have already been produced would be unlikely. Permission to utilize Chemical Engineering Departmental facilities was gained, pending identification of promising synthesis routes. Late in this reporting period, a literature search showed an aerosol based synthesis procedure for creating carbon-based aerogels which will be further investigated for its adaptability to synthesis of silicone-based aerogels.

Earlier efforts under this subproject to measure the fluorescence behavior of plutonium compounds of interest have been suspended due for personnel reasons. The intention of the PI is for this matter to be resolved during the third or fourth quarter of the current project year and for the work to be performed or arrangements made by August, 1996, for performing the work. If resolution is not reached, as indicated, no further efforts on the fluorescence subtask will be pursued. Use of gas-phase conductivity monitoring for physical leak detection of plutonium has been discussed with Sandia National Laboratory personnel. They have indicated strong support for this thrust which will supplant the fluorescence spectroscopy thrust in activities of this Subproject.

Primary Task 4. Collection of Plutonium Aerosol Particles Through an Electrical Means Followed by an Automated IC Measurement (P.K. Dasgupta Department of Chemistry, Texas Tech University)

Most aerosol particles are charged naturally. In addition, it is possible to deliberately make these particles highly charged. When these particles are introduced to an electric field, positively charged particles will deposit onto the negative electrode while negatively charged particles deposit onto the positive electrode. In most cases, when the particle hits the electrode surface it will stick. These characteristics of aerosol particles allow their collection electrically. The composition of the aerosol particles can be obtained through chemical or radiochemical analysis. The goal of this task is to develop an automated system to collect aerosol particles through an electrical means and to measure the content of plutonium in the particles.

An experimental system has already been developed to carry out this primary task. The system consists of three major parts; an aerosol generation system, and aerosol collection interface, and an ion chromatographic measurement system. Preliminary experimental results, using a surrogate aerosol consisting of sulfate particles, are encouraging, and have provided direction for continued research over the remainder of the first year of research. A detailed description of the experimental system and preliminary experimental results were provided as Attachment A to the last progress report. Research is progressing on schedule.

RADIATION DAMAGE AND MICROSTRUCTURAL CHANGES OF STAINLESS STEEL DUE TO LONG-TERM IRRADIATION BY ALPHA PARTICLES EMITTED FROM PLUTONIUM

Ron R. Hart (Co-PI), Department of Nuclear Engineering, Texas A&M University
Kenan Ünlü (Co-PI), Nuclear Engineering Teaching Laboratory, University of Texas at Austin

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

Research Activities

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.

During the period of 11/1/95 to 1/31/96 the following steps, which are described in our research plan, were accomplished.

1. A comprehensive literature search was continued. A number of relevant articles were obtained and reviewed.

2. Sample preparation equipment for Scanning and Transmission Electron Microscopy was purchased through an invited bid process. The vendor is South Bay Technology, Inc., San Clemente, CA. All of the equipment will be delivered by 2/23/96.

3. Room 3.106 at the Nuclear Engineering Teaching Laboratory has been designated as the Sample preparation Laboratory. This room has been prepared for the sample preparation equipment.

4. Mehmet Saglam, a graduate student, began training in the use of an electron microscope for scanning and transmission electron microscopy at the University of Texas.

5. Three senior nuclear engineering students began training in the operation of a 160-KV ion accelerator at Texas A&M University.

6. Both He-3 and He-4 ion beams were obtained with intensities of several microamps per cm^2. This is one of the major objectives of the second phase of the research plan.

7. Dr. Kenan Ünlü, CoPI, presented an invited lecture entitled, "Neutron Beam Research at the University of Texas at Austin," at the University of Illinois, Champaign/Urbana. This lecture included some details of the ANRCP project.

