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**Decontamination Systems Information And Research
Program**

**Quarterly Report
January - March 1996**

April 1996

Work Performed Under Contract No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
West Virginia University
Civil and Environmental Engineering
Morgantown, West Virginia

MASTER

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For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
West Virginia University
Civil and Environmental Engineering
Morgantown, WV 26506

EXECUTIVE SUMMARY

The projects for the 1996 WVU Cooperative Agreement are categorized into three task focus areas: Task 1.0 Contaminant Plume Containment & Remediation, Task 2.0 Cross Cutting Innovative Technologies, and Task 3.0 Small Business Support Program. Summaries of the significant accomplishments for the subtasks reporting under these categories during the period 1 January 96 through 31 March 96 are presented below.

Task 1.0 CONTAMINANT PLUME CONTAINMENT & REMEDIATION

Subtask 1.1 Analysis of the Vortec Cyclone Melting System (VMS) for Remediation of PCB

Contaminated Soils Using CFD: Excellent progress has been reported on this new project for the first reporting period. Preliminary axi-symmetric and three-dimensional modeling have been performed. From this effort, the significant findings indicate that the three-dimensional modeling identified a recirculation zone within the Vortec combustion chamber not indicated by the axi-symmetric modeling. The three dimensional modeling will continue to be the focus of the work performed during the next reporting period.

Subtask 1.2 Drain Enhanced Soil Flushing (DESF) Using Prefabricated Vertical Drains: This project has begun its third year of funded research during this period. The significant accomplishments documented during the first reporting period include two major project coordination meetings with the industry partners: NILEX Corporation and the ASHLAND PETROLEUM Company. The meetings laid out the groundwork associated with the design and planning requirements for the PVD field demonstration. Other activities performed this period include the design and fabrication of a prototype field connection details and lab testing of the connection on full size PVD specimens.

Subtask 1.3 Performance and Characteristics Evaluation of Acrylates as Grout Barriers: This period saw progress with work on the urethane grout injections into large diameter columns, column permeability tests on injected grout, and flexible wall permeability tests on the saturated region of a grouted sample. The results of the flexible wall permeability tests showed that the

thickness of the grouted region in the columns is much too large and there appeared to be sufficient waste. The average resulting hydraulic conductivity for the HCL and NaOH permeated tests were determined. Progress is reported as being slower than expected due to unforeseen problems with equipment, efforts have been taken to correct the problems.

Subtask 1.4 Development of Standard Test Protocols Barrier Design Models for Desiccation

Barriers: During this period work progressed on revising the METC required Operating Permit and on revisions to the associated engineering drawings. Design and assembly drawings for a CAB vessel have been developed by WVU researchers and submitted to EG&G for fabrication and assembly. Procedures and experimental setups for determining sandpack permeability were performed at WVU.

Subtask 1.5 Development of Standard Test Protocols & Barrier Design Models for In Situ

Formed Barriers - Technical Support: This project was delayed during the first quarter due to constraints in establishing the funding transfers between METC and WVU. At the end of the first quarter the transfers were completed and BDM has now initiated their efforts in providing technical services for the project.

Subtask 1.6 In Situ Bioremediation of Chlorinated Solvents at the Portsmouth Gaseous Diffusion

Plant: This is a new project which received funding authorization at the end of this quarter. The project's progress will be reported at the end of the second quarter.

Task 2.0 CROSS CUTTING INNOVATIVE TECHNOLOGIES

Subtask 2.1 A GIS-Based Infrastructure for Site Characterization and Remediation: This project reported progress on two fronts during this period. Meetings with the US Corps of Engineers and Marshall University researchers have taken place for the purpose of coordinating the transfer and continual updating of information necessary for Marshall to remain current. A draft of the interactive tutorial system has been prepared and continues to be developed.

Subtask 2.2 Treatment of Mixed Wastes via Fluidized Bed Steam Reforming - Capture of Hazardous Chemical Waste Utilizing Fluidization Coating Technology: Work this quarter focused on equipment upgrades to the Gas Chromatograph followed with equipment calibrations. Experimentation is planned to get underway during the next quarter.

Subtask 2.3 Use of centrifugal Membrane Technology with Novel Membranes to Treat Hazardous/Radioactive Waste: This project reported progress on four tasks during this period. The literature search is progressing with acquiring publications on membrane technologies. Spintek personnel visited WVU in January and March for the purpose of training the faculty and students in the operation of the technology. Research using the Spintek device reported success in the removal of colloidal material from the aqueous phase. The waste tested showed a 100 time increase in concentration with a corresponding volume reduction of 99 percent.

Subtask 2.4 Environmental Pollution Control devices Based on Novel Forms of Carbon: This project reported continued progress with the experimentation using carbonaceous materials to remove metal ions from solution. An industrial application of this technology was demonstrated on the removal of nickel from a rinse solution where a removal efficiency of 89% was achieved. Removal of strontium was demonstrated using the carbon fiber technology and efficiencies up to 34% were obtained. Removal schemes with similar metal reaction mechanisms to those used for nickel are currently being examined.

Subtask 2.5 Development of Instrumental Methods for Characterization and Analysis of Nuclear Wastes and Environmental Contaminants: Results of work performed this quarter included continuation of the literature review where useful references were found. Several operating buffer compositions were reviewed and used in a buffering study. A field strength study was performed to determine the speed and efficiency of electrokinetic separations. High field strengths were found to increase the migration velocities of charge species and increase the electroosmotic flow velocity.

Subtask 2.6A Production and Evaluation of Biosorbents and Cleaning Solutions for Use in Decontamination and Decommissioning: This is a new project which received funding authorization at the end of this quarter. The project's progress will be reported at the end of the second quarter.

Subtask 2.6B Use of SpinTek Centrifugal Membrane Technology and Sorbents/Cleaning Solutions for D&D Work: This is a new project which received funding authorization at the end of this quarter. The project's progress will be reported at the end of the second quarter.

Task 3.0 SMALL BUSINESS SUPPORT PROGRAM

Subtask 3.1 WVHTC - West Virginia High Tech Consortium Foundation - Environmental Technology Support Program: Work this quarter focused on creation of a formal business plan for the incubator, setting up of the infrastructure to administer the incubator, performance of several efforts to determine feasibility of business plan components, and the acceptance of a candidate small business under a "pre-admission" status.

Subtask 3.2 Small Business Interaction Opportunities: Efforts continued in support of the WVHTC- Environmental Technology Incubator for selection of candidate small businesses. Interaction was continued with the Institute of Gas Technology and GENESYST for development of project proposals and funding. Contact was made with the INTERA Corp. and a project has been successfully awarded through the Cooperative Agreement for the project. The Kanawha River Voluntary Assessment project, which is a carry-over from last year, was given funds to continue the project to fruition.

Subtask 3.4 Approach for Assessing Potential Voluntary Environmental Protection - Kanawha River Area: During this period, final meetings with the chemical companies were held. A meeting with the USEPA Region III was held to ascertain the interest in the program. The EPA expressed interest and groundwork was laid for the discussion of a memorandum of understanding to be developed between the EPA and the state regarding voluntary cleanups.

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1.0 CONTAMINANT PLUME CONTAINMENT & REMEDIATION

- 1.1 ANALYSIS OF THE VORTEC CYCLONE MELTING SYSTEM (VMS) FOR REMEDIATION OF PCB CONTAMINATED SOILS USING CFD

I. Celik, Dept. of Mechanical & Aerospace Eng.

- 1.2 DRAINED ENHANCED SOIL FLUSHING (DESF) USING PREFABRICATED VERTICAL DRAINS

M. Gabr, Dept. of Civil & Environmental Eng.

- 1.3 PERFORMANCE AND CHARACTERISTICS EVALUATION OF ACRYLATES AS GROUT BARRIERS

M. Gabr, Dept. of Civil & Environmental Eng.

- 1.4 DEVELOPMENT OF STANDARD TEST PROTOCOLS & BARRIER DESIGN MODELS FOR DESICCATION BARRIERS

S. Ameri and K. Aminian, Dept. of Petroleum Eng.

- 1.5 DEVELOPMENT OF STANDARD TEST PROTOCOLS & BARRIER DESIGN MODELS FOR IN-SITU FORMED BARRIERS - TECHNICAL SUPPORT

B. Overby and C. Locke, BDM

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J. Hooper, Marshall University

- 2.2 TREATMENT OF MIXED WASTES VIA FLUIDIZED BED STEAM
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R. Turton, Dept. of Chemical Eng.

- 2.3 USE OF CENTRIFUGAL MEMBRANE TECHNOLOGY WITH NOVEL
MEMBRANES TO TREAT HAZARDOUS/RADIOACTIVE WASTE

B. Reed, Dept. of Civil & Environmental Eng.
W. Green, SpinTek

- 2.4 ENVIRONMENTAL POLLUTION CONTROL DEVICES BASED
ON NOVEL FORMS OF CARBON

J. Zondlo, A. Stiller, A. Brennsteiner,
Dept. of Chemical Eng.

- 2.5 DEVELOPMENT OF INSTRUMENTAL METHODS FOR
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V. Remcho, Dept. of Chemistry
N. Ballou, Battelle-Pacific Northwest Ntl. Laboratories

3.0 SMALL BUSINESS SUPPORT PROGRAM

- 3.1 WVHTC - WEST VIRGINIA HIGH TECH CONSORTIUM FOUNDATION
ENVIRONMENTAL TECHNOLOGY SUPPORT PROGRAM

J. Berkow, WVHTCF

CONTINUATION FROM LAST YEAR

- Old 3.4 APPROACH FOR ASSESSING POTENTIAL VOLUNTARY
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R. Lovett, NRCCE

Administrative Summary

Background

West Virginia University (WVU) and the US Department of Energy, Morgantown Energy Technology Center (DOE/METC) entered into a Cooperative Agreement in August 1992 titled "Decontamination Systems Information and Research Programs" (DOE Instrument No.: DE-FC21-92MC29467). Requirements stipulated by the Agreement require WVU to submit quarterly Technical Progress reports. This report contains the efforts of the research projects comprising the Agreement for the 1st calendar quarter of 1996.

Administrative Issues

For the period January 1 through December 31, 1996 twelve projects have been selected for funding, and the Kanawha Valley will continue under a no-cost extension. During this reporting period three new projects have been added to the program:

Subtask 1.6 *In Situ Bioremediation of Chlorinated Solvents at the Portsmouth Gaseous Diffusion Plant*

Subtask 2.6A *Production and Evaluation of Biosorbents and Cleaning Solutions for Use in Decontamination and Decommissioning*

Subtask 2.6B *Use of SpinTek Centrifugal Membrane Technology and Sorbents/Cleaning Solutions for D&D Work*

Project Variances, Accomplishments, and Problems

Discussion of the following two subtasks is warranted:

Subtask 1.5 Development of Standard Test Protocols & Barrier Design Models for In Situ Formed Barriers - Technical Support: This project was delayed as a result of difficulties experienced during the funding transfers between METC and WVU. At the end of April 96 all funding issues were resolved and the project was initiated. WVU and BDM have been in close contact, as well as with the necessary METC personnel and together we are working to bring the project on-line and within scope of achieving the scheduled deliverables.

Subtask 2.2 Treatment of Mixed Wastes via Fluidized Bed Steam Reforming - Capture of Hazardous Chemical Waste Utilizing Fluidization Coating Technology: As a result of equipment modifications requiring more time than initially intended, the project is lagging its planned schedule. The Research Principal Investigator is aware of the problem and has indicated that there will be a step-up in production during the summer session.

Accounting Issues

An accrued accounting system was adopted by Civil and Environmental Engineering (CEE) for the 1995 to provide a real time accounting by showing the actual expenses when incurred. Due to the amount of adjustments required for reconciliation, a simplified accounting system has been developed for 1996. The new report will contain an extra column for accrued expenses and obligated amounts that have not been disbursed. All adjustment except management salaries and subcontractors will be made in this column. For the first quarter of 1996 an accrued adjustment of approximately \$700,000 was made.

ACCRUED ACCOUNTING OF AWARDED FUNDS

PERIOD COVERED 1/1 - 3/31/96

OUTLAYS

PREVIOUS OUTLAYS (Grant Start - 12/31/95)

FUND 7631 - NRCCE	3,526,420
1995 Adjustments	(187)

FUND 8527 - WVU	2,607,537
1995 Adjustments	<u>(13,390)</u>

TOTAL PREVIOUS OUTLAYS	6,120,380

CURRENT OUTLAYS (1/1 - 3/31/95)	<u>158,952</u>

<u>TOTAL OUTLAYS TO DATE 3/31/95</u>	6,279,332

<u>UNLIQUIDATED OBLIGATIONS</u>	<u>678,461</u>

<u>TOTAL SHARE OF OUTLAYS & UNLIQUIDATED OBLIGATIONS</u>	6,957,793

FUNDS AUTHORIZED

FUND 8731 (Prior to 1995)	<u>4,749,048</u>	4,749,048

FUND 8527		
1995 Award	1,547,000	
Amendment No. A013	75,950	
1996 Award	<u>1,900,000</u>	<u>3,522,950</u>

<u>TOTAL FUNDS AUTHORIZED TO DATE 3/31/95</u>	<u>8,271,998</u>

<u>AMOUNT REMAINING</u>	<u>\$1,314,205</u>

METC TASK #	PROJECT TITLE	PLANNED ACTUAL	TOTAL PLANNED	TOTAL ACTUAL	OBLIGATED Encumbrances	AMOUNT REMAINING
1.0 CONTAMINANT PLUME CONTAINMENT & REMEDIATION						
1.1	Analysis of the Vortec Cyclone Melting System (VMS) for Remediation of contaminated Soils using CFD	PLANNED ACTUAL	77,542	286	429	76,827
1.2	Drained Enhanced Soil Flushing (DESF) using Prefabricated Vertical Drains	PLANNED ACTUAL	184,682	6,525	44,094	134,063
1.3	Performance and Characteristics Evaluation of Acrylates as Grout Barriers	PLANNED ACTUAL	123,703	9,745	7,504	106,454
1.4	Development of Standard Test Protocols & Barrier Design Models for Dessication Barriers	PLANNED ACTUAL	173,152	22,725	18,804	131,623
1.5	Development of Standard Test Protocols & Barrier Design Models for In-Situ Formed Barriers - Technical Support	PLANNED ACTUAL	510,684	17,748	246,091	246,845
**1.6	In Situ Bioremediation of Chlorinated Solvents at PORTS	PLANNED ACTUAL	0	0		0
TOTAL TASK 1.0		PLANNED ACTUAL	1,069,763	57,029	316,922	695,812
2.0 CROSS CUTTING INNOVATIVE TECHNOLOGIES						
2.1	A GIS Based Infrastructure for Site Characterization and Remediation	PLANNED ACTUAL	157,296	31,058	111,604	14,634
2.2	Treatment of Mixed Wastes via Fluidized Bed Steam Reforming - Capture of Hazardous Chemical Waste Utilizing Fluidization Coating Technology	PLANNED ACTUAL	45,127	5,299	5,921	33,907
2.3	Use of Centrifugal Membrane Technology with Novel Membranes to Treat Hazardous/Radioactive Waste	PLANNED ACTUAL	133,795	4,048	6,693	123,054
2.4	Environmental Pollution Control Devices Based on Novel Forms of Carbon	PLANNED ACTUAL	99,890	18,199	25,123	56,568
2.5	Development of Instrumental Methods for Characterization & Analysis of Nuclear Wastes & Environmental Contaminants	PLANNED ACTUAL	100,940	6,628	42,780	51,532
**2.6A	Production and Evaluation of Biosorbents and Cleaning Solutions for Use in Decontamination & Decommissioning	PLANNED ACTUAL	0	0		0
**2.6B	Use of SpinTek Centrifugal Membrane Technology and Sorbents/Cleaning Solutions for D & D Work	PLANNED ACTUAL	0	0		0
TOTAL TASK 2.0		PLANNED ACTUAL	537,048	65,232	192,121	279,695
3.0 SMALL BUSINESS SUPPORT PROGRAM						
3.1	WVHTC - West Virginia High Tech Consortium Foundation Environmental Technology Support Program	PLANNED ACTUAL	142,998	18,435	106,565	17,998
3.2	Small Business Interaction Opportunities	PLANNED ACTUAL	336,494	16,944	16,692	302,858
TOTAL TASK 3.0		PLANNED ACTUAL	479,492	35,379	123,257	320,856
CONTINUED FROM LAST YEAR						
old 3.4	Approach for Assessing Potential Voluntary Environmental Protection - Kanawha River Area	PLANNED ACTUAL	58,946	1,312	46,161	9,473
Unsettled 1995 accounts			8,369			8,369
GRAND TOTALS		PLANNED ACTUAL	2,151,618	158,952	678,461	1,314,205

**Note: Above projects are planned for next quarter

METC	PLANNED	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	TOTAL	OBLIGATED	AMOUNT
TASK #	ACTUAL	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	PLANNED	ACTUAL	Encumbrances	REMAINING
1.0 CONTAMINANT PLUME CONTAINMENT & REMEDIATION																	
1.1	PLANNED	119	119	405	763	9,433	12,384	13,636	9,255	7,857	7,857	7,857	7,857	77,542			
	ACTUAL	0	0	286											286	429	76,827
1.2	PLANNED	13,170	13,400	13,400	14,830	13,400	21,914	20,484	20,484	13,400	13,400	13,400	13,400	184,682			
	ACTUAL	1,841	1,451	3,233											6,525	44,094	134,063
1.3	PLANNED	9,686	13,951	10,391	9,786	8,456	10,399	13,603	13,603	8,457	8,457	8,457	8,457	123,703			
	ACTUAL	1,124	4,291	4,330											9,745	7,504	106,454
1.4	PLANNED	9,787	9,787	10,502	10,502	10,502	27,508	27,508	27,508	9,887	9,887	9,887	9,887	173,152			
	ACTUAL	6,347	8,986	7,392											22,725	18,804	131,623
1.5	PLANNED	6,791	6,791	6,791	54,479	54,479	54,479	54,479	54,479	54,479	54,479	54,479	54,479	510,684			
	ACTUAL	5,916	5,916	5,916											17,748	246,091	246,845
**1.6	PLANNED													0			
	ACTUAL														0		0
TOT	PLANNED	39,553	44,048	41,489	90,360	96,270	126,684	129,710	125,329	94,080	94,080	94,080	94,080	1,069,763			
1.0	ACTUAL	15,228	20,644	21,157	0	0	0	0	0	0	0	0	0		57,029	316,922	695,812
2.0 CROSS CUTTING INNOVATIVE TECHNOLOGIES																	
2.1	PLANNED	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	157,296			
	ACTUAL	9,855	9,216	11,987											31,058	111,604	14,634
2.2	PLANNED	4,469	3,056	2,527	1,669	7,972	15,134	1,669	1,669	1,812	1,669	1,669	1,812	45,127			
	ACTUAL	0	3,290	2,009											5,299	5,921	33,907
2.3	PLANNED	6,568	10,138	5,066	54,709	4,709	5,066	13,458	15,961	5,066	4,709	4,280	4,065	133,795			
	ACTUAL	563	1,689	1,796											4,048	6,693	123,054
2.4	PLANNED	11,343	10,343	7,274	6,773	6,773	11,312	10,955	10,955	7,131	5,987	5,343	5,701	99,890			
	ACTUAL	0	9,395	8,804											18,199	25,123	56,568
2.5	PLANNED	12,174	9,174	2,352	7,337	9,720	13,712	14,835	9,306	5,672	5,493	5,493	5,672	100,940			
	ACTUAL	0	4,019	2,609											6,628	42,780	51,532
**2.6A	PLANNED													0			
	ACTUAL														0		0
**2.6B	PLANNED													0			
	ACTUAL														0		0
TOT	PLANNED	47,662	45,819	30,327	83,596	42,282	58,332	54,025	50,999	32,789	30,966	29,893	30,358	537,048			
2.0	ACTUAL	10,418	27,609	27,205	0	0	0	0	0	0	0	0	0		65,232	192,121	279,695

METC TASK #	PLANNED ACTUAL	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	TOTAL PLANNED	TOTAL ACTUAL	OBLIGATED Encumbrances	AMOUNT REMAINING
3.0 SMALL BUSINESS SUPPORT PROGRAM																	
3.1	PLANNED	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	142,998			
	ACTUAL	6,145	6,145	6,145											18,435	106,565	17,998
3.2	PLANNED	8,624	8,624	14,538	93,659	17,909	99,573	47,909	7,909	11,323	7,909	7,909	10,608	336,494			
	ACTUAL	5,332	5,415	6,197											16,944	16,692	302,858
TOT	PLANNED	20,541	20,541	26,455	105,576	29,826	111,490	59,826	19,826	23,240	19,826	19,826	22,525	479,492			
3.0	ACTUAL	11,477	11,560	12,342	0	0	0	0	0	0	0	0	0		35,379	123,257	320,856
CONTINUATION FROM LAST YEAR																	
old 3.4	PLANNED	5,307	5,307	5,307	13,675	13,675	13,675							56,946			
	ACTUAL	1,210	102	0											1,312	46,161	9,473
Unsettled 1995 accounts														8,369			8,369
GRAND TOTALS																	
	PLANNED	113,063	115,715	103,578	293,207	182,053	310,181	243,561	196,154	150,109	144,872	143,799	146,963	2,151,618			
	ACTUAL	38,333	59,915	60,704	0	0	0	0	0	0	0	0	0		158,952	678,461	1,314,205

**Note: Above projects are planned for next quarter

***Note 2: The above numbers were rounded to the nearest dollar.

Summary of Planned Versus Actual Expenses

1996 WVU Cooperative Agreement

■ Planned Expenditures * Actual Expenditures

METC Task 1-1

Refinement of Combustion & Melting System

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	NEPA Information	1M	100.00%																					
2	Information Search: Conceptual Design Criteria	1M	50.00%																					
3	Recuperator Base Analysis	3M	50.00%																					
4	Analysis of Separator/Reservoir	5M	0.00%																					
5	Recuperator Analysis	2M	0.00%																					
6	Analysis of Results	2M	0.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

**PROJECT: Analysis of the Vortec Cyclone Melting System (CMS)
for Remediation of PCB Contaminated Soils Using CFD**

PRINCIPAL INVESTIGATOR: I. Celik

METC TASK NO.: 1.1

WVU ACCOUNT #: 8527-090-3536

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
Full-time I. Celik	planned	0	0	0	0	3,150	6,300	6,300	3,150	2,393	2,393	2,393	2,393	\$28,470			
	actual	0	0	0											\$0		28,470
BENEFITS																	
29% of Full Time Salaries	planned	0	0	0	0	914	1,827	1,827	914	694	694	694	694	\$8,256			
	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	0	8,256
STUDENTS																	
Graduate	planned	0	0	200	200	200	200	1,200	2,200	2,200	2,200	2,200	2,200	\$13,000			
	actual	0	0	200											\$200	300	12,500
SUPPLIES																	
	planned	0	0	0	250	250	250	125	125	125	125	125	125	\$1,500			
	actual	0	0	0											\$0		1,500
TRAVEL																	
	planned	0	0	0	0	2,000	0	0	0	0	0	0	0	\$2,000			
	actual	0	0	0											\$0		2,000
OTHER																	
	planned	83	83	83	83	83	83	83	83	83	83	83	83	\$1,000			
	actual	0	0	0											\$0		1,000
INDIRECT COSTS																	
43% of Direct Costs except *	planned	36	36	122	229	2,837	3,724	4,100	2,783	2,383	2,363	2,363	2,363	\$23,317			
	actual	0	0	86	0	0	0	0	0	0	0	0	0		\$86	129	23,102
CUMULATIVE																	
PLANNED TOTALS: PER MONTH		119	119	405	763	9,433	12,384	13,636	9,256	7,857	7,857	7,857	7,857	\$77,544			
ACTUAL TOTALS: PER MONTH		0	0	286	0	0	0	0	0	0	0	0	0		\$286	429	76,829
CUMULATIVE																	
PLANNED TOTALS		119	238	644	1,406	10,840	23,224	36,859	46,114	53,972	61,829	69,686	77,544	\$77,544			
ACTUAL TOTALS		0	0	286	286	286	286	286	286	286	286	286	286		\$286		76,829
Budget Variance		\$119	\$238	\$358	\$1,120	\$10,554	\$22,938	\$36,573	\$45,828	\$53,686	\$61,543	\$69,400	\$77,258				

SubTask 1.1 - Analysis of Vortec Cyclone Melting System for Remediation

PRINCIPAL INVESTIGATOR: I. Celik

METC Task 1-2

Drain-Enhanced Soil Flushing

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	NEPA Information	1M	100.00%																					
2	Pilot-Scale Experiment Design	4M	75.00%																					
3	Field Site Selection	5M	60.00%																					
4	Engineering Design & Drafting	3M	70.00%																					
5	Permit Application Process	3M	70.00%																					
6	Procure Equipment & Supplies	2M	50.00%																					
7	Field Mobilization & Layout	1M	0.00%																					
8	Construction & Setup	3M	0.00%																					
9	Testing Phase	5M	0.00%																					
10	Chemical Lab Analysis	4M	0.00%																					
11	Testing Completion & Equipment Breakdown	3M	0.00%																					
12	Site Closure & Restoration	1M	0.00%																					
13	Equipment Final Disposition	1M	0.00%																					
14	Data Reduction & Report Preparation	12M	25.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

**PROJECT: Drained Enhanced Soil Flushing (DESF) Using
Prefabricated Vertical Drains**

METC TASK NO.: 1.2

PRINCIPAL INVESTIGATOR: M.A. Gabr

WVU ACCOUNT NO.: 8527-090-3239

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
M.A. Gabr	planned actual	0 0	0 0	0 0	0 0	0 0	3,840 3,840	3,840 3,840	3,840 3,840	0 0	0 0	0 0	0 0	\$11,520	\$0		11,520
Research Associate	planned actual	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	1,073 0	\$12,870	\$0		12,870
Management	planned actual	609 608	609 608	609 608	609 608	609 608	609 608	609 608	609 608	609 608	609 608	609 608	609 608	\$7,308	\$1,825	3,651	1,833
BENEFITS																	
29% of Full Time Salaries	planned actual	488 176	488 176	488 176	488 0	488 0	1,601 0	1,601 0	1,601 0	488 0	488 0	488 0	488 0	\$9,193	\$529	1,059	7,605
STUDENTS																	
Graduate	planned actual	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	1,993 0	\$23,920	\$0		23,920
Undergraduate	planned actual	750 0	750 0	750 285	750 0	750 0	750 0	750 0	750 0	750 0	750 0	750 0	750 0	\$9,000	\$285		8,715
SUPPLIES	planned actual	1,500 319	1,500 114	1,500 1,029	1,500 0	1,500 0	1,500 0	1,500 0	1,500 0	1,500 0	1,500 0	1,500 0	1,500 0	\$18,000	\$1,462	659	15,878
TRAVEL	planned actual	0 0	1,000 0	0 0	1,000 0	0 0	1,000 0	0 0	0 0	0 0	0 0	0 0	0 0	\$3,000	\$0	466	2,534
OTHER	planned actual	458 184	458 0	458 162	458 0	458 0	458 0	458 0	458 0	458 0	458 0	458 0	458 0	\$5,500	\$346		5,154
EQUIPMENT	planned actual	1,500 0	1,500 116	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$3,000	\$116		2,884
* > \$500	planned actual	1,200 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$1,200	\$0		1,200
SUB-CONTR.	planned actual	0 0	0 0	2,500 0	2,500 0	2,500 0	2,500 0	2,500 0	2,500 0	2,500 0	2,500 0	2,500 0	2,500 0	\$25,000	\$0	25,000	0
INDIRECT COSTS																	
43% of Direct Costs except *	planned actual	3,599 554	4,029 436	4,029 972	4,459 0	4,029 0	6,590 0	6,160 0	6,160 0	4,029 0	4,029 0	4,029 0	4,029 0	\$55,174	\$1,962	13,259	39,953
PLANNED TOTALS: PER MONTH		13,170	13,400	13,400	14,830	13,400	21,914	20,484	20,484	13,400	13,400	13,400	13,400	\$184,686			
ACTUAL TOTALS: PER MONTH		1,841	1,451	3,233	0	0	0	0	0	0	0	0	0	\$6,525		44,094	134,067
CUMULATIVE																	
PLANNED TOTALS		13,170	26,571	39,971	54,802	68,202	90,116	110,600	131,084	144,486	157,885	171,286	184,686	\$184,686			
ACTUAL TOTALS		1,841	3,292	6,525	6,525	6,525	6,525	6,525	6,525	6,525	6,525	6,525	6,525	\$6,525			134,067
Budget Variance		\$11,329	\$23,279	\$33,446	\$48,277	\$61,677	\$83,591	\$104,075	\$124,560	\$137,960	\$151,360	\$164,761	\$178,161				

Sub-Task 1.2 - Drained Enhanced Soil Flushing Using Prefabricated Vertical Drains

PRINCIPAL INVESTIGATOR: M.A. Gabr

METC TASK 1-3

Evaluation of Acrylates as Grout Barriers

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4		Dec	Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	NEPA Information	1M	100.00%																					
2	Grout Development & Characteristics Testing	11M	25.00%																					
3	Viscosity Tests	4M	75.00%																					
4	Setting Time Tests	4M	50.00%																					
5	Immersion Tests	6M	35.00%																					
6	Durability	3M	0.00%																					
7	Permeability	8M	13.00%																					
8	Shear Strength	5M	0.00%																					
9	Compressibility Characteristics	5M	0.00%																					
10	Toxicity	4M	0.00%																					
11	Grout Performance Testing	9M	0.00%																					
12	Data Reduction & Report Preparation	12M	25.00%																					

	Critical		Noncritical		Complete		Summary
	Critical Milestone		Noncritical Milestone		Complete Milestone		Summary Milestone
	Free Float		Total Float (+)		Total Float (-)		Baseline
	Delay		Effort %Complete				

Quarterly Report for January - March 1996

**PROJECT: Performance & Characteristics Evaluation of
acrylates as Grout Barriers for In Situ Containment**
PRINCIPAL INVESTIGATOR: M.A. Gabr

SUMMARY on/off Campus

METC TASK NO.: 1.3

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
Full-time	planned	0	1,500	1,500	0	0	0	3,000	3,000	0	0	0	0	\$9,000			
M.A. Gabr	actual	0	0	0											\$0		9,000
Research	planned	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	\$12,870			
Associate	actual	0	0	0													12,870
Management	planned	609	609	609	609	609	609	609	609	609	609	609	609	\$7,309			
	actual	609	609	609											\$1,827		5,482
BENEFITS																	
29% of Full	planned	488	923	923	488	488	488	1,358	1,358	488	488	488	488	\$8,462			
Time Salaries	actual	177	177	177	0	0	0	0	0	0	0	0	0		\$530	0	7,932
STUDENTS																	
Graduate	planned	1,993	1,993	1,993	1,993	1,993	1,993	1,993	1,993	1,993	1,993	1,993	1,993	\$23,920			
	actual	0	2,300	1,450											\$3,750	3,450	16,720
Undergraduate	planned	1,040	1,040	1,040	1,040	1,040	1,040	1,040	1,040	1,040	1,040	1,040	1,040	\$12,480			
	actual	0	168	120											\$288		12,192
SUPPLIES																	
	planned	2,500	2,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	\$20,000			
	actual	0	107	798											\$905		19,095
TRAVEL																	
	planned	0	1,000	0	1,000	0	500	0	0	0	0	0	0	\$2,500			
	actual	0	0	0											\$0		2,500
OTHER																	
	planned	42	42	42	42	42	42	42	42	42	42	42	42	\$500			
	actual	0	0	239											\$239		261
EQUIPMENT																	
* > \$500	planned	0	1,000	0	0	0	0	0	0	0	0	0	0	\$1,000			
	actual	0	0	0											\$0		1,000
INDIRECT COSTS																	
Variable																	
43% / 23%	planned	1,942	2,272	1,712	2,042	1,712	3,155	2,989	2,989	1,713	1,713	1,713	1,713	\$25,665			
On / Off	actual	338	930	938											\$2,206	4,054	19,405
Campus																	
PLANNED TOTALS:		9,686	13,951	10,381	9,786	8,456	10,399	13,603	13,603	8,457	8,457	8,457	8,457	\$123,706			
PER MONTH																	
ACTUAL TOTALS:		1,124	4,291	4,330	0	0	0	0	0	0	0	0	0		\$9,745	7,504	106,458
PER MONTH																	
CUMULATIVE																	
PLANNED TOTALS		9,686	23,638	34,029	43,815	52,271	62,671	76,274	89,877	98,334	106,792	115,249	123,706	\$123,706			
ACTUAL TOTALS		1,124	5,414	9,745	9,745	9,745	9,745	9,745	9,745	9,745	9,745	9,745	9,745		\$9,745		106,458
Budget Variance		\$8,563	\$18,223	\$24,284	\$34,070	\$42,527	\$52,926	\$66,529	\$80,132	\$88,590	\$97,047	\$105,504	\$113,962				

Sub-Task 1.3 - Evaluation of Acrylates as Grout Barriers for In-Situ Containment

PRINCIPAL INVESTIGATOR: M.A. Gabr

METC TASK 1-4

Desication Barriers

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	NEPA Information	1M	100.00%																					
2	Testing Protocol Development	2M	100.00%																					
3	Sand Pack Characterization	11M	25.00%																					
4	Adiabatic Cooling	11M	0.00%																					
5	Liquid Storage & Migration	11M	0.00%																					
6	Data Reduction & Report Preparation	12M	25.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

**PROJECT: Development of Standard Test Protocols and Design
Models for Dessication Barriers**

** Summary on/off Campus

METC TASK NO. 1.4

PRINCIPAL INVESTIGATOR (S): K. Aminian & S. Ameri

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
Full-time	planned actual	2,617 2,617	2,617 2,617	2,617 2,617	2,617 2,617	2,617 2,617	12,885 12,885	12,885 12,885	12,885 12,885	2,617 2,617	2,617 2,617	2,617 2,617	2,617 2,617	\$62,208	\$7,851	7,851	46,506
Management	planned actual	609 609	609 609	609 609	609 609	609 609	609 609	609 609	609 609	609 609	609 609	609 609	609 609	\$7,309	\$1,827	0	5,482
BENEFITS																	
29% of Full Time Salaries	planned actual	936 936	936 936	936 936	936 0	936 0	3,913 0	3,913 0	3,913 0	936 0	936 0	936 0	936 0	\$20,160	\$2,807	2,277	15,077
STUDENTS																	
Graduate	planned actual	3,000 870	3,000 2,570	3,000 1,720	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	\$36,005	\$5,160	5,160	25,685
SUPPLIES																	
	planned actual	125 0	125 447	125 0	125	125	125	125	125	125	125	125	125	\$1,500	\$447	0	1,053
TRAVEL																	
	planned actual	0 0	0 0	500 0	500	500	500	500	500	500	500	500	500	\$5,000	\$0	0	5,000
OTHER																	
	planned actual	42 0	42 0	42 0	42	42	42	42	42	42	42	42	42	\$500	\$0	0	500
EQUIPMENT < \$500																	
	planned actual	500 0	500 0	500 0	500	500	0	0	0	0	0	0	0	\$2,500	\$0	0	2,500
INDIRECT COSTS																	
Variable Rate	planned	1,958	1,958	2,173	2,173	2,173	6,434	6,434	6,434	2,058	2,058	2,058	2,058	\$37,969			
See On/Off Campus Detail	actual	1,315	1,808	1,510											\$4,633	3,516	29,820
PLANNED TOTALS: PER MONTH		9,787	9,787	10,502	10,502	10,502	27,508	27,508	27,508	9,887	9,887	9,887	9,887	\$173,151			
ACTUAL TOTALS: PER MONTH		6,347	8,986	7,392	0	0	0	0	0	0	0	0	0		\$22,724	18,804	131,623
CUMULATIVE																	
PLANNED TOTALS		9,787	19,573	30,075	40,577	51,079	78,587	106,096	133,604	143,491	153,377	163,264	173,151	\$173,151			
ACTUAL TOTALS		6,347	15,333	22,724	22,724	22,724	22,724	22,724	22,724	22,724	22,724	22,724	22,724		\$22,724		131,623
Budget Variance		\$3,440	\$4,241	\$7,351	\$17,853	\$28,354	\$55,863	\$83,371	\$110,880	\$120,766	\$130,653	\$140,540	\$150,427				

Sub-Task 1.4 - Dessication Barriers *Summary on/off campus work*

PRINCIPAL INVESTIGATOR (S): K. Aminian & S. Ameri

METC TASK 1-5

Technical Support for Barrier Test Program

#	Task Name	Dura	%Compl	1996												1997												1998						
				Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3			Qtr4			Qtr1		Qtr2				
				J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
1	Planning & Technology Transfer	8M	0.00%																															
2	Circulating Air Barrier Permitting	1M	0.00%																															
3	Circulating Air Barrier QA/QC	4M	0.00%																															
4	Circulating Air Barrier Reporting	12M	0.00%																															
5	Grout Permitting	3M	0.00%																															
6	Grout QA/QC	4M	0.00%																															
7	Grout Reporting	12M	0.00%																															
8	Freeze Barrier Development	9M	0.00%																															
9	Dual Barrier Report	10M	0.00%																															

Critical	Noncritical	Complete	Summary	External
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone	External Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline	Non-Resource
Delay	Effort %Complete			

Project Schedule

PROJECT: Development of Standard Test Protocols and
Design Models for Insitu Formed Barriers
<<<Technical Support >>>

METC TASK NO.: 1.5 ***Summary***

PRINCIPAL INVESTIGATOR (S): B. Overby & C. Locke

WVU ACCOUNT NO.: 8527-090-3237

PERIOD ENDING: 3/31/96

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
Management SALARIES																	
Director	planned	950	950	950	950	950	950	950	950	950	950	950	950	\$11,400			
	actual	475	475	475											\$1,425	5,225	4,751
Assistants to the Director	planned	2,132	2,132	2,132	2,132	2,132	2,132	2,132	2,132	2,132	2,132	2,132	2,132	\$25,581			
	actual	2,132	2,132	2,132											\$6,396	10,050	9,135
Clerical Support	planned	600	600	600	600	600	600	600	600	600	600	600	600	\$7,197			
	actual	600	600	600											\$1,800	1,800	3,597
BENEFITS																	
29% of Full Time Salaries	planned	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	\$12,812			
	actual	930	930	930	0	0	0	0	0	0	0	0	0		\$2,790	4,952	5,070
SUB-CONTR.																	
* > \$25,000	planned	0	0	0	47,687	47,687	47,687	47,687	47,687	47,687	47,687	47,687	47,687	\$429,187			
	actual	0	0	0											\$0	214,594	214,593
INDIRECT COSTS																	
43% of Direct Costs except *	planned	2,042	2,042	2,042	2,042	2,042	2,042	2,042	2,042	2,042	2,042	2,042	2,042	\$24,506			
	actual	1,779	1,779	1,779	0	0	0	0	0	0	0	0	0		\$5,337	9,471	9,698
PLANNED TOTALS PER MONTH																	
		6,791	6,791	6,791	54,479	54,479	54,479	54,479	54,479	54,479	54,479	54,479	54,479	\$510,683			
ACTUAL TOTALS PER MONTH																	
		5,916	5,916	5,916	0	0	0	0	0	0	0	0	0		\$17,748	246,091	246,844
CUMULATIVE																	
PLANNED TOTALS		6,791	13,583	20,374	74,853	129,332	183,810	238,289	292,768	347,247	401,725	456,204	510,683	\$510,683			
ACTUAL TOTALS		5,916	11,832	17,748	17,748	17,748	17,748	17,748	17,748	17,748	17,748	17,748	17,748		\$17,748		246,844
Budget Variance		\$875	\$1,750	\$2,626	\$57,104	\$111,583	\$166,062	\$220,541	\$275,019	\$329,498	\$383,977	\$438,456	\$492,934				

SubTask 1.5 - Standard Test Protocols & Design Models - Insitu Barriers

PRINCIPAL INVESTIGATOR (S): B. Overby and C. Locke - *** SUMMARY ***

◆ PLANNED SPENDING * ACTUAL SPENDING

METC TASK 2-1

GIS-Based Infrastructure

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	NEPA Information	1M	0.00%																					
2	GIS Application	9M	35.00%																					
3	Assessment for D&D Use	5M	0.00%																					
4	Tutorial Development	12M	25.00%																					
5	Data Reduction & Report Preparation	12M	25.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

PROJECT: A GIS Based Infrastructure for Site Characterization & Remediation

WVU ACCOUNT NO.: 8527-090-3247

METC TASK NO.: 2.1 *** Summary ***

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
Director	planned	475	475	475	475	475	475	475	475	475	475	475	475	\$5,700			
	actual	475	475	475											\$1,425		4,275
Assistant Director	planned	305	305	305	305	305	305	305	305	305	305	305	305	\$3,655			
	actual	0	0	0											\$0		3,655
BENEFITS																	
29% of Full Time Salaries	planned	226	226	226	226	226	226	226	226	226	226	226	226	\$2,713			
	actual	138	138	138	0	0	0	0	0	0	0	0	0		\$413	0	2,300
SUB-CONTR.																	
* > \$25,000	planned	11,669	11,669	11,669	11,669	11,669	11,669	11,669	11,669	11,669	11,669	11,669	11,669	\$140,034			
	actual	8,979	8,340	11,111											\$28,430	111,604	(0)
INDIRECT COSTS																	
43% of Direct Costs except *	planned	432	432	432	432	432	432	432	432	432	432	432	432	\$5,189			
	actual	263	263	263	0	0	0	0	0	0	0	0	0		\$790	0	4,399
PLANNED TOTALS:																	
PER MONTH		13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108	\$157,291			
ACTUAL TOTALS:																	
PER MONTH		9,855	9,216	11,987	0	0	0	0	0	0	0	0	0		\$31,059	111,604	14,628
CUMULATIVE																	
PLANNED TOTALS		13,108	26,215	39,323	52,430	65,538	78,645	91,753	104,861	117,968	131,076	144,183	157,291	\$157,291			
ACTUAL TOTALS		9,855	19,072	31,059	31,059	31,059	31,059	31,059	31,059	31,059	31,059	31,059	31,059		\$31,059		14,628
Budget Variance		\$3,252	\$7,144	\$8,264	\$21,371	\$34,479	\$47,587	\$60,694	\$73,802	\$86,909	\$100,017	\$113,124	\$126,232				

* Sub Contractor Detail Follows

SubTask 2.1 - A GIS Based Infrastructure for Characterization & Remediation
Overall Summary

**PROJECT: A GIS Based Infrastructure for Site
Characterization and Remediation**
PRINCIPAL INVESTIGATOR (S): J. Hooper & A. Lodgher

METC TASK NO.: 2.1 Sub-Contractor Detail
Marshall University
PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Amount Remaining
SALARIES	planned actual	5,432 5,641	5,432 5,110	5,432 5,368	5,432	5,432	5,432	5,432	5,432	5,432	5,432	5,432	5,432	\$65,182		
															\$16,118	49,064
BENEFITS	planned actual	869 862	869 768	869 1,088	869	869	869	869	869	869	869	869	869	\$10,429		
															\$2,718	7,711
STUDENT Salaries	planned actual	0 0	0 0	0 0	1,456	1,456	1,456	1,456	1,456	1,456	1,456	1,456	1,456	\$13,108		
															\$0	13,108
GENERAL EXPENSE	planned actual	250 5	250 165	250 13	250	250	250	250	250	250	250	250	250	\$3,000		
															\$183	2,817
TRAVEL	planned actual	0 0	0 0	1,000 418	1,000	1,000	0	1,000	1,000	0	0	0	0	\$5,000		
															\$418	4,582
EQUIPMENT < \$1,000	planned actual	1,400 0	1,400 0	0 1,165	0	0	0	0	0	0	0	0	0	\$2,800		
															\$1,165	1,635
* > \$1,000	planned actual	2,200 0	0 0	0 0	0	0	0	0	0	0	0	0	0	\$2,200		
															\$0	2,200
INDIRECT COSTS																
Average 38.5%	planned	3,021	3,021	2,869	3,423	3,423	3,043	3,513	3,513	3,123	3,123	3,123	3,123	\$38,318		
Direct Costs Except *	actual	2,473	2,296	3,060	0	0	0	0	0	0	0	0	0		\$7,829	30,489
PLANNED TOTALS: PER MONTH		13,172	10,972	10,420	12,430	12,430	11,050	12,520	12,520	11,130	11,130	11,130	11,130	\$140,037		
ACTUAL TOTALS: PER MONTH		8,979	8,340	11,111	0	0	0	0	0	0	0	0	0		\$28,430	111,607
CUMULATIVE																
PLANNED TOTALS		13,172	24,145	34,565	46,995	59,425	70,475	82,996	95,516	106,646	117,776	128,907	140,037	\$140,037		
ACTUAL TOTALS		8,979	17,319	28,430	28,430	28,430	28,430	28,430	28,430	28,430	28,430	28,430	28,430		\$28,430	111,607
Budget Variance		\$4,193	\$6,826	\$6,135	\$18,565	\$30,995	\$42,045	\$54,566	\$67,086	\$78,216	\$89,346	\$100,477	\$111,607			