8. An invited paper entitled, "Nuclear Analytical Techniques with Neutron Beams at the University of Texas at Austin," will also be presented by Dr. Kenan Ünlü at the 1996 Annual Meeting of the American Nuclear Society at Reno, Nevada. This paper covers some aspects of the ANRCP project and acknowledges support of the ANRCP. A copy of the manuscript is attached. This paper will be published in the American Nuclear Society Transactions, June 1996.

Most Tangible Accomplishments

- Review of relevant papers
- Obtain He-3 and He-4 ion beams.
- Purchase of sample preparation equipment

Other accomplishments related to the project were to give an invited lecture at the University of Illinois and to have an invited paper accepted at the 1996 Annual Meeting of the American Nuclear Society.

PLANNING GRANT FOR ANRCP PARTICIPATION IN DOE STUDY OF VULNERABILITY TO RESIDUAL HIGHLY ENRICHED URANIUM

Paul Nelson (PI), K.L. Peddicord and W.W. Pitt
Department of Nuclear Engineering
Texas A&M University

Robert E. Canaan, Department of Mechanical Engineering
The University of Texas at Austin

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

This project was actually funded effective January 1, 1996, so there has been only one month of activity during the current reporting period. Specific activities have been as follows:

I. Drs. Canaan, Peddicord and Pitt are participating as members of the Core Support Group organized by DOE/EH to provide the element of continuity required across all site assessments.

A. Dr. Pitt is spending 100% effort participating in the activities of this group, which until now have been centralized at the EH offices in Germantown, MD.

B. Dr. Peddicord is participating at the 50% level, primarily on the training activity, as described below.

C. Dr. Canaan is participating at the 100% level, partially on the training activity described below, but also on building a data base of significant international events involving highly-enriched uranium.

II. Drs. Canaan and Peddicord are working with representatives of the Texas Engineering Extension Service (TEES) to develop a proposal to provide significant support to the training of the projected Site Assessment Teams. This is tentatively scheduled for early April, possibly in San Antonio.

MOX use Evaluation

Dr. K. L. Peddicord
Department of Nuclear Engineering
Texas A & M University

PROGRESS REPORT
(1 November 1995 - 31 January 1996)

Executive Summary:

The scope of this program is currently being designed to fit in with the overall programmatic direction and needs of OFMD. It complements OFMD's efforts with ORNL, is being carried out in coordination with ORNL, and might achieve some very useful information at a modest cost (at no additional cost to MD).

As the scope of work develops, interaction with the Water-reactor Options Team will avoid overlap on the Gallium issue. The original focus of this study is to consider the fuel performance and materials aspect of MOX. The water reactor option is specifically looking at the neutronics and fuel Kyle implications of MOX (along with gallium).

1. Briefly summarize research activities during the period of 11/01/95 to 1/31/96 relating progress to objectives described in your work plan, and attach copies of reports or papers produced.

Contacts have been initiated with Belgonucleaire (BN) in order to participate to the FIGARO program. The FIGARO test will examine the fission gas release in MOX fuel. This is of importance because fission gas release is one of the prime considerations in fuel pin integrity and potential failure. Data available suggest that at higher fuel burnups, fission gas release may be higher in MOX fuel than in UO2 .

BN has the most MOX experience of any organization in the world (something like 60 or 70%) of all the irradiated MOX pins have been fabricated by BN. One of BN's primary activities is to conduct fuel irradiation experiments in which organizations from around the world are invited to take part and in exchange for a participation fee can define the project and receive the resulting data. BN has been conducting these programs for about 25 years and has looked at a number of "separate effects" in UO2 and MOX fuel. Historically the participants have been the Japanese, Germans, French, and in the US the NRC, DOE, EPRI and sometimes individual utilities. DOE and Oak Ridge National Laboratory (ORNL) have already taken part in another Belgonucleaire program called ARIANE. This program will irradiate MOX rods to specifically look at the behavior of the higher actinides above Pu. This would be very useful information to have if the

MOX option is among those chosen for Pu disposition. DOE and ORNL have decided not to proceed with any consideration of participation in FIGARO.