Sub-Task 2.1: GIS Infrastructure for Characterization & Remediation

PRINCIPAL INVESTIGATOR (S): J. Hooper & A. Lodgher - <<< Marshall University Detail >>>

METC TASK 2-2

Treatment of Mixed Wastes via Steam Reforming

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	NEPA Information	1M	100.00%																					
2	Calibrate GC	3M	30.00%																					
3	Destruction Efficiency Evaluation	5M	0.00%																					
4	Catalyst Evaluation	5M	0.00%																					
5	Data Reduction and Report Preparation	12M	25.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

**PROJECT: Treatment of Mixed Wastes via Fluidized Bed
Steam Reforming**

METC TASK NO.: 2.2

PRINCIPAL INVESTIGATOR: R. Turton

WVU ACCOUNT NO.: 8527-089-2406

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
R. Turton	planned	0	0	0	0	3,417	6,835	0	0	0	0	0	0	\$10,252			
	actual	0	0	0													10,252
BENEFITS																	
29% of Full Time Salaries	planned	0	0	0	0	991	1,982	0	0	0	0	0	0	\$2,973			
	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	0	2,973
STUDENTS																	
Graduate	planned	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	\$12,002			
	actual	0	2,200	1,100											\$3,300	2,200	6,502
SUPPLIES																	
	planned	167	167	167	167	167	167	167	167	167	167	167	167	\$2,000			
	actual	0	101	305											\$406	69	1,525
TRAVEL																	
	planned	0	0	500	0	0	500	0	0	0	0	0	0	\$1,000			
	actual	0	0	0											\$0	127	873
OTHER																	
	planned	0	0	100	0	0	100	0	0	100	0	0	100	\$400			
	actual	0	0	0											\$0		400
EQUIPMENT																	
< \$500	planned	0	970	0	0	0	0	0	0	0	0	0	0	\$970			
	actual	0	0	0											\$0		970
* > \$500	planned	2,800	0	0	0	0	0	0	0	0	0	0	0	\$2,800			
	actual	0	0	0											\$0	2,495	305
INDIRECT COSTS																	
43% of Direct Costs except *	planned	502	919	760	502	2,397	4,551	502	502	545	502	502	545	\$12,727			
	actual	0	989	604	0	0	0	0	0	0	0	0	0		\$1,594	1,030	10,103
PLANNED TOTALS: PER MONTH																	
		4,469	3,056	2,527	1,669	7,972	15,134	1,669	1,669	1,812	1,669	1,669	1,812	\$45,123			
ACTUAL TOTALS: PER MONTH																	
		0	3,290	2,009	0	0	0	0	0	0	0	0	0		\$5,299	5,921	33,902
CUMULATIVE																	
PLANNED TOTALS		4,469	7,524	10,051	11,719	19,692	34,826	36,495	38,163	39,975	41,643	43,312	45,123	\$45,123			
ACTUAL TOTALS		0	3,290	5,299	5,299	5,299	5,299	5,299	5,299	5,299	5,299	5,299	5,299		\$5,299		33,902
Budget Variance		\$4,469	\$4,234	\$4,751	\$6,420	\$14,392	\$29,527	\$31,195	\$32,864	\$34,675	\$36,344	\$38,012	\$39,824				

SubTask 2.2 - Trmt of Mixed Waste via Fluidized Bed Steam Reforming

PRINCIPAL INVESTIGATOR: R. Turton

METC TASK 2-3

Centrifugal Membrane Technology

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	NEPA Information	1M	100.00%																					
2	Literature Review	2M	100.00%																					
3	Waste & Membrane ID & Acquisition	2M	90.00%																					
4	Technology Modification Acquisition & Training	1M	100.00%																					
5	Testing & Evaluation	8M	0.00%																					
6	Data Reduction & Report Preparation	12M	25.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

PROJECT: Use of Centrifugal Membrane Technology w/ Novel
Membranes to Treat Hazardous/Radio Active Waste
PRINCIPAL INVESTIGATOR: B. Reed

METC TASK NO.: 2.3

WVU ACCOUNT NO.: 8527-090-3236

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
Principal	planned	0	0	0	0	0	0	3,580	6,100	0	0	0	0	\$9,680			
B. Reed	actual	0	0	0													9,680
Management	planned	305	305	305	305	305	305	305	305	305	305	305	305	\$3,655			
T. Beatty	actual	305	305	305											\$915	915	1,825
BENEFITS																	
29% of Full	planned	88	88	88	88	88	88	1,127	1,857	88	88	88	88	\$3,867			
Time Salaries	actual	88	88	88	0	0	0	0	0	0	0	0	0		\$265	265	3,336
STUDENTS																	
Graduate	planned	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	\$14,400			
Ph.D.	actual	0	0	0											\$0		14,400
Graduate	planned	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	\$12,000			
M.S.	actual	0	788	698											\$1,485	1,500	9,015
SUPPLIES	planned	2,000	1,000	700	700	700	700	700	700	700	700	400	0	\$9,000			
	actual	0	0	165											\$165	2,000	6,835
TRAVEL	planned	0	0	0	0	0	0	1,500	0	0	0	0	0	\$1,500			
	actual	0	0	0											\$0		1,500
OTHER	planned	0	0	250	0	0	250	0	0	250	0	0	250	\$1,000			
	actual	0	0	0											\$0		1,000
EQUIPMENT																	
* > \$500	planned	0	5,000	0	50,000	0	0	0	0	0	0	0	0	\$55,000			
	actual	0	0	0											\$0		55,000
INDIRECT COSTS																	
43% of Direct	planned	1,975	1,545	1,523	1,416	1,416	1,523	4,047	4,800	1,523	1,416	1,287	1,222	\$23,694			
Costs except *	actual	169	508	540	0	0	0	0	0	0	0	0	0		\$1,217	2,013	20,464
PLANNED TOTALS:																	
PER MONTH		6,568	10,138	5,066	54,709	4,709	5,066	13,458	15,961	5,066	4,709	4,280	4,065	\$133,795			
ACTUAL TOTALS:																	
PER MONTH		563	1,689	1,796	0	0	0	0	0	0	0	0	0		\$4,047	6,693	123,055
CUMULATIVE																	
PLANNED TOTALS		6,568	16,706	21,772	76,481	81,189	86,256	99,714	115,675	120,741	125,450	129,730	133,795	\$133,795			
ACTUAL TOTALS		563	2,251	4,047	4,047	4,047	4,047	4,047	4,047	4,047	4,047	4,047	4,047		\$4,047		123,055
Budget Variance		\$6,005	\$14,454	\$17,724	\$72,433	\$77,142	\$82,208	\$95,666	\$111,628	\$116,694	\$121,403	\$125,683	\$129,748				

Sub-Task 2.3: Centrifugal Membranes to Treat Haz./Radio Active Wastes

PRINCIPAL INVESTIGATOR: B. Reed

METC Task 2-4

Environmental Pollution Control Devices

#	Task Name	Dura	%Comp	199	1996												1997						
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	NEPA Information	1M	100.00%																				
2	Small Cell Carbon Tests	9M	20.00%																				
3	Access Metal & Radionuclide Removal	11M	20.00%																				
4	Construct Prototype	3.7M	90.00%																				
5	Parametric Studies	6M	0.00%																				
6	Derive Correlations	6M	0.00%																				
7	Test Recovery Schemes	11M	10.00%																				
8	Apply Prototype	5M	0.00%																				
9	Data Reduction & Report Preparation	12M	25.00%																				

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

**PROJECT: Environmental Pollution Control Devices Based
on Novel Forms of Carbon**
PRINCIPAL INVESTIGATOR (S): J. Zondlo, A. Stiller, A. Brennsteiner

METC TASK NO.: 2.4

WVU ACCOUNT NO.: 8527-089-2405

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
A. Brennsteiner	planned	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	\$32,510			
	actual	0	4,750	2,375											\$7,125	7,125	18,260
J. Zondolo & A. Stiller	planned	0	0	0	0	0	2,267	2,267	2,267	0	0	0	0	\$6,800			
	actual	0	0	0												0	6,800
BENEFITS																	
29% of Full Time Salaries	planned	786	786	786	786	786	1,443	1,443	1,443	786	786	786	786	\$11,400			
	actual	0	1,378	689	0	0	0	0	0	0	0	0	0		\$2,066	2,066	7,267
GRADUATE ASSISTANT	planned	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000	450	0	0	\$6,450			
	actual	0	0	0											\$0	3,000	3,450
SUPPLIES	planned	242	242	242	242	242	242	242	242	242	242	242	242	\$2,900			
	actual	0	0	282											\$282	55	2,563
TRAVEL	planned	0	0	1,100	0	0	0	0	0	0	0	0	0	\$1,100			
	actual	0	0	0											\$0	1,076	24
OTHER	planned	0	0	250	0	0	250	0	0	250	0	0	250	\$1,000			
	actual	0	0	0											\$0	470	530
EQUIPMENT																	
* > \$500	planned	6,000	5,000	0	0	0	0	0	0	0	0	0	0	\$11,000			
	actual	0	632	4,019											\$4,651	5,400	949
INDIRECT COSTS																	
43% of Direct Costs except *	planned	1,607	1,607	2,187	2,037	2,037	3,402	3,294	3,294	2,144	1,800	1,607	1,714	\$26,729			
	actual	0	2,635	1,439	0	0	0	0	0	0	0	0	0		\$4,074	5,931	16,725
PLANNED TOTALS: PER MONTH		11,343	10,343	7,274	6,773	6,773	11,312	10,955	10,955	7,131	5,987	5,343	5,701	\$99,889			
ACTUAL TOTALS: PER MONTH		0	9,395	8,804	0	0	0	0	0	0	0	0	0		\$18,199	25,123	56,568
CUMULATIVE																	
PLANNED TOTALS		11,343	21,686	28,960	35,733	42,507	53,819	64,773	75,728	82,859	88,845	94,189	99,889	\$99,889			
ACTUAL TOTALS		0	9,395	18,199	18,199	18,199	18,199	18,199	18,199	18,199	18,199	18,199	18,199		\$18,199		56,568
Budget Variance		\$11,343	\$12,292	\$10,762	\$17,535	\$24,308	\$35,620	\$46,575	\$57,529	\$64,660	\$70,647	\$75,990	\$81,691				

Sub-Task 2.4 - Pollution Control Devices Based on Novel Forms of Carbon

PRINCIPAL INVESTIGATOR (S): A. Stiller, J. Zondolo & A. Brennstainer

METC Task 2-5

Development of Instrumental Methods

#	Task Name	Dura	%Comp	199	1996												1997								
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3		
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
1	NEPA Information	1M	100.00%																						
2	Literature Review	0.5M	100.00%																						
3	Analysis & Speciation of Iodine	.75M	100.00%																						
4	Analysis & Speciation of Re & Tc	3.5M	15.00%																						
5	Analysis & Speciation of Iodine	3M	0.00%																						
6	Analysis & Speciation of Re & Tc	3M	0.00%																						
7	Data Reduction & Report Preparation	12M	25.00%																						

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

PROJECT: Development of Instrumental Methods for Characterization and Analysis of Nuclear Wastes & Environmental Contaminants

PRINCIPAL INVESTIGATOR (S): V. Remcho - Dept. of Chemistry, WVU

N. Ballou - Battelle-Pacific Northwest National Laboratories

METC TASK NO.: 2.5

WVU ACCOUNT NO.: 8527-047-0702

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
V. Remcho	planned	0	0	0	0	2,067	4,134	4,134	2,067	0	0	0	0	\$12,402			
	actual	0	0	0											\$0		12,402
Post Doc	planned	1,000	1,000	1,000	1,000	1,000	1,000	0	0	0	0	0	0	\$6,000			
H. Knobel	actual	0	2000	1000											\$3,000	3000	0
BENEFITS																	
29% of Full	planned	290	290	290	290	889	1,489	1,199	599	0	0	0	0	\$5,337			
Time Salaries	actual	0	580	290	0	0	0	0	0	0	0	0	0		\$870		4,467
STUDENTS																	
Graduate	planned	0	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000	\$6,000			
	actual	0	0	0											\$0		6,000
SUPPLIES																	
	planned	230	230	230	230	230	230	230	230	230	230	230	230	\$2,760			
	actual	0	231	535											\$765		1,995
TRAVEL																	
	planned	0	0	0	1,000	0	0	1,200	0	0	0	0	0	\$2,200			
	actual	0	0	0											\$0		2,200
OTHER																	
	planned	0	0	125	0	0	125	0	0	125	0	0	125	\$500			
	actual	0	0	0											\$0		500
EQUIPMENT																	
* > \$500	planned	10,000	7,000	0	0	0	0	0	0	0	0	0	0	\$17,000			
	actual	0	0	0											\$0	6175	10,825
SUB-CONTR.																	
< \$25,000	planned	0	0	0	2,611	2,611	2,611	2,611	2,611	2,611	2,611	2,611	2,611	\$23,500			
	actual	0	0	0											\$0	23,500	(0)
INDIRECT COSTS																	
43% of Direct	planned	654	654	707	2,206	2,923	4,123	4,461	2,798	1,705	1,652	1,652	1,705	\$25,240			
Costs except *	actual	0	1,209	785	0	0	0	0	0	0	0	0	0		\$1,993	10,105	13,142
PLANNED TOTALS:		12,174	9,174	2,352	7,337	9,720	13,712	14,835	9,306	5,672	5,493	5,493	5,672	\$100,939			
PER MONTH																	
ACTUAL TOTALS:		0	4,019	2,609	0	0	0	0	0	0	0	0	0		\$6,628	42,780	51,530
PER MONTH																	
CUMULATIVE																	
PLANNED TOTALS		12,174	21,347	23,700	31,037	40,758	54,470	69,305	78,610	84,282	89,775	95,267	100,939	\$100,939			
ACTUAL TOTALS		0	4,019	6,628	6,628	6,628	6,628	6,628	6,628	6,628	6,628	6,628	6,628		\$6,628		51,530
Budget Variance		\$12,174	\$17,328	\$17,071	\$24,409	\$34,129	\$47,841	\$62,676	\$71,982	\$77,653	\$83,146	\$88,639	\$94,310				

Sub-Task 2.5: Instrumental Methods for Characterization & Analysis

PRINCIPAL INVESTIGATOR (S): V. Remcho & N. Ballou

METC Task 3-1

WV High Tech Consortium

#	Task Name	Dura	%Comp	1995					1996															
				Qtr3		Qtr4			Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			
				Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	Phase II - Implementation	6M	50.00%																					
2	Start-Up Activities	6M	50.00%																					
3	Infrastructure Development	6M	50.00%																					
4	Operating Policies	6M	50.00%																					
5	Phase III - Continued ETI Development	6M	0.00%																					
6	Infrastructure Development	6M	0.00%																					
7	Operating Policies	6M	0.00%																					
8	Tenant Company Incubation	6M	0.00%																					
9	Report Preparation	12M	25.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
E. Cook	planned	475	475	475	475	475	475	475	475	475	475	475	475	\$5,700			
	actual	475	475	475											\$1,425		4,275
T. Beatty	planned	609	609	609	609	609	609	609	609	609	609	609	609	\$7,309			
	actual	609	609	609											\$1,827		5,482
BENEFITS																	
29% of Full Time Salaries	planned	314	314	314	314	314	314	314	314	314	314	314	314	\$3,773			
	actual	314	314	314	0	0	0	0	0	0	0	0	0		\$943	0	2,830
SUB-CONTR. > \$25,000	planned	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	\$119,000			
	actual	4,145	4,145	4,145											\$12,435	106,565	(0)
INDIRECT COSTS																	
43% of Direct Costs except *	planned	601	601	601	601	601	601	601	601	601	601	601	601	\$7,216			
	actual	601	601	601	0	0	0	0	0	0	0	0	0		\$1,804	0	5,412
PLANNED TOTALS: PER MONTH																	
		11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	11,917	\$142,998			
ACTUAL TOTALS: PER MONTH																	
		6,145	6,145	6,145	0	0	0	0	0	0	0	0	0		\$18,435	106,565	17,999
CUMULATIVE																	
PLANNED TOTALS		11,917	23,833	35,750	47,666	59,583	71,499	83,416	95,332	107,249	119,165	131,082	142,998	\$142,998			
ACTUAL TOTALS		6,145	12,290	18,435	18,435	18,435	18,435	18,435	18,435	18,435	18,435	18,435	18,435		\$18,435		17,999
Budget Variance		\$5,772	\$11,543	\$17,315	\$29,232	\$41,148	\$53,065	\$64,981	\$76,898	\$88,814	\$100,731	\$112,647	\$124,564				
*Sub Contractor Detail Follows																	

Sub-Task 3.1: WVHTC Foundation - Technology Support Program
PRINCIPAL INVESTIGATOR (S): E. Cook & J. Berkow <<SUMMARY>>>

PROJECT: West Virginia High Tech Consortium (WVHTC) Foundation
Environmental Technology Support Program
PRINCIPAL INVESTIGATOR: Jan Berkow

METC TASK NO.: 3.1
*** Sub-Contractor Detail ***
PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Amount Remaining
SALARIES																
Direct Labor	planned actual	3,333 1,735	3,333 1,735	3,333 1,735	3,333	3,333	3,333	3,333	3,333	3,333	3,333	3,333	3,333	\$40,000		
															\$5,204	34,796
Overhead	planned actual	2,695 995	2,695 995	2,695 995	2,695 0	2,695 0	2,695 0	2,695 0	2,695 0	2,695 0	2,695 0	2,695 0	2,695 0	\$32,336	\$2,985	29,351
Student Intern	planned actual	333 0	333 0	333 0	333	333	333	333	333	333	333	333	333	\$4,000	\$0	4,000
Technical/ Facilities Support	planned actual	1,583 1,063	1,583 1,063	1,583 1,063	1,583	1,583	1,583	1,583	1,583	1,583	1,583	1,583	1,583	\$19,000	\$3,190	15,810
Office Supplies	planned actual	500 114	500 114	500 114	500	500	500	500	500	500	500	500	500	\$6,000	\$343	5,657
Public Information Services	planned actual	417 3	417 3	417 3	417	417	417	417	417	417	417	417	417	\$5,000	\$10	4,990
Travel	planned actual	516 9	516 9	516 9	516	516	516	516	516	516	516	516	516	\$6,194	\$27	6,167
SUB-TOTAL	planned actual	9,378 3,920	9,378 3,920	9,378 3,920	9,378 0	9,378 0	9,378 0	9,378 0	9,378 0	9,378 0	9,378 0	9,378 0	9,378 0	\$112,530	\$11,759	100,771
General & Administrative	planned actual	539 225	539 225	539 225	539 0	539 0	539 0	539 0	539 0	539 0	539 0	539 0	539 0	\$6,470	\$676	5,794
PLANNED TOTALS: PER MONTH																
		9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	9,917	\$119,000		
ACTUAL TOTALS: PER MONTH																
		4,145	4,145	4,145	0	0	0	0	0	0	0	0	0		\$12,435	106,565
CUMULATIVE																
PLANNED TOTALS		9,917	19,833	29,750	39,667	49,584	59,500	69,417	79,334	89,250	99,167	109,084	119,000	\$119,000		
ACTUAL TOTALS		4,145	8,290	12,435	12,435	12,435	12,435	12,435	12,435	12,435	12,435	12,435	12,435		\$12,435	106,565
Budget Variance		\$5,772	\$11,543	\$17,315	\$27,232	\$37,148	\$47,065	\$56,982	\$66,899	\$76,815	\$86,732	\$96,649	\$106,565			

Sub-Task 3.1: WWHC Foundation, Support Program

PRINCIPAL INVESTIGATOR: Jan Berkow <<SUB-CONTRACTOR DETAIL>>>

METC TASK 3-2

Small Business Interaction Opportunities

#	Task Name	Dura	%Comp	199	1996												1997							
				Qtr4	Qtr1			Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3	
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Develop Small Business Contacts	12M	25.00%																					
2	Team Buisness & University Researchers	12M	25.00%																					
3	Develop New Subtasks & Outreach	12M	25.00%																					
4	Report Preparation	12M	25.00%																					

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

PROJECT: Small Business Opportunities

METC TASK NO.: 3.2

PRINCIPAL INVESTIGATOR: E. Cook

WVU ACCOUNT NO.: 8527-090-3234

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
Director	planned actual	2,375 2,375	2,375 2,375	2,375 2,375	2,375	2,375	2,375	2,375	2,375	2,375	2,375	2,375	2,375	\$28,501			
															\$7,125	7,601	13,775
Clerical	planned actual	750 476	750 476	750 476	750	750	750	750	750	750	750	750	750	\$8,996			
															\$1,428	1,428	6,140
Accounting	planned actual	0 0	0 0	1,560 0	0	0	1,560	0	0	1,560	0	0	1,560	\$6,240			
															\$0	0	6,240
BENEFITS																	
29% of Full Time Salaries	planned actual	906 827	906 827	1,359 827	906 0	906 0	1,359 0	906 0	906 0	1,359 0	906 0	906 0	1,359 0	\$12,684			
															\$2,480	2,618	7,585
SUPPLIES	planned actual	1,000 51	1,000 83	1,000 656	500	500	500	500	500	500	500	500	0	\$7,000			
															\$790	26	6,184
TRAVEL	planned actual	1,000 0	1,000 0	1,000 0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	\$12,000			
															\$0		12,000
OTHER	planned actual	0 0	0 25	375 0	0	0	375	0	0	375	0	0	375	\$1,500			
															\$25		1,475
SUB-CONTR.	planned	0	0	0	25,000	0	25,000	0	0	0	0	0	0	\$50,000			
< \$25,000	actual	0	0	0											\$0		50,000
* > \$25,000	planned actual	0 0	0 0	0 0	50,000	0	50,000	40,000	0	0	0	0	0	\$140,000			
															\$0		140,000
EQUIPMENT	planned	0	0	2,500	0	0	2,500	0	0	0	0	0	0	\$5,000			
> \$500	actual	0	0	0											\$0		5,000
INDIRECT COSTS																	
43% of Direct Costs except *	planned actual	2,593 1,603	2,593 1,628	3,620 1,863	13,128 0	2,378 0	14,155 0	2,378 0	2,378 0	3,405 0	2,378 0	2,378 0	3,190 0	\$54,578			
															\$5,095	5,019	44,462
PLANNED TOTALS: PER MONTH		8,624	8,624	14,538	93,659	7,909	99,573	47,909	7,909	11,323	7,909	7,909	10,608	\$326,497			
ACTUAL TOTALS: PER MONTH		5,332	5,416	6,197	0	0	0	0	0	0	0	0	0		\$16,944	16,692	292,862
CUMULATIVE																	
PLANNED TOTALS		8,624	17,249	31,787	125,446	133,355	232,929	280,838	288,747	300,070	307,980	315,889	326,497	\$326,497			
ACTUAL TOTALS		5,332	10,746	16,944	16,944	16,944	16,944	16,944	16,944	16,944	16,944	16,944	16,944		\$16,944		292,862
Budget Variance		\$3,292	\$6,502	\$14,843	\$108,502	\$116,412	\$215,985	\$263,894	\$271,803	\$283,127	\$291,036	\$298,945	\$309,553				

Sub-Task 3.2: Small Business Opportunities

PRINCIPAL INVESTIGATOR: E. Cook

OLD METC TASK 3-4 Voluntary Environmental Protection, Kanawha Valley Area

#	Task Name	Dura	%Comp	1995					1996																
				Qtr3		Qtr4			Qtr1			Qtr2			Qtr3		Qtr4			Qtr1					
				Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1	Initial Conact of Parties	1M	100.00%																						
2	Conduct Meetings with Parties	.86M	100.00%																						
3	Meetings with USEPA and WVDEQ	0.9M	100.00%																						
4	Prepare Summary of Meetings	.19M	10.00%																						
5	Group Meeting	8M	0.00%																						

Critical	Noncritical	Complete	Summary
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline
Delay	Effort %Complete		

Quarterly Report for January - March 1996

**PROJECT: Approach for Assessing Potential Voluntary Environmental Protection
Kanawha River Area *** Continuation from 1995*****

METC TASK NO.: Old 3.4

WVU ACCOUNT NO.: 8527-224-1422

PRINCIPAL INVESTIGATOR: Ray Lovett

PERIOD ENDING: March 31, 1996

DESCRIPTION	Planned Actual	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS	Obligated Encumbrances	Amount Remaining
SALARIES																	
R. Lovett	planned	0	0	0	1,047	1,047	1,047	0	0	0	0	0	0	\$3,142			
	actual	0	0	0											\$0		3,142
BENEFITS																	
29% of Full	planned	0	0	0	304	304	304	0	0	0	0	0	0	\$911			
Time Salaries	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	0	911
SUPPLIES																	
	planned	28	28	28	28	28	28	0	0	0	0	0	0	\$165			
	actual	0	0	0											\$0		165
TRAVEL																	
	planned	667	667	667	667	667	667	0	0	0	0	0	0	\$4,000			
	actual	0	71	0											\$71		3,929
OTHER																	
	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0			
	actual	0	0	0											\$0		0
SUB-CONTR.																	
< \$25,000	planned	3,766	3,766	3,766	3,766	3,766	3,766	0	0	0	0	0	0	\$22,595			
	actual	846	0	0											\$846	21,749	0
SUB-CONTR.																	
> \$25,000	planned	0	0	0	6,760	6,760	6,760	0	0	0	0	0	0	\$20,280			
	actual	0	0	0											\$0	20,280	0
INDIRECT COSTS																	
19% of Direct	planned	847	847	847	1,104	1,104	1,104	0	0	0	0	0	0	\$5,855			
Costs except *	actual	364	31	0	0	0	0	0	0	0	0	0	0		\$394	4,132	1,328
PLANNED TOTALS:																	
PER MONTH		5,307	5,307	5,307	13,675	13,675	13,675	0	0	0	0	0	0	\$56,948			
ACTUAL TOTALS:																	
PER MONTH		1,210	102	0	0	0	0	0	0	0	0	0	0		\$1,311	46,161	9,475
CUMULATIVE																	
PLANNED TOTALS		5,307	10,615	15,922	29,597	43,273	56,948	56,948	56,948	56,948	56,948	56,948	56,948	\$56,948			
ACTUAL TOTALS		1,210	1,311	1,311	1,311	1,311	1,311	1,311	1,311	1,311	1,311	1,311	1,311		\$1,311		9,475
Budget Variance		\$4,098	\$9,303	\$14,611	\$28,286	\$41,961	\$55,636	\$55,636	\$55,636	\$55,636	\$55,636	\$55,636	\$55,636				

Sub-Task *OLD 3.4* - Kanawha River Area Environmental Protection

PRINCIPAL INVESTIGATOR: Ray Lovett - Note: Continuation from 1995, only 1996 work shown

**ANALYSIS OF THE VORTEC CYCLONE MELTING SYSTEM (CMS™)
FOR REMEDIATION OF PCB CONTAMINATED SOILS USING CFD**

METC Task No. 1.1

Quarterly Technical Progress Report
Reporting Period: January 1 - March 29, 1996

Work Performed Under Contract
No.: DE-FE21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

by

Ismail Celik, Ph.D.

Department of Mechanical and Aerospace Engineering
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ABSTRACT

In this report, the results of flow and heat transfer analysis for selected retrofits of a cyclone melting system (CMS) are presented. The analysis is based on computational fluid dynamics (CFD) simulations. The assumptions, approximations, and the implications of the results with respect to the gas residence time, flow patterns, and temperature distribution, and conversion and destruction rates for selected chemical species are discussed. Problem specific mathematical models are presented. Recommendations are made for improved flow conditions that will lead to longer residence times, and higher conversion and destruction efficiency. Specific application target is the CMS^{TM} of Vortec Corporation. The results are summarized in the executive summary section as they become available for each quarterly reporting period.

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EXECUTIVE SUMMARY

Some preliminary computer simulations have been performed from the residence chamber of the Vortec Corporation's Cyclone Melting System (CMS^{TM}). The first set of calculations assumes axisymmetric, isothermal, flow of hot air at 1694 K (2590 °F) and a pressure of 1 atm. Flow through curves have been calculated to track the temporal variation of the relative concentration at the outlet of an instantaneously injected scalar at the inlet. These curves indicate various time scales such as the first arrival time, and the peak concentration time, from which an insight about the residence time and the degree of mixing in the unit can be gained. The present calculations did not show any improvement of the residence time with increased swirl velocity. This has led us to check the validity of the assumption of axisymmetric flow. Two sets of three-dimensional calculations for an approximate geometry showed that the three dimensional effects can be significant depending on the flow conditions, in particular depending on the ratio of swirl velocity to the radial velocity at the inlet, and hence the angle at which the flow is introduced into the residence chamber. It seems that the analysis should be done using three dimensional calculations.

1.0 INTRODUCTION

The low level radioactive waste and other hazardous waste materials such as Polychlorinated Biphenyls (PCB) has become an important risk factor in endangering human health and environment. Each year millions of tons of contaminated soil is identified and classified for clean up only in the United States. An efficient and safe way to reduce and in most cases eliminate this risk factor to health and environment is the so called vitrification and remediation process via thermochemical treatment at high temperatures. In this process the hazardous waste and the contaminated residuals are heated, where most organic contaminants are vaporized and oxidized, while the inorganic contaminants are immobilized within a glassy, vitrified matrix. One such system has been developed by Vortec Corporation (here and after referred as Vortec) which has been demonstrated to be flexible in processing a wide variety of contaminated soils, sludges, and other hazardous materials. The system consists of a counter rotating combustor (or melter), a separation unit where liquid phase is separated from the gas phase, a residence chamber to provide reaction time to complete the conversion processes, and a recuperator which provides further residence time in addition to providing hot air/gas to be used as a heating source for the combustor (see Figure 1). The design, refinement, and retrofits of such systems require calculation of optimum design parameters such as residence time, heat loss, pressure drop, mixing rates, and the flow field dependent conversion and destruction (C&D) rates.

In practice where detailed flow and temperature distributions are not available, usually a plug flow assumption is used to calculate the gas residence time from empirical relations(see e.g. Van Dell et al., 1994a, 1994b; Van Dell and Mahle, 1992; Duvall and Rubey, 1977). This is a crude assumption and it may lead to significant errors. For example Van Dell and Mahle's calculations show a two-three fold difference in residence time even in a controlled, bench-scale laminar flow reactor due to temperature differences within the same reactor. Such errors directly translate to the calculation of species concentrations, hence may lead to quite erroneous information for design of PCB destruction systems. Celik and Chattree (1988) developed a rigorous method for calculating mean gas and particle residence times in an entrained flow reactor. This method (which will also be used for the present analysis) takes into account the gas temperature and density changes locally in the reactor as well as the recirculation zones. Their results also showed significant differences between the particle and gas residence time due to inertia and gravitational effects.

Furthermore, the destruction rates of PCB's are usually modeled by a simple Arrhenius type rate expressions where the gas temperature is assumed to be constant. To obtain more accurate results the gas temperature needs to be varied locally within the reactor and the reaction rates should be generalized to account for reformation of the compounds. Thus the resulting rate expression should include both the coefficients for the rate of formation as well as for the rate of destruction. Such a model has been proposed by Van Dell et al. (1994a) and it is a good candidate to be used in the present analysis.

The computation and optimization of the above mentioned design parameters can be accomplished in a cost effective way using Computational Fluid Dynamics (CFD) analysis. With CFD codes the flow field, temperature distribution, and species concentrations can be calculated at many discrete spatial points inside the reactor as well as temporal (or transient) variations. These primitive flow variables, in turn, can be used, by appropriate post processing to calculate integral design parameters of interest. The calculated design parameters along with the detailed information and virtual visualization of flow patterns can increase our understanding of the physical processes involved, and hence reduce the risk and the cost of experimental testing and/or validation.

2.0 PURPOSE

The primary objective of the proposed research work is to provide via computer simulations, needed design information such as gas residence time, temperature distribution, species concentrations, and heat and pressure losses for refining the proposed design and/or validation of the assumptions made during the design of sub-component of a cyclone melting system (CMS) currently under development by the Vortec Corporation. The analysis is to focus on specific needs for remediation of PCB contaminated soils. A secondary objective is to develop and implement a global kinetic model for the formation and destruction of selected PCB's such as *o*-dichlorobenzenes in conjunction with a readily available computational fluid dynamics (CFD) code. This model will rely upon experimental information available in the literature (see. e.g. Van Dell et al., 1994a, 1994b; Sethuraman et al., 1992; Ritter and Bozzelli, 1990; Tsang, 1990;). If successful, the proposed analysis will allow important enhancements for processing capabilities, and it will further reduce the development risk associated with commercial implementation of the CMS^{TM} technology.

3.0 BACKGROUND

An extensive research and development (R&D) program is being implemented by the Vortec Corporation with considerable funding from the Department of Energy(DOE) to provide waste processing equipment and services for industrial and institutional waste generators, and to manufacture glass and ceramic products from these waste materials. In particular, Vortec is planning to modify their existing high temperature waste processing and recycling units and retrofit it with appropriate units so that the system can be used for efficient remediation of PCB (PolyChlorinated Biphenyls) contaminated soils. This requires determination of optimum design parameters, such as residence times, heat loss, pressure drop, and size for each subcomponent of the system. The conceptual system consists of four interconnected sub-components, namely, a cyclone melting system (CMS^{TM}), separation reservoir, recuperator base (or residence chamber), and recuperator (see Figure 1). The gas residence time in each of these components is strongly dependent on the degree of turbulent mixing and the presence of recirculation zones. The time required for complete conversion of the PCB compounds is, in turn, depends on the residence time as well as the temperature distribution. The very complex nature of the particle laden flow within the above mentioned units requires the use of sophisticated computer simulations to obtain a detailed and accurate description of the flow field, temperature distribution, species concentrations as well as calculating the total heat loss and the overall pressure drop within each unit.

Although this study specifically targets the CMS^{TM} of Vortec Corporation, the end results could also be used, with minor modifications, in assessment of other type of incinerators for waste material. More importantly, this analysis can be extended to such cases where severely toxic and radioactive materials can be tested with computer simulations which would otherwise be impossible.

4.0 METHODOLOGY

The difficulties mentioned above can be resolved effectively using a readily available and extensively tested computational fluid dynamics (CFD) code. In this way, the PCB tracking can be done dynamically during the computation of the flow field where the local variations in the gas properties are automatically taken into account. Heat transfer and flow analysis, and PCB tracking will be performed using a commercial CFD code to numerically simulate the processes in the above mentioned units with the objective of providing supplemental information to improve the conceptual designs towards the most efficient system. Once such a code is reconfigured to simulate a certain unit, the key parameters can then be easily changed, and results can be obtained within a matter of days to determine optimum operating conditions.

The present computations are performed using the commercial code FLUENT (FUG-V4.3, 1995) This is a general purpose, multidimensional CFD code suitable for simulating flows in complex geometries. However, application to turbulent reacting flows is not

trivial. To achieve properly converged solutions, and to avoid misinterpretation of large amounts of numerical data, extreme caution and expertise both in physics of fluids and in computational fluid dynamics is necessary. Moreover, the chemistry sub-model for PCB tracking is not available in any of these codes. Such a model shall be developed and attached to the main code as a subroutine. It may be necessary to use the well known chemical kinetics code, CHEMKIN (Kee et al., 1980) and/or the general purpose chemical equilibrium code, CET (Gordon et al., 1984) in an interactive manner with the hydrodynamic data that will be obtained from the CFD code.

5.0 WORK PERFORMED THIS PERIOD

In this period, the computer codes to be used were reviewed. It was decided that FLUENT would be a better choice because of its availability at Vortec as well at Morgantown Energy Technology Center in addition to the Department of Mechanical Engineering. This should provide compatibility and continuity among collaborating institutions. Literature review on PCB reaction rates at high temperatures has continued. Vortec engineers have been consulted as to which unit would be their priority for computer simulations. The gas residence chamber (recuperator base) has been selected to be analyzed first.

The geometry of the recuperator base as supplied by Vortec has been incorporated into separate input files for FLUENT. Both axisymmetric geometry (i.e. with a continuous inlet slot around the circumference of the chamber), and three-dimensional geometry have been used. The same geometry was represented in cylindrical coordinates as well in boundary fitted coordinates. The results of these studies will help us determine which configuration gives us the best turn around time without loss of accuracy.

Some preliminary simulations have been performed for the recuperator base. Cases include high and low swirl case, axisymmetric, and three-dimensional geometry. All calculations are performed as a first approximation under high temperature isothermal conditions. The results are presented in the next section.

6.0 RESULTS AND DISCUSSION

The case specific data is listed in Table 1. The first two cases are for an axisymmetric, adiabatic, turbulent flow of 1 kg/s (1751 scfm) at a constant temperature of 1694 K (2590 °F) and pressure of 1 atm. The fluid is taken to be air. It is assumed that the flow is axisymmetric with a 0.457 m (18 inch) slot around the circumference of the unit. The actual inlet is a square inlet of size (0.457 x 0.457 m² or 18 x 18 in²). The swirl velocity at the inlet was taken to be 10 m/s (32.8 ft/s) for Case 01 and 19.69 m/s (62.3 ft/s) for Case 02. The actual radial velocity at the inlet is $V_r = 12.40$ m/s (= 40.68 ft/s) when converted to an equivalent axisymmetric slot the radial velocity reduces to 1.72 m/s (= 5.64 ft/s). The average axial velocity inside the chamber is approximately 1.6 m/s which yields approximately a swirl number of $S (= V_\theta/V_x) = 6.25$, and 11.9, respectively, for Cases 01 and 02. The angle between the tangential direction and the main flow direction at the inlet, $\beta = 32.2^\circ$

Case 03a and b are for a 3-dimensional geometry which simulates the actual inlet but the geometry does not have yet the converging and diverging sections. These cases were run only for the purpose of checking the assumption of axisymmetry. Hence, no attempt was made to match the actual geometry nor very closely.

Table 1 Case specific data

Case #	Air flow rate	Pressure	Temperature	Inlet Vel. Ratio (V_θ/V_r)	Comments
01	1.0 kg/s (1751 scfm)	1.0 atm.	1694 K (2590 F)	5.8	Isothermal turbulent axisymmetric flow of air; $\beta=32.2^\circ$
02	1.0 kg/s (1751 scfm)	1.0 atm.	1694 K (2590 F)	11.5	Isothermal turbulent axisymmetric flow of air; $\beta=32.2^\circ$
03a	1.09 kg/s (1910 scfm)	1.0 atm.	1694 K (2590 F)	0.43	Isothermal, 3D turbulent flow of air (the geometry is approximate); $\beta=66.75^\circ$
03b	1.0 kg/s (1751 scfm)	1.0 atm.	1694 K (2590 F)	0.81	Isothermal, 3D turbulent flow of air (the geometry is approximate); $\beta=32.2^\circ$

The gas residence time was calculated by tracking the concentration history of an (almost) instantaneously injected passive scalar in to the reactor at the inlet. The time variation of the scalar concentration of the outlet (which is also referred to as the "flow-through curve") is shown in Figure 2. In this figure various time scales are indicated on the curve. The minimum (or first arrival) residence time, $t_{\min} = 0.6$ sec, the time which marks the arrival of the peak concentration, $t_{\text{peak}} = 1.4$ sec. One can also define a characteristic time which is associated with the percent of mass which has flown through the reactor within that time from the start of the injection. The 98% flow through time, $t_{98\%} = 4.7$ sec, and $t_{50\%} = 1.86$ sec. These characteristic time scales give an indication of the turbulent mixing in this reactor when compared with the ideal plug flow residence time defined as

$$t_0 = (\text{volume of the reactor})/(\text{volume flow rate})$$

which is computed to be $t_0 = 2.17$ sec for this case.

Figure 3 shows the flow through curve information for Case 02. It is seen that this curve is very similar to that shown in Figure 2 except that the first arrival time and the peak concentration time are slightly less. The $t_{50\%} = 2.05$ which is slightly larger than that for Case 01. Hence one can conclude that under the current assumptions increasing the swirl would not improve the gas residence time much. One must be careful however, as explained later, the three dimensional nature of the flow could make a significant difference.

Figure 4 shows the calculated streaklines which are the same as streamlines for this steady flow situation. The streamlines are quite regular and do not show any unusual flow structure under the axisymmetric flow conditions, i.e. there is no recirculation zones or any dead flow zones.

All of the above results were obtained with the assumption of axisymmetric flow. This assumption needed to be tested. This was done by running a three-dimensional calculation under the same conditions as Case 01. It must be emphasized that these calculations were performed for a simplified geometry by neglecting the converging and diverging sections of the residence chamber (Figure 5). The contours of the swirl velocity shown on Figure 5 seem to indicate that near the inlet the flow has significant three dimensionality. Away from the inlet the circular shapes of the swirl velocity indicate a nearly symmetric flow condition. To see this picture quantitatively, the swirl velocity profiles are plotted as a function of the dimensionless distance ($= \theta / 2\pi$) in the tangential direction on crosssections at several axial locations. It is seen from Figure 6 that there seems to be a significant variation in the flow structure in all three directions. The flow seems to be fairly symmetric away from the centerline and away from the inlet. However, near the inlet and near the centerline the swirl velocity changes significantly as a function of the tangential distance meaning that the flow is not axisymmetric. This is an unexpected result, because intuitively one would expect the flow to become more axisymmetric as it moves towards the center. This unusual behavior can be explained by observing the velocity vectors (not

including the swirl velocity) on an axial-radial (x-y) plane (Figure 7). This figure shows clearly that the 3-dimensional calculations predict a recirculation zone in the bottom half of the chamber with a strong eddy approximately spanning the entire cross section of the chamber. This explains the unusual behavior of the swirl velocity near the centerline. Away from the inlet flow region (approximately the upper 2/3 of the chamber) the flow can be considered to be approximately axisymmetric. It should be noted that the flow rate for Case 3a is slightly larger than the actual flow rate of 1.0 kg/s. The tangential velocity component is 10 m/s (32.81 ft/s)

Figure 8 shows the velocity vectors (V_x , and V_r) for similar case but with $\beta=32.2^\circ$ (the angle between the tangential direction and the main flow direction at the inlet). The tangential velocity is still 10 m/s, and the flow rate is 1.0 kg/s. It is seen that the recirculation zone in the bottom third of the chamber is still present, hence this case will have also some significant 3-dimensional flow structure.

The observation mentioned above need to be further validated by calculating the flow through curve as well as particle residence times via Lagrangian dynamics. This will be performed in the next quarterly period for the actual geometry and the flow conditions. The flow may become more axisymmetric when a higher swirl velocity is introduced. This could inhibit the penetration of the inlet jet flow towards the center, but it may also increase the strength of the central recirculation region via rotational pressure gradient due to V_θ^2/r .

7.0 CONCLUSIONS

Preliminary flow analysis of the residence chamber (or the recuperator base) has been completed. Axisymmetric, turbulent, and isothermal flow of air at 1694 K (2590 F0) and 1.0 atm. as well as approximate three-dimensional calculations have been performed. The axisymmetric calculations show a well behaved flow pattern inside the chamber, with a residence time, $t_{50\%} = 1.86$ sec, and 2.05 sec for Cases)1 & 02 with swirl velocity ratios ($=V_\theta/V_r$) of 5.8 and 11.5, respectively. This in agreement with the plug flow residence time of 2.17 sec.