Before contacts were initiated with Belgonucleaire, contacts were established with Trent Primm (ORNL) and Pat Rhoads (MD/DOE) on this issue. Coordination of our plans and efforts will continue in the future.

Meetings are scheduled with Belgonucleaire to explore with them a possible BN/ANRCP collaboration on the FIGARO program.

A student with an excellent background in the fuel behavior area who might be interested in working on this project has been identified.

2. Describe the most tangible accomplishments related to your research funding.

Initiation of contacts with BelgoNucleaire (BN) and MD/DOE for a possible BN/ANRCP collaboration on the FIGARO program aimed at studying fission gas releases in MOX flue pins.

TASK 5

Other Materials Studies

WORK PLAN PROGRESS REPORT
Explosives Disposal Demonstration Projects
Period Covered: November 1, 1995 through January 31, 1996

Institution: University of Texas at Austin

Principal Investigator: C. Grant Wilson
Department of Chemical Engineering
The University of Texas
Austin, TX 78712

Part 1: *Diamond Generation by Explosive Compression of Buckminsterfullerene*

During this reporting period the three dimensional test piece was re-calculated and re-designed and the "one dimensional" work-piece was designed, built and successfully tested. The goal of the re-design of the "3D" work piece was to successfully recover the compressed sample following detonation. Three changes in the structure were made based on analysis of the fragments recovered from the first test. It was clear from the analysis that the decompression wave generated a tensile stress in the copper shell that exceeded it's spall strength. Calculations show that the compression pulse is approximately 1.5 MBar over a period of about 2 microseconds. This compression is followed by a negative pressure of about 200 KBar. The spall strength of copper is only about 50 KBar so the fracture was predicted.

The new design involves several changes as depicted in figure1. The compressed, spherical sample is contained within a copper shell which is, in turn encased in a shell of material with a much higher modulus, in this case, steel. The bilayer metal structure is then fitted with explosives and the shell of explosives is encased in a bronze shell. The entire test piece is then buried in sand. In this way, a reflective, compression wave is generated at the inner surface of the bronze shell that is timed to coincide with arrival of the decompression wave at the copper-steel interface. The combined effect of the reflected compression wave and the higher modulus of the steel is predicted to result in sacrificial spallation of the steel shell and recovery of the copper sample holder intact.

We have experienced several delays in testing of this design. Most of the delay was the result of inability to access machining tools at Pantex. The machining problems have been solved, the work piece is built and is being assembled. The test is scheduled to occur during this month. Successful recovery of the copper sampleholder will represent a turning point in the program.

While tests are being conducted to verify the design of the "3D" test vehicle, we have initiated a "1D" program that allows efficient screening of materials variables. A recent paper from the Laboratory for Shock Wave and Detonation Physics at Chengdu, China reports having used "1D" explosive compression to produce diamond from C-60. This conversion had been previously reported and the unusually fast kinetics of the transformation were the inspiration for the choice of C-60 as a precursor in our "3d" experiments. The unique thing about the Chinese report is that they recovered ***only*** diamond! The Chinese report the use of "nano-nickel" as a catalyst in their experiments. The publication does not provide any experimental details nor does it describe "nanonickle" but we have managed to communicate with Dr. Jin who is the author of the paper. He kindly provided us with engineering detail regarding the experiments thahe conducted. We have also managed to find a source of "nano-nickel" and nano-cobalt" and have acquired samples of each of these materials.