Three dimensional calculations showed considerable differences in the flow patterns compared to the axisymmetric cases. In particular, they showed the presence of a recirculation zone in the bottom third of the chamber which may change the residence time. The three dimensional flow patterns and the corresponding residence time are currently being studied. The results will be delivered in the next quarterly period.

8.0 WORK PLANNED FOR NEXT PERIOD

There has been a change in the order of execution of the tasks. After consultation with Vortec engineers, it was decided that it was more important to analyze the recuperator

base (or the residence chamber) first. This change is reflected in the following task list. The time for completion of Task 3 and 2 are also modified as shown below. Otherwise the work is on schedule.

Task 1. Information required for the National Environmental Policy Act

Task 2. (*1 month*) Gathering of system specific-information, e.g. geometry, gas composition, conceptual design criteria etc., in consultation with Vortec.

Task 3. (*5 months*) Analysis of the recuperator base (*old task 4*)

Task 4. (*3 months*) Analysis of the separator/reservoir (*old task 3*)

Task 5. (*2 months*) Analysis of the recuperator

Task 6. (*1 month*) Analysis of the results for the whole system and preparation of the final report.

In the next quarterly period work on Task 5 will continue. Three dimensional calculations for the actual geometry and the flow conditions will be performed. An empirical heat loss distribution will be introduced, and its effects on flow field and residence time will be investigated. If necessary modification to the current geometry will be considered to increase the gas residence time. The work will continue with calculation of conversion and destruction rates for selected PCB compounds.

VORTEC'S CMS SYSTEM

Figure 1. Vortec CMS™ System Sketch

Figure 2 Predicted flow-through curve for the recuperator base
(Swirl Velocity Ratio = $V_{\theta}/V_r = 5.8$)

Figure 3 Predicted flow-through curve for the recuperator base
(Swirl Velocity Ratio = $V_{\theta}/V_r = 11.5$)

Figure 4. Streamlines for Case 02

Streamlines for the RECUPERATOR BASE
(Inlet Velocity Ratio = 11.5)

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2.90E+01

2.68E+01

2.46E+01

2.25E+01

2.03E+01

1.81E+01

1.59E+01

1.38E+01

1.16E+01

9.44E+00

7.27E+00

5.10E+00

2.93E+00

7.62E-01

-1.41E+00

-3.58E+00

Figure 5. Swirl Velocity Contours for Case 03

VORTEC RESIDENCE CHAMBER: 3D

Swirl Velocity (m/s) Contours

Max Swirl Vel. = 29.0 m/s; Min Swirl Vel. = -3.6 m/s

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(a) Swirl Velocity profiles at $x = 0.35$ m ($k = 5$)

(b) Swirl Velocity profiles at $x = 0.76$ m ($k = 10$)

Figures 6(a) and 6(b)

(c) Swirl Velocity profiles at $x = 1.84 \text{ m}$ ($k = 20$)

(d) Swirl Velocity profiles at $x = 3.60 \text{ m}$ ($k = 35$)

Figures 6(c) and 6(d)

6.00E+01
 5.79E+01
 5.58E+01
 5.38E+01
 5.17E+01
 4.97E+01
 4.76E+01
 4.55E+01
 4.35E+01
 4.14E+01
 3.93E+01
 3.73E+01
 3.52E+01
 3.31E+01
 3.11E+01
 2.90E+01
 2.70E+01
 2.49E+01
 2.28E+01
 2.08E+01
 1.87E+01
 1.66E+01
 1.46E+01
 1.25E+01
 1.04E+01
 8.38E+00
 6.31E+00
 4.25E+00
 2.18E+00
 1.19E-01

Figure 7. Velocity Vectors for Case 03 (a)

VORTEC RESIDENCE CHAMBER: 3D

Velocity Vectors (M/S)

Lmax = 5.998E+01 Lmin = 1.193E-01

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5.23E+01
 5.05E+01
 4.87E+01
 4.69E+01
 4.51E+01
 4.33E+01
 4.15E+01
 3.97E+01
 3.79E+01
 3.61E+01
 3.43E+01
 3.25E+01
 3.07E+01
 2.89E+01
 2.70E+01
 2.52E+01
 2.34E+01
 2.16E+01
 1.98E+01
 1.80E+01
 1.62E+01
 1.44E+01
 1.26E+01
 1.08E+01
 9.05E+00
 7.25E+00
 5.45E+00
 3.65E+00
 1.85E+00
 4.86E-02

Figure 8. Velocity Vectors for Case 03 (b)

VORTEC RESIDENCE CHAMBER: 3D

Velocity Vectors (M/S)

Lmax = 5.225E+01 Lmin = 4.855E-02

Apr 08 1996

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APPENDIX

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SITE REMEDIATION TECHNOLOGIES

DRAIN-ENHANCED SOIL FLUSHING (DESF) FOR ORGANIC CONTAMINANTS REMOVAL

TASK 1.2

Quarterly Report XIV for Period
January 1 through March 31, 1996

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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March 1996

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1.0 INTRODUCTION

Work on this project is conducted to investigate the use of Prefabricated Vertical Drain (PVD) systems for remediation of contaminated sites with fine grained soils. PVD systems are relatively simple in operation and installation. They require no drilling rig equipment and are expected to significantly reduce remediation and installation costs, and at the same time increase the efficiency of the remediation effort.

The use of PVDs in the current state of practice has been in the area of soil improvement. Other than the work performed in the first phase of this project, no research work has been conducted to investigate the feasibility of using PVDs for enhanced soil flushing.

2.0 PURPOSE

The main objective of this research phase is to investigate major parameters influencing the efficiency of contaminant extraction using PVD systems. Research in this phase is focused on conducting bench-scale tests with soils for simulation of in situ conditions. Specific objectives are as follows:

1. Development of the equivalent diameter for in situ characterization of the PVDs;
2. Investigating the effect of smear and well resistance on the hydraulic efficiency of the PVDs, and
3. Investigating the method of installation and its effect on the recovery efficiency of the PVD system.
4. Full development and Beta testing of the PVDs' contaminant transport model developed in Phase I.
5. Field demonstration program and testing, cost analysis, and performance of the recovery process using the PVDs.

3.0 BACKGROUND

The PVD system is used to shorten the drainage path of the groundwater flow and therefore promote subsurface liquid movement and expedite the soil flushing process in low permeability soils. Proved technologies exist for the in situ soil flushing for sites with granular soils (hydraulic conductivity approximately 1×10^{-2} cm/s). However in the case of sites where the soil is fine-grained with corresponding hydraulic conductivity ranging 1×10^{-3} to 1×10^{-7} cm/s, implementation of the traditional soil flushing technology is ineffective and cost prohibitive.

In the previous phase of this project progress was advanced along the following three fronts:

1. Contaminant and Soil Characterization: A study soil was developed and categorized in accordance with ASTM standards. The testing program included column and batch studies on contaminated soils with the study surfactant being anionic aqueous solution of sodium dodecylsulfate.
2. Injection/Extraction Flushing Concept: Several pilot scale Contaminant Recovery Cells (CRCs) were used to evaluate the flow characteristics of the soils sampled and the concept of using PVDs. Soil samples were prepared in the CRCs and PVDs were installed in rectangular and circular configurations.
3. A predictive model for PVD enhanced soil flushing was developed. The model was developed assuming full saturation and no diffusion or decay. Parameter studies were performed to predict soil flushing rates using a PVD system.

4.0 METHODOLOGY

Two different laboratory experiments were setup during this reporting period, 1) Pilot scale testing device for evaluation of Equivalent Diameter and Zone of Influence on field scale PVDs, and 2) Prototype of PVD field connection was constructed. The details of these experiments are discussed below.

Equivalent Diameter and Zone of Influence on Field Scale PVD

The equivalent diameter and zone of influence of the field scale PVD was evaluated using the apparatus shown in Figure #1. This apparatus was developed to observe the PVD drawdown cone of depression in the study soil for 100 mm wide PVDs, which are typically used in the field. A lab scale PVD connection was evaluated for extraction flowrate efficiency. The study soil was a mixture of Ottawa sand and kaolinite clay.

The soil was first compacted in the apparatus at a relatively low density and moisture content ($\gamma_d = 1.65 \text{ g/cm}^3$, $\omega = 5\%$). The PVD was then pushed into the study soil hydraulically, and piezometers were installed as shown in Figure #1. The soil was saturated, and a vacuum was applied to the PVD. The water table was monitored around the PVD, and the flowrate from the PVD was also recorded. At least two vacuum extraction pressures were evaluated for drawdown cone of depression and flowrate. Experimental results are discussed in Section 6.0.

Figure #1 - Field Scale PVD Testing Device

PVD Field Connection

This connection, shown in Figure #2, was constructed for use in a field application. Design considerations included that the connection be simple to construct in the field. Materials consist of CPVC piping, polyfilm tubing, and stainless steel band clamps. Tools consist of a cordless trim saw, a cordless drill, and a pair of sharp scissors.

5.0 WORK PERFORMED THIS PERIOD

Work performed during this reporting period included the following tasks:

1. Experimentation on the Equivalent Diameter and Zone of Influence on field scale PVD.
2. Design and construction of PVD field connection
3. Obtaining and evaluating a site for the Field Demonstration.

Equivalent Diameter and Zone of Influence on Field Scale PVD: Characterization of the PVD for use in the Field Demonstration site. Experiments performed were directed at determining the Equivalent Diameter and Zone of Influence of field scale PVDs. PVD installation in the study soil was done to simulate the field installation technique. At least two different vacuum extraction pressures were applied to the PVD, and the cone of depression around the PVD, as well as, the extraction flowrates were monitored during testing.

PVD Field Connection: Design and construction of a PVD field connection which can be fabricated easily in any field setting. Tools and materials needed to implement this connection can be obtained easily. Testing is still in progress on the efficiency of this connection, however, preliminary tests were done to locate and remediate vacuum losses.

DESF Field Demonstration Plan

A site located in Weston, WV was chosen for the Field Demonstration Phase of the project. This site is owned by Ashland Oil Company. We have met with Ashland concerning the use of their facility for the Field Demonstration. We also met with the Nilex Corporation who agreed to install the PVDs to our specifications at the site in Weston, WV.

Figure #2 - PVD Field Connection

6.0 EXPERIMENTAL RESULTS AND DISCUSSION:

Equivalent Diameter and Zone of Influence on Field Scale PVD: Sample results of the cone of depression developed for the study soil used are shown in Figure #4. Refer to Figure #1 for piezometer locations and distances. An evaluation of Figure #4 indicates that the Zone of Influence is a radial distance of approximately 70 cm. This is important when determining PVD spacing in the field. Also, the Equivalent Diameter was calculated as being 6.4 cm.

7.0 CONCLUSIONS

The laboratory experiments performed on the field scale PVD yielded important information needed in the design of the system to be used in the Field Demonstration site. The simple design of the PVD field connection will be invaluable to the implementation of this technology in the field.

8.0 WORK PLANNED FOR NEXT PERIOD

Tasks to be performed for the next reporting period include testing the efficiency of the PVD field connection under vacuum extraction pressures and injection pressures. Further evaluation of the field site, as well as, preliminary design of the PVD system.

Figure #3 - Field Scale PVD
 Average Drawdown vs. Piezometer Spacing Distance

- a). Piezometers 1 - 6
- b). Piezometers 7 - 12
- c). Piezometers 13 - 18
- d). Piezometers 19 - 24
- e). Piezometers 25 - 30

**PERFORMANCE AND CHARACTERISTICS EVALUATION
OF
ACRYLATES AS GROUT BARRIERS**

**METC Task No. 1.3
(Chemical Grout Barriers)**

PROGRESS REPORT
Reporting Period: January 1, 1996-March 15, 1996

Work Performed Under Contract No.
DE-FC21-92MC29467

For:
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, WV

Department of Civil and Environmental Engineering
West Virginia University
Morgantown, WV 26506

Evaluation of Acrylate Grouts for Subsurface Containment of Wastes

Abstract: A significant effort in the U.S. and the world is undertaken to develop remediation technologies for contaminated soils and waters. However, in some cases a permanent technology in response to some urgent environmental problems is yet to be developed. For this situation, a temporary barrier may be needed to retard the advancement of the plumes until a permanent remediation technology is implemented. As a result, extensive research is being conducted to evaluate the feasibility of using permeation grouts to develop subsurface containment/confinement systems to retard, or even prevent, the advancement of subsurface contaminant plumes.

A research program was conducted to assess the effectiveness of a urethane (Scotch-Seal (TM) Chemical Grout 5610 Gel manufactured by 3M Company) and a vinyl monomer (Duroseal^{TM} manufactured by Beton-Bau-Zubehor (BBZ) of Germany) grout in controlling the subsurface migration of waste. The study was carried out on the laboratory scale, and was intended to evaluate the chemical grouts ability to create a low-permeability barrier when injected into the soil and develop standard grout evaluation and testing protocols.

The experimental program was implemented in four phases: a) Grout Development, b) Performance Testing, and c) Grout Testing Chamber. The first phase included the evaluation of the grouts' properties and development of viable mix ratios. The second phase of the experimental program aimed at examining the feasibility of injecting the urethane grout into a uniformly graded Ottawa sand (i.e., groutability) in large diameter (29.2 cm), acrylic columns. Samples were collected from the grout bulb and subjected to additional testing which yielded results on the grouted-sands hydraulic conductivity, compressive strength, and durability under permeation and immersion

with various classes of chemicals. Phase 3 involves the design and construction of the Grout Testing Chamber (GTC) (essentially a 91.4 cm flexible-wall permeameter) and manufacture of a sand rain device to prepare uniform specimens for the GTC. The first phase of the study resulted in four urethane mixes and one vinyl monomer mix being developed for the next phase. All the urethane mixes were 10:1 (activator:gel) ratios; however, the mix additives varied. The vinyl monomer mix was comprised on 50% water and 50% gel concentrate.

Results from the second phase indicated that two of the urethane grout mixes could be easily injected into the Ottawa sand at its porosity extremes. Additionally, the larger the perforation size and perforation length on the injection probe, the larger the resulting grout bulb and bulb radius. Samples collected from the injected bulbs yielded hydraulic conductivities (k) of 2.4×10^{-7} cm/s with water and significantly increased when using chemical permeants. Grouted-sand samples from both of the grout mixes swelled excessively and decreased in strength when immersed in water, bases, and ethylene glycol solutions. Cupric sulfate, methanol, acetone, and acids appeared to have few observable affects on the samples.

The GTC was designed and is currently under construction. Additionally, a sand rain device was designed and manufactured to produce uniform density specimens for the GTC. It is currently being calibrated.

Within this paper, testing methodologies, data, and results from each phase of the experimental program are presented.

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1.0 INTRODUCTION

There is a significant effort in the U.S. and the world to develop remediation technologies for contaminated soils and waters. For some contaminated medias, no technologies are feasible or fully developed to meet today's environmental problems. For example, radioactive contaminated soils are impossible to treat with current technologies. Only waste minimization/segregation techniques are applicable which results in a highly concentrated (i.e., radioactive) residual material. Because of the lack of treatment methods, confinement and containment technologies are needed to retard, or even prevent, the advancement of subsurface contaminant plumes into the environment until the development of appropriate remediation technologies are identified and implemented.

There are numerous confinement/containment (C/C) methods available in today's market. Though these techniques are fully capable of preventing lateral migration of contaminants in soil and water, longitudinal migration of contaminants is generally not suppressed or retarded. One method that appears suitable for developing both vertical cut-off walls and/or horizontal bottom barriers is permeation (injection) grouting utilizing chemical grouts which is defined as the process of filling small interstitial voids and fissures in rock or soil (Karol 1990). If permeation grouting is proven to be preventative measure (i.e., secondary containment), as well as a post-release alternative, it could potentially be utilized at numerous sites (Superfund and RCRA) throughout the country.

Because of the potential benefits of this technology and the large number of sites where it could be implemented, research was conducted at West Virginia University to evaluate two chemical grout's effectiveness and applicability as a subsurface barrier. Unlike prior and other current studies, instead of immediately advancing from the lab-scale grout investigation to field scale injection testing, a meso-scale testing program was developed to investigate the material Injectability. Two types of chemical grouts were evaluated for barrier use: Duraseal™ (a vinyl monomer compound from Germany) and Scotch-Seal (TM) Chemical Grout 5610 (a urethane gel product manufactured by 3M). Both grout materials were evaluated on their ability to form in-situ barriers (i.e., injectability/viscosity), toxicity, resistance to chemical degradation, strength properties, and permeability. The research work was divided into the following tasks:

- I. Grout Development
- II. Performance Testing
- III. Grout Testing Chamber (GTC)

Grout Development involves the identification of the grout mix ratio which exhibits the optimum properties for use as a subsurface barrier. Performance Testing utilizes large diameter acrylic columns to investigate the injectability of the grout into Ottawa sand using different grout mixes and varying injection strategies. The structural and hydraulic performance of the formed barrier is also evaluated by performing immersion/strength testing (triaxial and unconfined compression) and permeability testing on samples collected from the grouted-sand bulb. Task III involves the design and construction of the Grout Testing Chamber (GTC), essentially a large-scale flexible wall permeameter with 3 feet diameter specimens which will be capable of simulating in-situ stress conditions. A sub-task was the development of a device and method for preparing specimens of a uniform density which can be accomplished through the use of a sand rain device.

2.0 EVALUATION OF A URETHANE GROUT FOR CONTAINMENT OF WASTES

2.1 Purpose

This research presented in this section was performed to successfully fulfill the requirements of Task I (Grout Development) and Task II (Performance Testing). Only urethane grout is performance is currently being pursued. The objectives of this research program are to establish grout testing protocol, evaluate grout performance, and determine grout characteristics for several injection strategies.

2.2 Background

Although the principles of permeation grouting were developed in the 1940's and numerous companies are in existence which specialize in this practice, none have utilized permeation grouting for waste containment. Past field studies (May et al. 1986, Dwyer 1994, Moridis 1995) conducted to evaluate subsurface barrier characteristics have identified the need for a barrier verification technique. A limited number of research programs (Bodocsi et al. 1988, Bodocsi et. al. 1991, Carson 1988, Heiser et al. 1992, Sherer 1986) have investigated the properties of various types of chemical grouts which make them amenable as a subsurface barrier. At present, there is a considerable amount of research being conducted on this topic at government facilities.

The urethane grout evaluated in this research was supplied by the 3M Company under the trade name Scotch-Seal (TM) Brand Chemical Grout 5610 (Gel). This was chosen after reviewing the product literature and past studies as well as discussing the grout's capabilities with various distributors and manufacturers with research objectives in mind. Furthermore, 3M defines Scotch-Seal (TM) as groutable. The 5610 gel is a hydrophilic material most commonly used for sewer and water line rehabilitation projects.

2.3 Methodology

The experimental program of this investigation was performed to develop a standard testing protocol to evaluate the performance (i.e., durability, hydraulic conductivity, and strength) of permeation grouts. Experimental testing was implemented in two phases: a) Materials Testing Phase and b) Performance Testing Phase. The first phase consisted of testing material properties which included: moisture content (ASTM D 2216), specific gravity (ASTM D 1429), minimum and maximum densities (ASTM D 4254 83 and D 4253 83), and triaxial compression (ASTM D 2850). Additionally, the permeability the material was determined using a rigid wall permeameter conducted in accordance with ASTM Draft Standard Test Method for Measurement of Hydraulic Conductivity Using a Rigid Wall, Compaction-Mold Permeameter. Performance testing examined the injectability (groutability) of the grout in large diameter columns and Post-grout testing (permeability testing, immersion testing, and strength testing).

2.4 Work Performed this Period

Work performed during this reporting period included the following tasks:

1. Urethane grout injections into large diameter (11.5" I.D.) columns
2. In column permeability tests on injected grout
3. Flexible wall permeability test on saturated region of grouted sample

During this period the urethane grout has been injected into six of the 11.5" diameter acrylic columns containing 20-30 sand at minimum density with a grout to gel time extender ratio of 1:10. Once the grout was allowed to cure for 24 hours, three of the columns were filled with a 0.1M NaOH solution and three of the columns were filled with a 0.1M HCL solution. These columns were then sealed and pressurized to 2.5 psi. The test continued for over 60 days and during this time, neither of the permeates infiltrated through the grouted region. Only a slight saturation of the first 4 cm was observed.

Since the chemical solutions did not permeate through the sample as anticipated, the columns were disassembled, the permeates were disposed of, and a sample of this saturated layer was taken from each column using a Shelby tube. In order to determine the hydraulic conductivity of this layer, flexible wall permeability tests are now in progress using water as the permeate.

2.5 Results and Discussion

Four samples were taken from the 0.1M HCL and the 0.1M NaOH saturated layers (two from each). These samples were then placed in a flexible wall permeameter for testing. The average resulting hydraulic conductivity from the HCL saturated layer was $5.1\text{E-}7$ cm/s. The tests on the NaOH layer are still in progress, but the average running hydraulic conductivity is $2.8\text{E-}8$ cm/s.

2.6 Conclusions

The results from the flexible wall permeability tests show that the thickness of the grouted region in the columns is much too large. There is a large amount of grout that serves no purpose in the function of the barrier and is therefore wasted.

2.7 Work Planned for next Period

Tasks to be performed next period include modifying the injection process to minimize the thickness of the grouted region to about 4" and to effectively reduce the height that the grout travels longitudinally in the sand. By increasing the gel time of the grout, the flow rate at which the grout is injected can be decreased. This should allow the grout more time to travel uniformly through the sand in the transverse direction and minimize the overall height of the grouted region. We also plan to resume testing with the vinyl monomer grout in different soil compositions

3.0 SAND RAIN DEVICE

3.1 Purpose

The grout testing chamber (GTC) is to be used to test grout characteristics on a larger or meso-scale to reproduce field conditions. This is to observe the effects of multiple injection wells on barrier formation and grout performance in this environment. Obviously, a large soil sample is needed to execute such an experiment. The sand rain device will be able to deliver such a sample at a uniform and desired relative density.