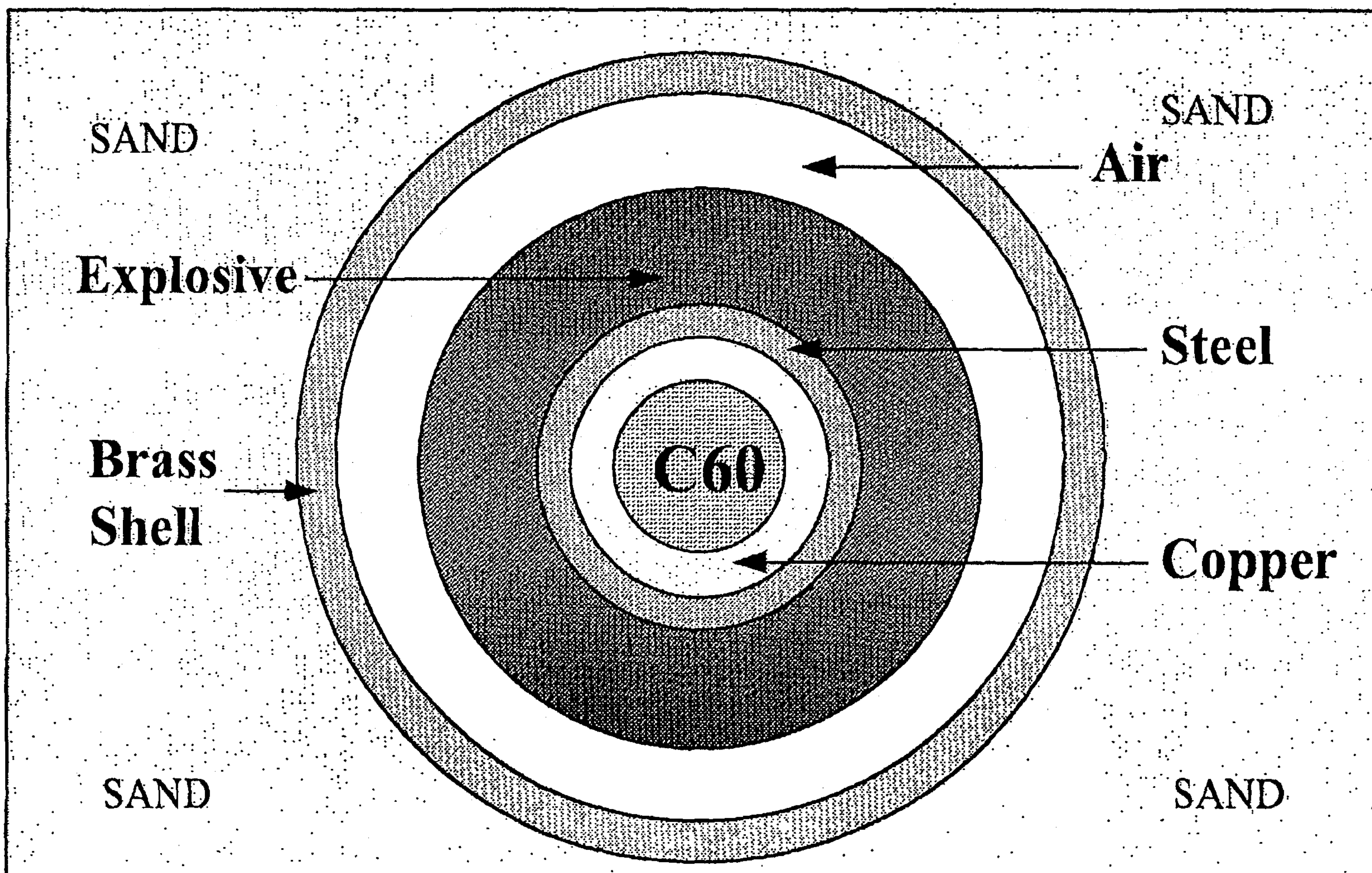
We have fabricated a "1D" device (Figure 2) that providescompression at least as high as Dr. Jin's. Our collaborators at Pantex have conductedsuch experiments in he past and their experience was very valuable. The advantageof the "1D" configuration is that it allows faster turn around and therefore faster materials optimization. The disadvantage is that the "1D" design is not as scaleable as the "3D" design and does not provide access to the extent or duration of compression that can be achieved with the "3d" design. Furthermore, it is our intention to ultimately use explosives recovered from weapons for diamond production. The parts recovered from weapons are most amenable to use in the "3d" design.