3.2 Background

Hydraulic conductivity is the soil characteristic that is believed will most affect the grout's performance. Sand was chosen as the soil for grout performance testing since it has a very high hydraulic conductivity and represents the worst case scenario for barrier formation in non-fractured soil. Controlling the value of hydraulic conductivity can be done by fixing the relative density of the test specimen.

Fabricating such sand specimens, especially on a large scale, presents a few obstacles, because guaranteeing a homogenous sample on any scale is difficult without automation. ASTM offers methods for finding the maximum and minimum densities that are adequate for relatively small sand samples, but are both impractical and inaccurate for large scale samples. Therefore, testing grout performance on meso-scale sand specimens dictates the need for a device. This can be done by constructing an apparatus that is able to insure the following in large scale test specimens:

- they must have the requested relative density
- they must have properties that are reproducible independent of the operator
- they must be homogenous

Although such a device is not commercially available, success has recently been realized by a handful of researchers in creating a machine to produce large-scale, homogenous sand samples. The machine they designed is called a sand rain device.

3.3 Methodology

The most important considerations for the design process were cost, durability, and the practical limitations of the technician employed to perform the actual construction. With this in mind sand rain device was designed much like those in the literature. Normally the upper sand reservoir allows flow out through a stopcock and funnel assembly. The sand rain device at WVU has dual perforated plates in place of this assembly to better facilitate dispersion. A scale drawing of the final design can be seen in FIG 3.1.

3.4 Work Performed this Period

Work this period has taken place in four different areas. They are: ASTM sand density tests, construction of the funnel platform, large scale radial homogeneity testing, and performance

SAND RAIN DEVICE

FIG 3.1. Scaled Drawing of the Sand Rain Device

enhancement.

In order to help predict the behavior of the sand specimens in the GTC, small scale density tests were performed according to ASTM D 4254 83 and D 4253 83 tests for maximum and minimum relative density. These values were plotted versus various water contents and normalized by calculating the corresponding dry densities. Preliminary results of these tests are shown in FIG 3.2.

Density Curves for Uniformly Graded Ottawa Sand

FIG. 3.2. Preliminary Results of Density Tests

The funnel platform was to serve a dual purpose. One was to allow sand to be funneled into trough so that refilling could be done more efficiently using gravity to fill five gallon buckets. The other was for it to serve as a base for the sand rain device. Work on the base has been nearly completed and all that remains is attaching legs and a locking mechanism on the doors. As a base for the device to rest upon, the construction is working out nicely. However, the remainder of the work has been temporarily suspended to carry out other tasks associated with the device as explained below.

Testing the radial homogeneity of the sand samples formed by the device has also begun. This is an important test since it is a measure of the quality of the sample. It is done by placing a series of containers with known volumes at the bottom of the sample mold which in this case are standard concrete testing molds. The sand is rained into these containers which are then weighed and the various densities are then calculated. Ideally these values are consistent throughout the sample and vary according to the mass flow rate and the drop height. Unfortunately, the nature of this test doesn't lend itself to the use of the funnel platform. This test was more critical to the project than completion of the platform and thus the delay in completion.

It became apparent after several of these calibration tests, that the sample wasn't uniform in the radial direction. The sand's surface level was noticeably higher toward the plate adjustment screw. After some observation, it became evident that the raining sand streams were all offset toward the screw and enough sand was falling between the edge of the mold and the diffuser assembly to cause the observed height differential. This was confirmed by rotating the device relative to the mold and raining in several different positions.

The possible causes were investigated as follows. The floor was level as was the diffuser

FIG 3.3. Offset Sand Flow Illustration

assembly with respect to it. And although the plates were not perfectly aligned with respect to the aperture area for mass flow, differences amounted to less than 1/16 of an inch at most. This difference was not enough to be a factor in the large height differential. Upon further investigation, it was discovered that the problem tended to be less pronounced the more the aperture was widened. What is believed to have happened was the sand stream was actually shifted by the unaligned plates so that it was thrown horizontally toward the screw as is illustrated in FIG 3.3. When PVC pipes of the same inside diameter as those in the bottom plate were attached to it to guide the flow vertically, the offset distance was again decreased which seemed to confirm the theory. It was still not enough to completely correct the problem however.

To eliminate the offset and to guide the flow correctly into the diffuser assembly, it was decided to construct a series of guides that would be suspended beneath the movable plate and aligned with the fixed plate. The guides are made of 1 inch PVC that are held in place by wooden struts placed in rows and attached via screws to the fixed plate. This of course required slots to be cut into the movable plate. An illustration of the guide assembly is shown in FIG 3.4.

FIG 3.4. Corrected sand flow illustration

3.5 Results and Discussion

Some unforeseen difficulties were encountered as related above. It would have been difficult to predict the stream offset since it was ultimately caused by an innovation in the design of such a device. Right now, the slots and mounting screws and all the metal work is done. The wooden struts are midway to completion as are the PVC guides. Though the metal work was difficult, the woodwork should go much faster comparatively.

3.6 Conclusions

Though progress is slower than expected due to the time and energy required in discovering the cause of the stream offset problem, the eventual solution, and the fabrication and metal work required because of that solution; the care taken in construction is expected to pay off with the completion of the guide assembly since it appeared to be the only problem encountered during the actual raining process.

After the guides are in place, there should be nothing further to inhibit the continuation of the homogeneity testing. Testing and calibration would then be finally completed and the device made ready.

3.7 Work Planned for next Period

Further radial and longitudinal uniformity testing will begin once the guide assembly is mounted and ready. With the completion of those tests the sand rain device will be ready to form samples for the GTC.

3.8 Technical/Administrative Difficulties

There are no difficulties to report at this time.

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**DEVELOPMENT OF STANDARD TEST PROTOCOLS AND DESIGN MODELS FOR
DESICCATION BARRIERS
METC Task No. 1.4**

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ABSTRACT

Significant research effort is currently being conducted in the United States and the world for remediation of contaminated soils and groundwater. In parallel to remediation efforts, confinement technologies are needed to retard, or even prevent, the advancement of contamination plumes into the environment until the implementation of remediation efforts is completed. Research proposed herein aims at developing and investigating containment/confinement technology using desiccation for in situ formation of barriers.

The desiccant barrier proposed to be investigated will be the recently developed circulating air barrier (CAB). The CAB utilizes the injection of dry gas (air, nitrogen, CO₂, etc.) to create an ultra dry zone in situ; beneath or adjacent to the zone of contamination. The CAB relies on the removal (drying) of in situ liquids (water) so that any contaminating liquids entering the zone of desiccation must replace the previously removed liquids before the contaminants can migrate further. In field application, the CAB may be established by means of specific patterns of vertical or horizontal (or a combination of vertical and horizontal) injection and withdrawal wells which enable the injected dry gas to travel through and dry the formation prior to exiting via a withdrawal well.

This research will be conducted using laboratory and meso-scale setups. In addition to conventional laboratory equipment proposed research will utilize a large scale reactor for simulating in situ conditions. Conducting the research based on a meso-scale setup will minimize problems associated with scale effects. Such problems are usually encountered when a method is developed in the laboratory with no considerations given to correlation of laboratory scale results to field implementation. The B-17 facility in METC with its infrastructure will be utilized to conduct the proposed work. The proposed experimental methodologies will simulate field conditions and should provide laboratory data to test and enhance predictions of CAB performance made by existing models and computer simulations.

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EXECUTIVE SUMMARY

This study aims at developing and investigating containment/confinement technology using a "Circulating Air Barrier (CAB)". The CAB utilizes the injection of dry air to create an ultra dry zone in situ; beneath or adjacent to the zone of contamination. The CAB system can provide many advantages, however, there are no laboratory data or CAB field performance data available in the literature. There are however a number of issues that must be settled before it can be decided if CAB technology is applicable. Key among these issues are the influence of the soil characteristics (such as porosity, permeability, water saturation, grain size distribution, and clay content) on the drying profile. This research will be conducted using laboratory and meso-scale setups to evaluate the soil characteristics influence on CAB performance and will determine the effects of flow and sweep efficiency for fixed and mixed grain size soils. These experiments will validate and/or improve model predictions of system behavior and drying profiles of different soil types.

Sand-packs are being utilized for bench-scale testing to determine the relationship between soil characteristics and in situ barrier quality. Sand-packs are being calibrated to determine porosity, permeability, and saturation characteristics. The soil characteristics will be varied by changing grain size and sorting of the pack materials. A detailed CAB vessel assembly has been designed and been approved for experimental studies at B-17 facilities. The procurement of materials and fabrication of the assembly is in progress by EG&G at METC. Additional laboratory tests on core samples have been undertaken to evaluate the influence of porous media on air-water equilibrium and mass transfer.

1.0 INTRODUCTION

Many contaminated subsurface sites can not be economically decontaminated because of the limitations in technologies for decontamination. In such cases, containment becomes the primary technology for environmental protection. For non-excavatable sites, in situ containment is the most viable approach for preventing further spread of contamination. Different approaches for achieving in situ containment have been proposed, however, the study herein is focused on the evaluation of in situ barriers created by soil desiccation.

The desiccant barrier proposed to be investigated is the recently developed (1,2) Circulating Air Barrier (CAB). The CAB utilizes the injection of dry gas into a porous media to create an ultra dry zone in situ by removing water and reducing the water saturation below the level required for liquids to flow in order to prevent migration of underground contaminants. The CAB, once established, will also provide a means of monitoring and removing contaminants entering the zone. The proposed experimental methodology should provide laboratory data to test and enhance predictions of CAB performance made by existing models and computer simulations.

2.0 PURPOSE

The concept of the Circulating Air Barrier was conceived (1,2) to solve the subsurface contamination problems at the Hanford site used by the former Atomic Energy Commission. The references to CAB (1,2,3) are mainly related to CAB as a concept, and no field or laboratory data is available in the literature. The previous studies (1,2) concluded that a CAB system provided many advantages, however, the concept needs to be demonstrated to develop data necessary for scale-up and regulatory acceptance.

Among issues that must be settled before it can be decided if CAB technology is applicable to all DOE sites are the influence of the soil characteristics (such as, porosity, permeability, water saturation, grain size distribution, and clay content) on the drying profile and CAB performance. The laboratory study to be undertaken will evaluate the soil characteristics influence on CAB performance and will determine the effects of flow and sweep efficiency for fixed and mixed grain size soils. These experiments will validate and/or improve model predictions of system behavior and drying profiles of different soil types.

3.0 BACKGROUND

The Circulating Air Barrier (CAB) system is a desiccant-type barrier designed to prevent the movement of liquid contaminants toward groundwater, using air circulation and a processing system to lower water saturation in a targeted subsurface zone. The concept of Circulating Air Barrier was introduced in a study (1) that evaluated the barrier systems that could be installed beneath and around the tank farms with a minimum of excavation at DOE's Hanford Site. The CAB can be installed using either vertical or horizontal wells, establishing a pattern of air injection and extraction wells. The moving air vaporizes water in the zone and carries the water vapor to an extraction well. In time, circulation of the air reduces the water saturation in the swept interval, and continues to remove, by evaporation, liquids that move into the zone such as a leaked plume. No liquids can flow through this interval until a critical saturation is achieved, a saturation level that is well above the initial saturation. In the event that a leak occurs, the CAB system serves as a tool for early leak detection and provides a means to withdraw volatile contaminants for surface treatment. The study concluded that CAB system provided many advantages including non-physical confinement, active monitoring and leak detection, commercially available oil and gas technologies and equipment, emergency response and rapid deployment capability, and high potential for integration with other remediation technologies. However, the concept needs to be demonstrated to develop data needed for scale-up and regulatory acceptance.

A follow up study by K&M/BDM (2) which addressed modeling, cold test design, and surface processing and control design for the CAB demonstration at Hanford concluded that several issues must be settled before it can be decided if CAB technology is applicable to all DOE sites. Key among these issues is the influence of the soil characteristics such as porosity, permeability, water saturation, grain size-distribution, and clay content on the drying profile and CAB performance. This report further recommended a laboratory study to be undertaken to evaluate the soil characteristics influence on CAB performance and to find out the effects of flow and sweep efficiency for fixed grain-size and mixed grain-size soils. This would also serve to validate and/or improve model predictions of system behavior and drying profiles of different soil types. In addition, a range of geologic and climatic environments within which the CAB could successfully operate, baseline equilibrium moisture curve for a specific grain-size, and relative humidity for a specific temperature could be determined.

4.0 METHODOLOGY

Experimental procedures will be developed to address the problem of evaluating a desiccant barrier, i.e., a barrier based on creation of a dry zone of earth beneath a contaminated zone to store contaminating liquids, thus preventing their further migration. Two phases of experimental research are proposed in this study. The B-17 facility in METC with its infrastructure will be utilized to conduct the proposed work. The first phase deals with bench-scale experiments using laboratory setups. The second phase will deal with a meso-scale setup that will utilize large tanks for simulations of in situ conditions in order to minimize problems associated with scale effects.

Bench-scale testing of the CAB process parameters will utilize sand packs to determine the relationship between soil characteristics and in situ barrier quality. Sand packs will be calibrated to determine porosity, permeability, and saturation characteristics. The soil characteristics will be varied by changing grain size and sorting of the pack materials. Residual water saturation of the pack will be established by first saturating the pack with water and then desaturating the pack by injection of water-saturated air. The pack will then be dried at various rates of air injection to determine drying characteristics as a function of rate, remaining water saturation, and soil characteristics. The final phase of sand pack testing will be to resaturate the packs with simulated contaminant fluids injected at low pressure (near atmospheric) at the top while monitoring any effluent at the bottom. This will allow determination of contaminants migration rate as well as total storage capacity of the packs.

Meso-scale performance testing will be used to investigate the effectiveness of the CAB system in containment/confinement of the study waste under simulated field conditions. The meso-scale tests of the CAB system will utilize large rectangular tanks in DOE/METC's B-17 building to create a three-dimensional test bed to verify, refine, and extrapolate the results of sand pack experiments to field like conditions. The tanks will be filled to a desired depth by slurring sand of predetermined grain size range into the tanks with water. All or part of bed will then be desaturated, dried, and "contaminated" with a safe liquid to simulate the CAB process on the meso-scale. Instrumentation and sampling ports and tubes will be placed in strategic locations in or at the tanks to monitor the status of the CAB.

5.0 WORK PERFORMED THIS PERIOD

5.1 Task 1: SARS Activity

A draft of the 'Project Operating Plan' has been completed and will be submitted as per the "Process Safety Committee Handbook, part 6. Operating Permit: New Request, subpart f. Project Operating Plan."

A draft of the 'Operating Procedure' has been completed and will be submitted as per the "Process Safety Committee Handbook, part 6. Operating Permit: New Request, subpart g. Operating Procedure." This includes (g-1) Safety Precautions, (g-2) Material List, (g-3) Pre-Run Procedures, (g-4) Start-up Procedures, (g-5) Operating Procedures, (g-6) Shut-down Procedures, (g-7) Emergency Procedures, and (g-8) Training Plan.

A draft of the 'Risk Assessment' has been completed and will be submitted as per the "Process Safety Committee Handbook, part 6. Operating Permit: New Request, subpart i. Risk Assessment."

The CAB vessel assembly component parts were re-drawn to scale and these drawings will be submitted as per the "Process Safety Committee Handbook, part 6. Operating Permit: New Request, subpart p. Drawings."

5.2 Task 2.1: Literature Review

A comprehensive literature review relative to CAB was conducted and completed during previous quarters and reported earlier.

Additional literature searches relative to procedures and instrumentation for measuring and monitoring air humidity, soil moisture, and permeability have been completed. The key issues in the selection of the instruments are those relative to the accuracy necessary for acceptable measurement and data acquisition while minimizing intrusion in the sand pack or CAB bed.

Based on an in depth investigation of instrumentation manufacturers products and cost effectiveness; sensors/transmitters, electronic packages, and a data acquisition system have been selected, ordered, and received which should adequately provide accurate data and should also have application in the larger scaled experiments to be performed in the METC building B-17.

A comprehensive literature review relative to air-water mass transfer in porous

media is in progress to establish the foundation for sand pack drying experiments.

5.3 Task 3: Laboratory Equipment and Preliminary Testing

With receipt of the completed CAB vessel assembly, several chambers have been calibrated and the previously determined methodologies for sand compaction have proceeded with these chambers (Figure 1). Compaction tests to determine the optimum water saturation for compaction of 20/30 mesh size sand (Figure 2) and 30/40 mesh size sand (Figure 3) have been completed.

5.3.1 Sand Pack Assembly Characteristics Evaluation

The procedural and experimental configurations for determining sand pack porosity/permeability (Figure 4) and permeability/mass transfer (Figure 5) have been developed and a permanent air-flow manifold is being constructed. The main portions of these experiments will be conducted at the METC building B-17, however, this series of preliminary experiments have been designed to evaluate the instrumentation and procedural protocols for determining sand pack properties.

6.0 RESULTS AND DISCUSSION

6.1 SARS Activity

Detailed CAB vessel assembly drawings were submitted to EG&G personnel for CAB fabrication and the machine work for the CAB vessel assembly component parts has been completed and the assembly has been received by WVU. A substantial amount of interaction with EG&G personnel transpired in an attempt to produce a CAB vessel assembly which will not only produce quality data but will also be extremely safe, durable, and easy to assemble, operate, and maintain.

During the fabrication of the CAB vessel assembly, several minor design modifications were constituted in order to enhance the fundamental functions of the sand pack chambers, that is, enabling the repeatability of measuring sand pack properties. As a result of these modifications, the CAB vessel assembly component parts were re-drawn to scale and the 'Operating Procedures' for the 'Operating Plan' were revised which will enable submission of a draft of the 'Operating Permit' for METC perusal and modification prior approval.

6.2 Sand Pack Assembly Characteristics Evaluation

The procedure and experimental setups for determining sand pack porosity and permeability have been developed and previously reported using a prototype experimental configuration. The measured porosity and permeability values based on the developed protocols have been found reasonable and repeatable. A delay in receiving valves and fittings has prevented completion of a permanent air-flow manifold for conducting these experiments with the CAB sand pack chambers.

The effect of dry air on an unconsolidated porous medium at irreducible water saturation was investigated through a series of air-water equilibrium experiments performed on the sand packs at optimum compaction water saturation using the prototype experimental chamber. The main portions of these experiments will be conducted at the B-17 Building at METC utilizing the CAB vessel assembly, however, this series of preliminary experiments was designed to evaluate the protocols for determining sand pack properties.

Experimental data collection will begin with the CAB sand pack chamber of the completed CAB vessel assembly upon receipt of ordered valves and fittings.

7.0 CONCLUSIONS

7.1 SARS Activity

The next phase of SARS activity is submission of the preliminary form of the 'Operating Permit' and presentation to METC for approval. The completion of this document was contingent upon design and fabrication modifications of the CAB vessel assembly in order to complete the drawings and operating procedures relative to the requirements of the 'Operating Plan'. This SARS activity has been completed.

7.2 Sand Pack Assembly Characteristics Evaluation

The sand-pack tests have been useful in establishing experimental protocols and identifying the necessary instrumentation for the CAB vessel assembly experimentation. The earliest experimental results indicated that accurate air-water equilibrium measurements could not be generated until an actual CAB vessel chamber is used for experimentation. However, the experimental test chambers were modified in an attempt to procure fundamental data prior to calibration and use of the CAB vessel assembly and

these modifications have produced acceptable results.

The incorporation of the CAB vessel sand pack chamber, coupled with the procured instrumentation, should enable generation of high quality data.

The sand compaction tests for the 30/40 mesh sand indicate a higher water content than the 20/30 mesh sand. Compaction tests will be performed with assorted sand particle sizes to further evaluate this relationship. These compaction tests, coupled with porosity and permeability measurements, could provide baseline data for the larger scale experiments to be performed at METC building B-17.

8.0 WORK PLANNED FOR NEXT PERIOD

8.1 SARS Activity

Submit 'Operating Permit' for METC approval in preparation to begin conducting experiments in METC building B-17.

8.2 Sand Pack Assembly Characteristics Evaluation

Initiate experimentation to determine sand pack assembly characteristics based on previously determined protocols utilizing the various CAB vessel assembly components.

8.3 Grain Size and Sorting Influence on Sand Pack Characteristics

Continue packing 20/30 and 30/40 mesh size sand as per modified 'Standard Ordinary Compaction Test', measuring porosity and permeability. Perform similar experimentation using sand of a different grain sizes.

8.4 Sand Pack Drying Characteristics Determination

Initiate drying tests on sand packs to evaluate the effect of porous media on equilibrium and mass transfer.

9.0 TECHNICAL/ADMINISTRATIVE DIFFICULTIES

Delays in receiving necessary funds have created some difficulties in the ordering of valves and fittings to complete a permanent air-flow manifold for the various CAB experimental configurations.

Problems with either the currently used computer or the data acquisition system printed circuit board have delayed getting transmitters on-line in real time. Efforts are in progress to resolve these problems.

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Sand Compaction

Sequence of Blows

Figure 1: The experimental setup for optimum water saturation for sand compaction

SAND COMPACTION - OPTIMUM WATER CONTENT DETERMINATION

CAB CHAMBER - 20/30 SAND

Figure 2: Optimum compaction water saturation for 20/30 mesh sand

SAND COMPACTION - OPTIMUM WATER CONTENT DETERMINATION

CAB CHAMBER - 30/40 SAND

Figure 3: Optimum compaction water saturation for 30/40 mesh sand

Porosity/Permeability Configuration

Figure 4: Porosity/Permeability Configuration

Permeability/Mass Transfer Configuration

Figure 5: Permeability/Mass Transfer Configuration

**A GIS-BASED INFRASTRUCTURE
FOR SITE CHARACTERIZATION AND REMEDIATION**

METC Task No. 2.1

Quarterly Technical Progress Report
Reporting Period:
January 1, 1996 - March 31, 1996

Work Performed Under Contract
No.: DE-FC21-92MC29467

For:
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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ABSTRACT

The overall goal of this effort is to determine an effective geographic information system (GIS)-based infrastructure for describing, characterizing, and remediating contaminated sites. The work is being carried out with the remediation needs of the U.S. Army Corps of Engineers Huntington, WV district office as a basis, providing the benefit of real needs of on-going remediation projects. Working closely with METC and the Corps of Engineers, during 1996 we will (a) achieve actual on-site application of the system to a Corps project in Mason County, WV, (b) assess and augment the infrastructure for use in decontamination and decommissioning (D&D) efforts, and (c) develop a prototype interactive tutorial system to effectively transfer infrastructure concepts and skills to prospective users and managers.

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EXECUTIVE SUMMARY

This document constitutes the required Quarterly Report for the first quarter of 1996, for Task No. 2.1 under the DOE/METC/WVU Cooperative Agreement, contract no. DE-FC21-92MC29467. It documents technical accomplishments and provides cost status as of March 31, 1996.

Although we have not yet received official notification of contract award for this 1996 effort as of March 31, we proceeded with the work based on the expectation of award. We will respond formally to Task 1 (NEPA) upon contract award.

Of the three primary tasks (2, 3 and 4), we are progressing on schedule for tasks 2 and 4. Task 3 is scheduled to begin in August 1996. We had received WV Ordnance site data in the last quarter of 1995. We uploaded the data into the MGE GIS, and spent considerable effort understanding the structure and organization of the data tables. We have had several meetings with the Huntington District Corps personnel with regards to acquiring further updates of the data, and conducting future work with the data.

We have also begun building the prototype interactive tutorial system using Director 4.0. The setup of the infrastructure of the GIS system, the preliminary data from WV Ordnance site, and the prototype tutorial system were demonstrated at the WVU Cooperative Agreement Program Review meeting on March 22, 1996 in Morgantown, WV.

In summary, we are in an excellent position to successfully complete all tasks during the calendar year.

1.0 INTRODUCTION

Under the 1995 METC contract, the Marshall University (MU) Environmental Center determined and set up an effective geographic information system (GIS) based infrastructure for describing, characterizing and remediating contaminated sites. The 1995 effort resulted in (1) a detailed description of hardware and software comprising a system proven effective through experimentation and evaluation, (2) operating procedures for effective system use, (3) educational/training materials for technology transfer, and (4) recommendations for follow-on system implementation. In carrying out this effort, we worked with the U.S. Army Corps of Engineers, Huntington, WV District, using their needs for characterization and remediation of contaminated sites as a realistic basis for determining system requirements. In this multi-year effort, we are strongly emphasizing the need to integrate this resulting technology into activities of interest and benefit to DOE. The working relationship with the Corps of Engineers has been closely coordinated with METC.

2.0 PURPOSE

This follow-on work for calendar year 1996 continues to address the DOE focus area Cross Cutting Innovative Technologies, Characterization sub-area. The results of this year's effort will be (1) actual on-site application of the GIS-Based Infrastructure in an ongoing project of the Corps of Engineers in Mason County, West Virginia, (2) assessment and augmentation of the Infrastructure for use in decontamination and decommissioning (D&D) efforts, and (3) development and evaluation of a prototype interactive tutorial system to effectively transfer the Infrastructure technology and underlying GIS concepts and skills to prospective users and managers.

3.0 BACKGROUND

Geographic Information Systems (GISs) are increasing rapidly in numbers and areas of application. No doubt the expansion is influenced strongly by the growing national interest in environmental protection and restoration. Numerous GIS systems are available--including commercial (e.g., ARC/INFO, Intergraph MGE, MapInfo), government-sponsored (GRASS), and university research based (IDRISI, ICASE/GRACE). The desired applicability of GISs is extremely broad (e.g., air quality monitoring, groundwater contamination, areas in a city accessible by public transport). Thus the GIS systems must be very generic in their capabilities. This genericness is attractive in providing versatility of application breadth, but of necessity limits the depth of features for a given application area.

The nation faces a massive problem relative to contaminated sites. The U.S. Department of Energy, the U.S. Army Corps of Engineers, and many other government agencies are faced with requirements to remediate contaminated sites under their purview. The Huntington District of the U.S. Army Corps of Engineers (USACE) has undertaken to assemble computer-

based tools to help them in describing, characterizing, and remediating contaminated sites. They have obtained the Integrated Computer Assisted Site Evaluator / Graphical Remedial Assessment and Cost Evaluation (ICASE/GRACE) system, developed at the University of Cincinnati, for evaluation. They have also obtained and installed Intergraph's MGE system, and anticipate obtaining Intergraph's ERMA (for Environmental Resource Management Application) system, intended to support site assessment, modeling and remediation. Under an earlier METC task (1994), Marshall University evaluated ICASE/GRACE for use by the Huntington USACE District.

4.0 METHODOLOGY

Following are descriptions of the 1996 tasks to be conducted, and associated schedules.

Task 1: *Information Required for the National Environmental Policy Act.*

Schedule: Within 60 days of contract award.

Task 2: *Application of the GIS-Based Infrastructure at the West Virginia Ordnance Site.*

Personnel from Marshall University will work as a team with Corps of Engineers personnel to transfer the GIS-Based Infrastructure technology to actual use on a project managed by the HTRW Section of the Huntington District office. The project will include obtaining/developing digitized maps of the WV Ordnance area, and associating on-line with the maps data characterizing contaminated sites (actual data when available, or modeled) in various forms from many sources. We will work with Corps personnel in all aspects of the project, including translating data for compatibility, entering data into the GIS database, and associating it with corresponding map elements.

Since the area of this site is very large (about 3000 acres), it will present many challenging issues such as organization of database tables, interaction of multiple contaminants from various locations on the site, handling of incomplete and/or inconsistent data, and extraction of the effect of individual contaminants.

Once the database is established, it will be possible to model various contamination scenarios. Based on such scenarios, we will model and assess remediation strategies for some of the contaminants, in collaboration with the Corps of Engineers. The Environmental Resource Management Application (ERMA) package, which is an Intergraph product, will be used for this purpose.

Schedule: January 1 through September 30, 1996.

Task 3: *Assessment and Augmentation of the Infrastructure for D&D Use.*

In concert with METC personnel, we will make use of available characterization of contaminated sites within WV Ordnance to assess strategies for D&D. The GIS-Based Infrastructure, with its open software architecture, accommodates incorporation of additional models. The WV Ordnance site data resulting from Task 2 will provide a diversity of contaminants and geological characteristics for evaluating D&D remedial technologies and operational strategies. We will coordinate the selection of specific sites and technologies with METC, prior to undertaking. We will support METC in evaluating remediation approaches relative to specific D&D contaminated sites, by means of models operating on site data. The Intergraph ERMA remediation software will be considered for applicability in this effort, as well as models available to METC and the Corps of Engineers.

Schedule: August 1 through December 31, 1996.

Task 4: *Prototype Development and Evaluation of an Interactive Tutorial System.*

By use of commercially available courseware authoring tools, we will develop a prototype interactive tutorial system to transfer the GIS-based technology concepts and skills to users and managers. The tutorial sessions will provide step by step lessons incorporating real data. The approach will be based on sound pedagogical principles, and will be practically oriented to maximize use on the job. The tutorials will mimic the interface (menus, buttons and windows) of the actual system. We will incorporate selectable modes by degree of user sophistication, so that more or less guidance is provided based on need. We will also develop tutorial materials of varying abstraction/detail based on the needs of various personnel--ranging from managers to the every-day user of GIS technology. In these lessons we will cover representative facets of the Intergraph MGE system, and additional models and features incorporated into our GIS-Based Infrastructure. A significant benefit of the resulting approach will be the availability of the tutorials for use and reuse after an employee begins to use the skills on the job.

We will conduct a limited field test of the prototype using a representative range of personnel in order to ensure its effectiveness and make any needed adjustments. The result of this effort will be a working prototype incorporating proven concepts which can later serve as the basis for developing an operational tutorial system.

Schedule: January 1 through December 31, 1996.

5.0 WORK PERFORMED THIS PERIOD

5.1 Activities

During this period, we started Task 2 (Application of the GIS-Based Infrastructure at the West Virginia Ordnance Site) and Task 4 (Prototype Development and Evaluation of an Interactive Tutorial System) and are on schedule with both the tasks. The following paragraphs give more details on each task.

Task 1: *Information Required for the National Environmental Policy Act.*

This material will be delivered upon official contract award.

Task 2: *Application of the GIS-Based Infrastructure at the West Virginia Ordnance Site.*

In the last quarter of 1995, we had received an "MGE data dump" of WV Ordnance data from the Nashville District Corps Office. The Nashville District is responsible for receiving and entering data from the WV Ordnance site. In the month of January, we went through the process of understanding the database tables and "loaded" the data into the GIS system.

Personnel from Marshall University (MU) Environmental Center held a meeting on Feb 2, 1996 with Huntington District Corps of Engineers personnel to discuss the continuing use of the GIS-based technology for site characterization and remediation analysis of the WV Ordnance site in Mason County, WV. Sample queries and test scenarios were generated and discussed in the meeting. At that time, it was established that MU would have to get data from Nashville on a continuing basis, in order to keep the system current. Dave Meadows, Chief of the HTRW and Special Studies Section of Huntington District Corps, is currently setting up the data transfer process.

Another need indicated by the Huntington Corps is identification and association of real estate data with the Ordnance site. We are currently in the process of establishing a mechanism of acquiring real-estate data from the county office and the real estate division of the Corps.

Following the February meeting, we have received the digitized maps of the site, and have further studied the organization of the database tables. We have used ERMA, the remediation software from Intergraph, to produce map elements from the database. The combination of ERMA map elements and digitized maps were part of the presentation at the 1996 Cooperative Agreement Program Review held on March 22 in Morgantown, WV.

Task 3: *Assessment and Augmentation of the Infrastructure for D&D Use.*

Scheduled to begin August 1, 1996.

Task 4: *Prototype Development and Evaluation of an Interactive Tutorial System.*

We have acquired the Director 4.0 suite of multimedia software, and have built a skeletal prototype of the interactive tutorial system. The prototype was part of the presentation at the 1996 Cooperative Agreement Program Review held on March 22. Various components of the tutorial are being added to the prototype on a continuing basis.

5.2 Costs

The following is an unofficial summary of costs incurred during this quarter; Marshall University Research Corporation is the agent for formal contract and financial transactions.

Salaries	\$16,117.99
Benefits	\$ 2,718.19
Students	\$ 0.00
Supplies	\$ 182.58
Travel	\$ 417.90
Equipment	
< \$500 (Software)	\$ 200.00
> \$ 500 (Hardware)	\$ 964.77
Total Direct Costs	\$ 20,601.43
Indirect Costs (less Hardware)	\$ 7,461.93
Total	\$ 28,063.36

6.0 RESULTS AND DISCUSSION (CURRENT PERIOD)

We are underway and on schedule with Task 2 and Task 4. We are working with the Huntington District Corps personnel to set up a mechanism of getting continual updates to the WV Ordnance site data.

7.0 CONCLUSIONS (CURRENT PERIOD)

We are on schedule with the 1996 tasks, have an excellent working relationship with the Corps of Engineers, and are well positioned to achieve successful completion of all tasks during this year.

8.0 WORK PLANNED FOR NEXT PERIOD

8.1 Activities

We will continue our efforts on Task 2 and Task 4, and will complete Task 1 (NEPA) upon official contract award.

8.2 Costs

The following table summarizes anticipated costs for the next quarter.

Salaries	\$ 17,287.30
Benefits	\$ 3,477.42
Students	\$ 2,414.40
Supplies	\$ 900.00
Travel	\$ 1,500.00
Equipment	
< \$500 (Software)	\$ 864.00
> \$ 500 (Hardware)	\$ 700.00
Total Direct Costs	\$ 27,143.13
Indirect Costs (less Hardware)	\$ 10,048.39
Total	\$ 37,191.51

9.0 TECHNICAL/ADMINISTRATIVE DIFFICULTIES

We have proceeded with this work without formal contract award. It appears that formal award will occur during April 1996, according to the Director of the Cooperative Agreement, Dr. Bud Cook.

APPENDICES

A. LIST OF ACRONYMS AND ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
CD-ROM	compact disk read only memory
COTS	commercial off-the-shelf
D&D	decontamination and decommissioning
DOE	Department of Energy
DOS	disk operating system
ERMA	Environmental Resource Management Application (an Intergraph product)
GB	gigabyte; approximately 1,000 MB
GIS	geographic information system
HP	Hewlett Packard
HTRW	hazardous, toxic & radioactive waste
ICASE/GRACE	Integrated Computer Assisted Site Evaluator/Graphical Remedial Assessment and Cost Evaluator
IP	Internet protocol
LCD	liquid crystal display
MB	megabyte; approximately one million bytes
MGE	Modular GIS Environment (an Intergraph product)
MHZ	megahertz
MS	Microsoft
MU	Marshall University
NT	New Technology (as part of Windows NT)
PC	Personal Computer
PCMCIA	Personal Computer Microchannel Interface Adaptor
RAM	random access memory
RIS	relational interface system
SCSI	small computer systems interface
SQL	system query language
SVGA	super video graphics adapter
TD 3	Technical Desktop 3
TD 4	Technical Desktop 4
UPS	un-interruptible power supply
USACE	United States Army Corps of Engineers

Treatment of Mixed Wastes via Steam Reforming

METC Task No.2.2

Quarterly Technical Progress Report
Reporting Period: January 1 - March 31, 1996

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Office of Fossil Energy
Morgantown Energy Technology Center
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Abstract

This work addresses the evaluation of the destruction efficiency of RCRA organic components and surrogates in a steam reforming atmosphere. The benefit of using a steam atmosphere to destroy RCRA organics, e.g. dichlorobenzene, lies in the virtual elimination of dioxins and furans in the product gases. This technology has been proven by ThermoChem Inc., Columbia, MD, which currently is developing a two-stage fluidized bed unit to dispose of mixed wastes. The work outlined in this proposal addresses the quantification of the destruction efficiency of key RCRA organics and surrogates in the second stage of the ThermoChem process. A series of experimental runs will be performed in a 6.5 cm internal diameter reactor. The purpose of these runs is to evaluate the efficiency of destruction of organic materials as a function of residence time, gas composition and reaction temperature. In addition, the efficacy of using catalysts to improve the destruction efficiency will be determined.

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Executive Summary (Current Work)

Due to an unforeseen delay in upgrading the Gas Chromatograph (GC) the work performed this quarter has fallen behind schedule. The experimental program cannot begin in earnest until the GC has been upgraded with an FID and suitable calibration has been performed. Recently, March 21, 1996, the GC was returned to Dr. Turton's laboratory and initial testing and calibration is currently underway. It is believed that the GC will be operational in the new two weeks and that the experimental program can start by the end of April. A concerted effort will be made to accelerate the experimental program in order to get the research back on schedule by the end of the next reporting period.

1.0 Introduction

The treatment and destruction of mixed wastes is becoming an increasingly important problem in the environmental arena. Many of the problems associated with mixed wastes are due to the wide variety in the type, content and form of the waste itself. For example, clothing contaminated with small quantities of radioactive elements and sludges from fuel storage tanks would both be considered mixed wastes. The challenge, therefore, in dealing with this type of waste is to create processes which are flexible enough to handle a wide variety of feeds and to render them harmless to the environment. This research is aimed at determining the destruction efficiencies of RCRA organics in a variety of reforming atmospheres and at different temperatures. The work is essentially supporting an on going effort by ThermoChem Inc., Columbia, MD to develop a two stage process for the treatment of mixed wastes.

2.0 Purpose

There have been several reports regarding the destruction of organic materials at elevated temperatures in a variety of non-oxidative environments (1,2,3). However, the results are generally applicable to specific equipment and cannot be easily extrapolated to different operating conditions. The purpose, therefore, of this work is to systematically evaluate the destruction efficiencies of a variety of organic materials at different conditions and to establish correlations to support the design of new equipment.

This work relates directly to an existing process developed by ThermoChem Inc., Columbia, MD, and will be performed in close association with ThermoChem Inc.

3.0 Background

The ThermoChem Process utilizes a two stage fluidized bed system to volatilize and subsequently destroy organic materials. The process uses the first stage fluid bed to vaporize organic material from shredded mixed wastes and to concentrate the inorganic material in the remaining solids. The inorganic portion of the waste, containing heavy metal compounds etc., is eventually vitrified with glass frit in a separate unit. The gas from the first stage is sent to a second stage, operating at elevated temperatures (1600 - 1800°F), where the organics are reformed in a steam environment. In addition to steam, the ThermoChem process may have some hydrogen and carbon monoxide in the gas entering the second stage. The use of hydrogen and carbon monoxide as additional reforming gases and the possibility of using a catalyst to promote the reforming reaction are of interest in this process and will be investigated in this research.

It is envisioned that the results of this work will help to define the optimum conditions for the steam reforming process and to determine the efficacy of using a catalyst to promote

destruction efficiency of RCRA organics and surrogates in such a process.

4.0 Methodology

The work proposed is a continuation of a current project under the WVU/METC cooperative agreement. The scope of the current project was modified to enable a closer working relationship with ThermoChem Inc. which currently is developing a process to destroy mixed wastes via steam reforming. At present, the test equipment consists of a 6.5 cm inside diameter stainless steel reactor which is expected to operate in the temperature range of 850 - 930°C (approx. 1600 - 1800°F). The bed is mounted in a vertical, 3-zone tube-furnace. The feed gas, mixtures of hydrogen, carbon monoxide and dioxide and steam, are fed from gas bottles and are metered through valves and flowmeters to the reactor. Organic liquid material is fed from a pressurized tank via a flowmeter and vaporized prior to being sent into the reactor.

The object of the current work is to quantify the destruction efficiency of RCRA organics and surrogates in a steam reforming atmosphere for a variety of operating conditions. A gas chromatograph, fitted with a flame ionization detector, will be used to evaluate the destruction efficiency of the organic material down to the 99.99% level of destruction or better. The need for a catalyst to improve the destruction efficiency will be addressed if the homogeneous reaction rates are too low. The tasks for this project are outlined below.

Task 1: Information Required for the National Environmental Policy Act.

Task 2: Upgrading and Calibration of Gas Chromatograph.

The gas chromatograph currently in use in Dr. Turton's laboratory will be upgraded with a Flame Ionization Detector (FID) to enable destruction efficiencies of up to and greater than 99.99% to be measured accurately. Once the GC has been upgraded a series of tests will be performed to calibrate the unit for measuring the organic components used in this work. Calibrations will consist of running the test bed at low temperatures (<200°C) using an inert or non-inert carrier gas and injecting (spraying) the organic material at different flowrates into the bed. Samples will be taken after the gas cooler and used to calibrate the peaks obtained from the GC. A minimum of three concentrations points, for each organic material, will be used to calibrate the gas chromatograph. Due to the widely differing characteristics of the organic materials used in this study it may be difficult to identify all the components in a reasonable time using a single column in the GC. Since the destruction efficiency of the RCRA organics and aromatic surrogates (in this case ethylene glycol, dichlorobenzene, toluene and naphthalene) are the most important measures of the process's effectiveness, these will be evaluated and used as the measure of the destruction efficiency.

Task3: Experimental determination of Destruction Efficiency of Organic Material without the use of Catalyst.

The experimental program to be used in this part of the work will consist of an experimental test matrix in which the following independent variables will be varied:

	Number of Levels
Temperature	3 (1800, 1700 and 1600°F)
Residence Time	2 (1 and 2 s)
Hydrogen Content of Gas	3 (0, 5% and 10% on a volume basis)
Carbon Monoxide Content of Gas	2 (0 and 5% on a volume basis)

This test matrix is consistent with the needs of ThermoChem Inc. and was discussed with Mr. G.Voelker and Dr. R.Chandran of ThermoChem Inc. The organic materials to be tested were also discussed with ThermoChem Personnel and the materials given in Task 2 above will be used in the preliminary tests.

The dependent variables will be the destruction efficiencies of the organic components fed to the bed. Currently the organic feed material of interest consists of the following components: Toluene, DiChlorobenzene, Ethylene Glycol, Naphthalene. These components may be substituted with other RCRA components or surrogates, if the destruction efficiencies of other organics are desired.

Task 4: Correlation of Experimental Results

Using the results from Task 3 the conversion (destruction) of the different organic species will be correlated with the independent variables listed above in Task 3. The experimental results and correlation will be compared to existing homogeneous kinetics data in the literature. Any limitations, due to equilibrium considerations, will be investigated.

Task 5: Experimental determination of Destruction Efficiency of Organic Material using Catalyst.

The investigation into the use of catalysts to promote the destruction of the organic materials will be investigated if the results of Task 3 indicate that this is necessary. This phase of the work will involve input from ThermoChem Inc. The test matrix for part of the work will include operating temperature, gas composition, and gas-solid contact time in the reactor using a fixed organic feed. The mode of operation of the reactor will be a packed or fluidized bed and the particle size will be chosen to obtain the required gas residence time with a bed height of 24-30" of catalyst.

Task 6: Preparation of Quarterly and Annual Reports

Three quarterly and one annual report will be prepared for this project.

5.0 Worked Performed in this Period

The work to be performed in this period consisted mainly of task 2 outlined above. However, due to unforeseen circumstances the upgrading of the GC with an FID detector was delayed and only recently was the unit returned to Dr. Turton's lab. Currently, the GC is undergoing calibration and it is expected to be functional by mid April. Since, the experimental work cannot be started until the GC is working correctly, the experimental program is behind schedule. It is believed that the experimental program can be started soon into the next period and that any lost time can be made up in the next quarter.

6.0 Results and Discussion for Current Reporting Period

Due to the problems reported in 5.0 above there are no conclusions to report for the current period.

7.0 Conclusions for Current Period

Due to the problems reported in 5.0 above there are no conclusions to report for the current period.

8.0 Work Planned for Next Period

The work planned for the next reporting period includes the completion of the upgrade and calibration of the gas chromatograph. In addition, the experimental program will be started. The destruction of several organic materials will be investigated and the experimental matrix given in section 4.0 task 3.0 will commence.