Four "1D" detonations have been conducted during this reporting period. In the first experiment the diameter of the explosive charge waslarger than that of the steel flyer. (See Figure 2) The brass case was ruptured and the sample (graphite) was lost. The diameter of the explosive was matched to that of theflyer in test two but the case ruptured again the graphite was lost. Test three was similar totest two except that C-60 (which has a different equation of state) was used rather than graphite. The sample was lost. Test 4 was conducted with a steel momentum trap instead of brass and the sample (C-60) was retained. This sample is en route to The University of Texas for analysis.

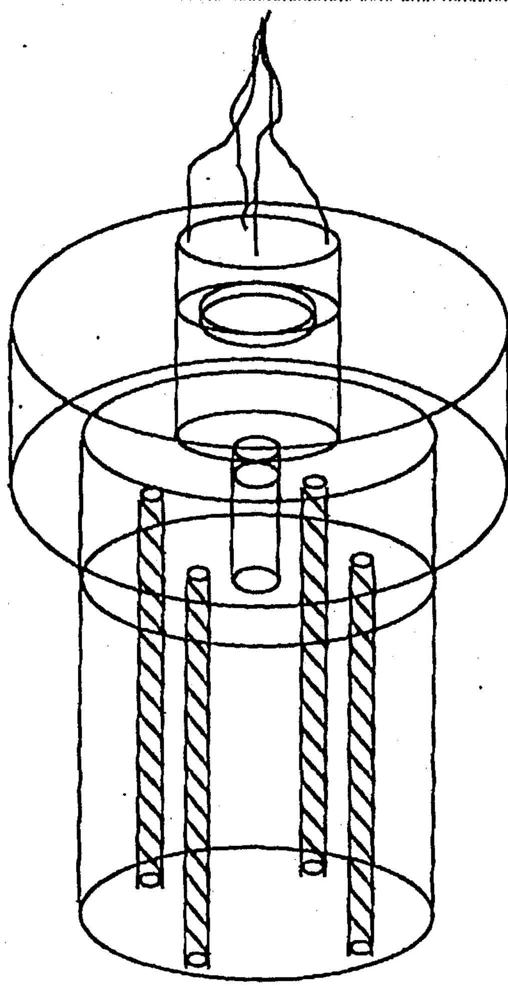
Now that we have a working "1D" design, the focus of effort will shift to materials evaluation. The "1D" work pieces will be fabricated and loaded athe University of Texas and sent to Pantex. The detonations will be carriedout at Pantex and the samples returned to The University of Texas for analysis.

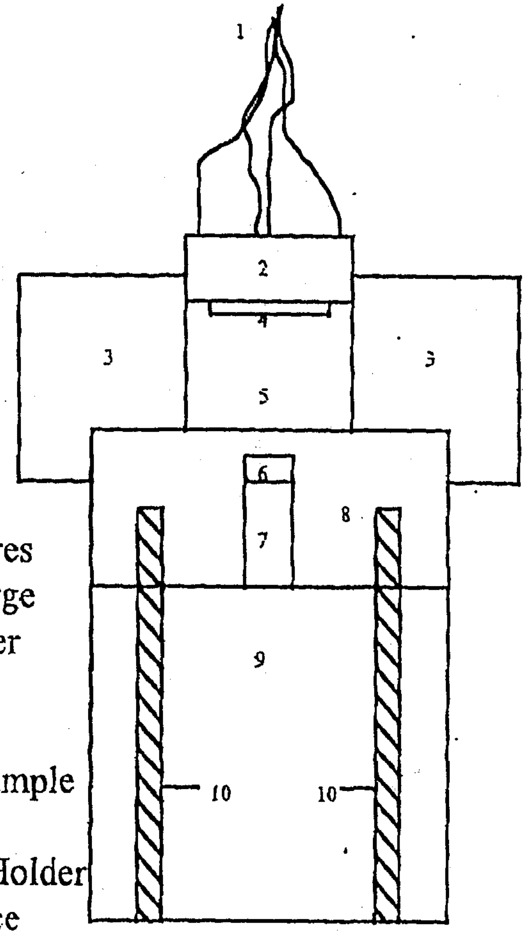
The first sequence of tests are designed to study the influence of catalysts on diamond yield. We will study nano-nickel and nano-cobalt first. These materials are so finely divided that they are pyrophoric, that is, the burst into flame upon contact with oxygen. Hence, the samples must be loaded in a glove box under inert atmosphere conditions and hermetically sealed prior to transport to Pantex. We havenegotiated access to a glove box that belongs to a colleague, Professor Barlow in the Department of Chemical Engineering. We will move this equipment into new space provided by the department to support this research activity.

Work Piece Modifications



1-D Experimental Design





1. Detonation Wires
2. Explosive Charge
3. Plexiglas Holder
4. Steel Flyer
5. Air
6. Compressed Sample
7. Brass Plug
8. Brass Sample Holder
9. Brass Resistance
10. Screws

Part 2: *Demonstration Burn for Energy Recovery*

Progress has been made toward establishment of a "contract" with the Naval Air Warfare Center Weapons Division at China Lake, California. The purpose of this contract is to establish the thermodynamic properties of the fuel composite and the composition of the combustion products. This data is required to insure the safety of the demonstration burn. We believe that the Office of Sponsored Projects at the University of Texas at Austin has now found a way to establish this contract. The funds are being returnedto the Department of Energy and the Department of Energy is working directly with the Department of Defense to establish the contract thereby avoiding the insurmountable problems that arose as a result of Department of Defense demands for indemnification by the University of Texas. We hope that work on this partof the program can begin during the next reporting period.

Three facilities have been identified in Texas that are licensed to burn solid municipal waste materials for energy recovery. They are located in Carthage, Center and Cleburne. The feed stream of these waste facilities is immediately compatible with the pelletized fuel that we propose to produce from recycled plasticwaste and high explosives. The specifications for formulation of the fuel that will insure that it burns without detonation are dependent on the engineering data that is to be supplied by the Naval Air Warfare Center contract.

TASK 5

Plutonium Textbook & Training

WORK PLAN PROGRESS REPORT
Plutonium Text and Training
Period Covered: November 1, 1995 through January 31, 1996

Institution: Amarillo National Resource Center for Plutonium

Principal Investigator: Dr. Elda Zounar

Purpose:

The purpose of the Plutonium Text and Training task is to write text for a textbook on plutonium chemistry and handling practices, develop training materials, and conduct training programs, in close cooperation with the Pantex Plant, for Pantex and other DOE sites.

Scope:

This task will include evaluation of the information in the open literature and in classified documents. Training modules will incorporate "lessons learned" and the latest issues associated with on-site plutonium.

Accomplishments:

The ANRCP Obtained the services of an outside consultant (Tom Carden) to assess the status of training and qualification programs at the Pantex Plant. Mr. Carden visited the Pantex site from October 12-14th, 1995 to visit with training managers and instructors regarding training methods, effectiveness, culture, and recordkeeping. A report was provided by Mr. Carden to the ANRCP.

Initiated the Plutonium Text and Training partnership with Mason & Hanger. To that end, a program plan between ANRCP and Mason & Hanger (Pantex) will be written. The plan will include the tasks: (a) in the open literature and available documents, identify research areas where information is either weak or missing; (b) define and design a pilot training program; (c) develop training materials for the pilot training program; (d) produce text on plutonium chemistry and handling practices for the training program; (e) implement the pilot training program with information for the plutonium textbook; and (f) evaluate the pilot training program with an eye toward training for other DOE sites.