9.0 Technical and Administrative Difficulties for Current Period

Due to an unforeseen delay in upgrading the Gas Chromatograph (GC) by SRI the work performed this quarter has fallen behind schedule. The experimental program cannot begin in earnest until the GC has been upgraded with an FID and suitable calibration has been performed. Recently, March 21, 1996, the GC was returned to Dr. Turton's laboratory and initial testing and calibration is currently underway. It is believed that the GC will be operational in the new two weeks and that the experimental program can start by the end of April. A concerted effort will be made to accelerate the experimental program in order to get the research back on schedule by the end of the next reporting period.

Appendix

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Acronyms and Abbreviations

FID - Flame Ionization Detector

GC - Gas Chromatograph

RCRA - Resource Conservation and Recovery Act (1976)

SRI - Scientific Research Instruments, Inc.

**USE OF CENTRIFUGAL MEMBRANE TECHNOLOGY WITH NOVEL MEMBRANES
TO TREAT HAZARDOUS/RADIOACTIVE WASTES**

METC Task No. 2.3

Quarterly Technical Progress Report
Reporting Period: 1/1/96 - 3/31/96

Work Performed Under Contract
No.: DE-FC21-92MC29467

For:
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Office of Fossil Energy
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ABSTRACT

SpinTek, a California-based company, has developed and patented a cross-flow technology that improves upon the conventional membrane process. The SpinTek system uses a series of flat, round membrane disks packs set on a hollow rotating shaft inside a cylindrical housing. The fluid stream enters the shaft and is distributed across the membrane surfaces by centrifugal and hydraulic action. The permeate exits out the periphery of the unit and the concentrate exits at the edge of the membrane packs. The centrifugal action continuously cleans the membrane surface decreasing cleaning chemical use and maintenance and increasing the volume of waste treated per area of membrane. Because of the reactive nature of most DOE wastewaters, the use of conventional membrane materials may not be viable. Thus, specialty membranes that can separate hazardous contaminants from the permeate stream and are chemically and radiologically stable will also be tested.

The objective of this research is to investigate the feasibility of using centrifugal membrane technology combined with innovative membranes for the treatment hazardous/radiological wastes. The following tasks will be completed during this research: 1) perform extensive literature review on membrane technology, 2) identify and acquire waste and membranes, 3) modify, acquire, and be trained in the use of SpinTek technology, and 4) test and evaluate SpinTek technology and specialty membranes.

The following variables will be monitored as a function of run time: 1) contaminant concentration in concentrate and permeate, 2) membrane flux, 3) temperature and pressure, 4) conductivity and pH of all liquids. The following parameters will be used to judge the effectiveness of the process: 1) contaminant concentration in the permeate, 2) physical and chemical resistance of membranes, 3) volume and waste reduction factors, 4) quantity and quality of residuals, 5) energy and requirements, 6) ease of operation and likelihood of process upsets.

The result of this work will be a technology that can treat a variety of wastes such as contaminated groundwater, mixed-waste process water, and existing waste residual (e.g., low-level waste). The process can be used for both inorganic (e.g. radionuclides and heavy metals) and organic contaminants. It is envisioned that the volume reduction factors for this technology will be high and a relatively a low amount of residual requiring additional treatment will be produced.

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EXECUTIVE SUMMARY

Two hundred twenty gallons of colloidal wastewater having an initial total suspended solids (TSS) concentration of 480 mg/L, was treated. Temperature was kept constant at 110 ± 2 °F using a cooling water heat exchanger. The system pressure and rotational speed was 40 psi and 1750 rpm, respectively. The membrane, PV-100K, had a molecular weight cut-off of 100,000. Permeate flux, turbidity, TSS concentration and pH were measured periodically.

The feed tank temperature stabilized after about 20 hours of operation at 110 ± 2 °F. If a heat exchanger was not employed the feed temperature would have increased because of the energy transferred to the liquid from the pump and the rotational device. While it is advantageous to operate the membrane system at the highest possible temperature (because of increased permeate flux) many polymeric membranes are damaged at high temperatures.

The lowest permeate flux observed was 32 gal/ft²-day and occurred during initial operation. The flux increased with time during the first 60 hours, after which it was relatively constant at about 78 gal/ft²-day. The average flux $\pm$ one standard deviation was 73 ± 10 gal/ft²-day. For conventional membrane systems, the flux is typically high in the beginning of the run but decreases rapidly because of membrane fouling (as the concentration increases, membrane fouling increases). This did not occur with the SpinTek system because the fouling layer was efficiently disrupted using the rotational action. Thus, a high flux was able to be maintained over the duration of the run, including during batch-down.

The concentration factor (CF) increased gradually from 1X at the start of the run to 14.6X at the end of semi-batch operation. During batch-down, the CF increased rapidly from 14.6X to 100X. The volume reduction for the entire run was 99% (220 gallons wastewater to 2.2 gallons residual).

The majority of permeate samples had turbidity below 5 NTU. As a reference, the turbidity standard for drinking water is 1 NTU. The TSS of the permeate was always less than the detection limit (5 mg/L). At the end of batch-down, the TSS concentration of the feed tank contents (concentrate) was 51,800 mg/L. A 7.75% error in closing the mass balance was calculated and is considered acceptable given the high TSS concentration of the concentrate.

Based on the single test conducted to date, the SpinTek centrifugal membrane technology appears to be a feasible method for the removal of colloidal material from the aqueous phase. Provided that the majority of the contamination is sorbed onto colloidal or larger sized particles, the SpinTek system would be effective in decontaminating a similar type liquid waste.

1.0 INTRODUCTION

SpinTek, a California-based company, has developed and patented a cross-flow technology that improves upon the conventional membrane process. The SpinTek system uses a series of flat, round membrane disks packs set on a hollow rotating shaft inside a cylindrical housing. The fluid stream enters the shaft and is distributed across the membrane surfaces by centrifugal and hydraulic action. The permeate exits out the periphery of the unit and the concentrate exits at the edge of the membrane packs. The centrifugal action continuously cleans the membrane surface decreasing cleaning chemical use and maintenance, increasing the volume of waste treated per area of membrane, and increasing the contaminant/solids concentration in the residual (*i.e.* increases volume reduction factor). SpinTek's centrifugal membrane technology represents an improvement over conventional ultrafiltration technology and increases the number of waste streams that can be treated using membrane treatment.

2.0 PURPOSE

The purpose of this research is to investigate the feasibility of using centrifugal membrane technology combined with innovative membranes for the treatment hazardous/radiological wastes. The result of this work will be a technology that can treat a variety of wastes such as waste from DOE decontamination/decommissioning efforts, biological wastes, and waste with a high solids content (*e.g.*, low level tank waste), contaminated groundwater, mixed-waste process water, and existing waste residual. The process can be used for both inorganic (*e.g.* radionuclides and heavy metals) and organic contaminants. It is envisioned that the volume reduction factors for this technology will be high and a relatively a low amount of residual requiring additional treatment will be produced.

3.0 BACKGROUND

SpinTek, a California-based company, has developed and patented a cross-flow technology that improves upon the conventional membrane process. The SpinTek system uses a series of flat, round membrane disks packs set on a hollow rotating shaft inside a cylindrical housing. The fluid stream enters the shaft and is distributed across the membrane surfaces by centrifugal and hydraulic action. The permeate ("clean" liquid) exits out the periphery of the unit and the concentrate (liquid containing the contaminants) exits at the edge of the membrane packs.

With time, the membrane surface will become fouled resulting in a decrease in the permeate flow rate. To reduce fouling in conventional membrane systems, a large portion of the concentrate is recycled back to the membrane unit producing large liquid velocities near the membrane surface. The large velocities increase turbulence which reduces the thickness of the fouling layer. In centrifugal membrane systems, the rotation of the membrane disk induces the turbulence required to minimize the thickness of the fouling layer. In conventional membrane system, maximum surface velocities of about 15 ft/s are possible while with centrifugal systems surface velocities of 60 ft/s are typical. As the concentrate thickens with treatment time, conventional systems are not able to maintain the high velocities because of the difficulty in pumping viscous material at large flow rates. Because the centrifugal membrane system does not rely on pumping to produce the required surface velocities, extremely concentrated wastes can be treated.

Membrane systems are typically operated in either the semi-batch mode or the batch mode. In the semi-batch mode, fresh waste is added to the system at a rate equal to the permeate production rate. In the batch-mode, which normally occurs at the end of semi-batch operation, no fresh waste is added to the system and the concentrate remaining from semi-batch operation is concentrated further ("batched-down"). During batch-down, large concentration factors are achieved (permeate is still being produced reducing the concentrate volume).

All membrane technologies are volume reduction technologies because contaminants are not degraded or destroyed. Thus, an important measure of the efficiency of membrane technology is the concentration factor (CF). The CF during semi-batch and batch-down operation are calculated using the following two equations:

Semi-Batch Operation

$$CF_{SB} = 1 + V_{perm}/V_{feed\ tank}$$

Batch-Down Operation

$$CF_{BD} = CF_{SB} \times [V_{feed\ tank}/(V_{feed\ tank} - V_{perm})]$$

where,

CF_{SB} = concentration factor during semi-batch operation.

V_{perm} = volume of permeate produced, gal.

$V_{feed\ tank}$ = volume of the feed tank (15 gal), gal.

CF_{DB} = concentration factor during batch-down operation.

Concentration factors are expressed as 1X, 2X, *etc.*, and increase with treatment time. CFs in excess of 100X are obtainable with the membrane technology. Another measure of treatment efficiency is the permeate flux (volume of permeate/membrane area per time). The permeate flux for a given membrane is dependent on the waste's viscosity, solids content, and temperature. These waste characteristics can also change during treatment.

Membranes that are used for ultrafiltration are characterized by the molecular weight of a molecule that is not allowed to pass through the membrane. For example, the membrane used in this quarter's research had a molecular weight cut-off (MWCO) of 100,000. In theory, compounds having a molecular weight greater than the MWCO would be retained by the membrane and compounds with molecular weights less than the MWCO would pass through the membrane and be contained in the permeate. It should be noted that the MWCO designation is somewhat misleading because a molecule having a molecular weight less than the membrane's MWCO may still be retained by the membrane because its 3-dimensional shape will not allow it to pass through the membrane pores and vice-versa.

4.0 METHODOLOGY

Centrifugal membrane technology will be tested using several combinations of wastes and membranes. For each membrane type, the clean water flux (CWF) will be determined for the virgin membrane. The CWF serves as a baseline indicator to determine if the membrane is 1) permanently fouled and 2) sufficiently cleaned. For each waste-membrane combination, the SpinTek system will be operated first in the semi-batch mode and then at the end of the treatment run in the batch mode. The following variables will be monitored during technology testing:

1. Contaminant concentration in concentrate and permeate.
2. Membrane flux.
3. Temperature and pressure.
4. Conductivity and pH of all liquids.

Permeate flux, contaminant(s) concentration in the permeate, concentration factor, operational ease, and the membrane's physical/chemical resistance and cleanability will be used to judge the effectiveness of the process. Several runs will be conducted for each membrane-waste combination. Special attention will be placed on identifying the quantity and quality of any residuals produced. Quality assurance/quality control practices, as outlined in US EPA's Test Methods for Evaluating Solids Wastes, will be followed. The use standard analytical methods (*i.e.*, ASTM, Standard Methods for the Measurement of Water and Wastewater, etc.) will also be followed.

5.0 WORK PERFORMED DURING THIS PERIOD

The following work was conducted during the period 1/1/96 to 3/31/96: 1) literature search, 2) technology acquisition and training, 3) initial waste and membrane identification and acquisition, and 4) technology testing.

1.1 Literature Search

A comprehensive literature search on membrane technology was conducted and over 50 articles and reports have been acquired. Additional articles/reports have been requested through West Virginia University's Interlibrary Loan program. When all articles/reports have been acquired, a comprehensive summary of the state-of-art and state-of-practice for membrane technology will be developed.

1.2 Technology Acquisition and Training,

The SpinTek centrifugal membrane systems was sent to WVU Department of Civil and Environmental Engineering's Environmental Laboratories during the first month of the project. SpinTek personnel visited WVU in January, 1996 and in March, 1996 to help setup the membrane system and train faculty and students in the operation of the technology.

1.3 Waste and Membrane Identification and Acquisition

The identification of wastes and membranes that warrant further study will be an ongoing task for this research project. In the this quarter a waste having a high suspended solids content and containing colloidal particles was developed ("colloidal waste"). This waste physically simulates waste that is contained in lagoons, tanks, *etc.* A membrane having a molecular weight cut-off of 100,000 was procured with SpinTek's help and was used to treat the "colloidal waste".

1.4 Technology Evaluation

In the first quarter the SpinTek technology was used to treat the colloidal waste. Experimental results and discussion are presented in Section 6.0 Results and Discussion.

6.0 RESULTS AND DISCUSSION

In this chapter results from the treatment of the colloidal wastewater will be presented and discussed. Two hundred twenty gallons of colloid wastewater having an initial total suspended solids (TSS) concentration of 480 mg/L, was treated. Semi-batch operation was conducted for 130 continuous hours and batch operation was conducted for 5 hours. The feed tank temperature was allowed to rise to 110° F after which it was kept constant at 110 ± 2 °F using a cooling water heat exchanger. The system pressure and rotational speed was 40 psi and 1750 rpm, respectively. The membrane, PV-100K, had a molecular weight cut-off of 100,000. Permeate flux, turbidity, TSS concentration and pH were measured periodically. The concentration factor was calculated based on the amount of permeate produced at a given time. At the end of the batch-down period, a concentration factor of 100X was reached (220 gallons of waste initially and 2.2 gallons of residual produced).

In Figure 1, the temperature of the permeate and the feed tank (concentrate) versus operational time is presented. The permeate temperature was slightly lower than the feed tank temperature because of heat loss in the permeate tube. The feed tank temperature stabilized after about 20 hours of operation at 110 ± 2 °F. If a heat exchanger was not employed, the feed tank temperature would increase because of the energy transferred to the liquid from the pump and the rotational device. During the training period, temperature control was not practiced and the feed tank temperature reached 160 °F. Polymeric membranes are temperature sensitive (e.g., the PV-100K has a maximum allowable temperature = 120°F) while ceramic membranes are relatively insensitive to high temperatures. Permanent damage can be done to a polymeric membrane if high temperatures are allowed to occur during waste treatment. However, as the temperature increases, the viscosity of the liquid decreases and the permeate flux increases. Thus, it is advantageous to operate the membrane system at the highest allowable temperature.

In Figure 2, the permeate flux and concentration factor verses operational time are presented. The lowest flux observed was 32 gal/ft²-day and occurred during initial operation. The flux increased with time during the first 60 hours, after which it was relatively constant at about 78 gal/ft²-day. The average flux $\pm$ one standard deviation was 73 ± 10 gal/ft²-day. For conventional membrane systems, the flux is typically high in the beginning of the run but decreases rapidly because of membrane fouling (as the waste is concentrated, fouling of the membrane increases). This did not occur with the SpinTek system because the fouling layer is efficiently disruptive using rotational action. This, a high flux was able to be maintained over the duration of the run, including during batch-down.

The concentration factor (CF) gradually increased from 1X at the start of the run to 14.6X at the end of semi-batch operation. During batch-down, the CF rapidly increased from 14.6X to 100X. The volume reduction for the entire run was 99% (220 gallons waste to 2.2 gallons residual). It should be noted that the amount of residual could have been decreased further except for logistical reasons.. The outlet pipe in the feed tank was located such that the lowest waste level that could be achieved was equivalent to 2.2 gallons. If the waste level was reduced further air would have been introduced to the system.

Figure 1. Temperature Versus Operational Time

Figure 2. Permeate Flux and Concentration Factor Verses Operational Time

In Figure 3, the permeate turbidity versus operational time is presented. The majority of samples had turbidity below 5 NTU. As a reference, the turbidity standard for drinking water is 1 NTU. The SpinTek system was very effective in removing colloidal material.

In Figure 4, the permeate and feed tank TSS are presented versus operational time. Also presented in Figure 4 is the CF. The TSS of the permeate was always less than the detection limit (5 mg/L). As expected the feed TSS increased gradually during semi-batch operation and then rapidly during batch-down. The TSS concentration of the feed tank contents (concentrate) was 51,800 mg/L. Performing a mass balance on TSS yields:

$$\begin{aligned}\text{Initial mass of TSS} &= 480 \text{ mg/L} \times 220 \text{ gal} \times 3.785 \text{ gal/L} \times 10^{-6} \text{ kg/mg} = 0.400 \text{ kg TSS} \\ \text{Final mass of TSS} &= 51,800 \text{ mg/L} \times 2.2 \text{ gal} \times 3.785 \text{ gal/L} \times 10^{-6} \text{ kg/mg} = 0.431 \text{ kg TSS} \\ \text{Error in mass balance} &= [(0.400 \text{ kg} - 0.431 \text{ kg})/0.40 \text{ kg}] \times 100\% = 7.75\%\end{aligned}$$

A 7.75% error in closing the mass balance is acceptable given the high TSS concentration of the concentrate.

Figure 3. Permeate Turbidity Versus Operational Time

Figure 4. Permeate and Feed Tank TSS Versus Operational Time

7.0 CONCLUSIONS

Based on the single test conducted to date, the SpinTek centrifugal membrane technology appears to be a feasible method for the removal of colloidal material from the aqueous phase. Provided that the majority of the contamination is sorbed onto colloidal or larger sized particles, the SpinTek system would be effective in decontaminating a similar type liquid waste. The waste was concentrated by 100X and the volume of the waste was reduced by 99%. The error in the mass balance was only 7.75% indicating the soundness of the design and conduct of the experiment.

8.0 WORK PLANNED FOR NEXT QUARTER

The following experiments will be conducted during the next quarter: 1) treatment of a biomass waste and 2) treatment of a waste having a high oil and grease content. The biomass waste stream will be used to simulate the treatment of a biosorbent waste that is produced during the decontamination/decommissioning of pipes. The oil and grease waste stream will be used to assess the ability of the SpinTek system to treat a waste that many consider one of the hardest to treat using membrane technology.

9.0 TECHNICAL/ADMINISTRATIVE DIFFICULTIES

None.

ENVIRONMENTAL POLLUTION CONTROL DEVICES BASED ON NOVEL FORMS OF CARBON

Report for Period
ending March 31, 1996

Work Performed Under METC Task 2.4
as Part of the WVU-DOE Cooperative Agreement.
Contract No.: DE-FC21-92MC29467

For :
U.S. Department of Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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ABSTRACT

The use of electrochemistry is an effective means to remove heavy metal contaminants from aqueous effluent streams. This project deals with the development and testing of novel carbon materials for the electrochemical removal of radionuclides and heavy metal ions from aqueous wastes. Both electroplating and electrosorption are employed for this task. The purpose of this work was to develop and test carbonaceous materials for their ability to perform this task. This is accomplished by using a "packed-bed" of the carbon material in a "flow-through" electrochemical remediation cell.

The concentration of heavy metal ions and radionuclides in waste streams is usually very low: typically 1 to 1000 ppm. These low concentrations lead to relatively low current densities and low conversion of electroactive species at electrodes with a small surface area. Therefore, the electrolytic cell must be designed to increase the degree of conversion of the electroactive species (metal ion) as it passes through the remediation cell. This increase in conversion can be obtained by two means: (1) the use of a 3-dimensional electrode (increase surface area and residence time) and (2) turbulence (rotated electrode or flowing stream). The desire is to create a very high ratio of electrode surface area to electrolyte volume within the cell, coupled with turbulent mass transport within the electrode material. In this type of electrode, it is possible to control conversion efficiency using the length of electrode material through which the contaminated waste must pass.

This purpose of this work is to develop and test a cathodic material with an extremely large ratio of surface area to volume. This will be accomplished by using a packed-bed of conductive carbon, either as carbon fibers or carbon foams. Activation of these materials can lead to even greater surface areas. The increased surface area can help minimize the length of electrode through which the solution must pass. This decreased distance leads to reduced resistance to solution flow.

The removal of cadmium, lead and copper from laboratory-prepared samples using a small-scale model of the electrolytic cell has already been demonstrated in our laboratory. Removal efficiencies above 90% have been observed for continuous removal over a 72 hour period. This corresponds to an effluent concentration below 10 ppm for a inlet solution feed of 100 ppm. This work shall examine the use of this electrolytic remediation cell on waste streams containing radionuclides and "real" samples (obtained from industrial partners) and for the selective removal and recovery of precious metals. The final objective is to transfer this technology for "on-site" use in industrial applications.

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EXECUTIVE SUMMARY

Novel types of carbon materials have been tested for their ability to remove radionuclides and heavy metal ions from aqueous samples via electroplating and electrosorption. Removal efficiencies above 90% have been obtained for the reductive removal of cadmium, lead and copper. Long-term removal of lead over using electroplating on carbon nanofibers, vapor grown carbon fibers and carbon foam decreased the concentration of a 100 ppm lead feed to less than 10 ppm. Even after 72 hours, the carbon nanofibers showed no sign of saturation. For the 72 hour period, a capacity of $1.025 \text{ g}_{\text{Pb}}/\text{g}_{\text{carbon fibers}}$ is realized.

Removal via electrosorption using carbon nanofibers produced similar results, but with an early drop-off of efficiency and a much smaller capacity ($7.1 \times 10^{-4} \text{ g}_{\text{Pb}}/\text{g}_{\text{carbon fibers}}$ for a 57 hour period). This is due to the neutralization of the charge on the carbon surface caused by the electrosorption of the positively charged metal ions. It is envisioned that for aqueous streams, electrosorption will be applied to remove radionuclides and other metal ions that have reduction potentials more negative than that of water. The removal of radionuclides would decrease the volume of radioactive waste produced from the clean-up of decommissioned nuclear sites.

The recovery of metals was demonstrated using lead ions. The recovered effluent resulted in a 7-fold concentration of lead after reversal of the potential applied to the carbon material. This resulted in a decrease in the volume of lead waste by one-seventh.

ELECTROCHEMICAL REMEDIATION OF RADIONUCLIDES AND HEAVY METAL IONS

INTRODUCTION

PURPOSE

The purpose of this research was to assess the feasibility of using novel carbonaceous devices to remove radionuclides and heavy metal contaminants from aqueous streams. This work addresses the fabrication, behavior and analytical utility of these novel carbonaceous materials. Electrochemical techniques were employed to meet this objective.

BACKGROUND

Currently, there exists a rather serious problem associated with several nuclear production and processing facilities in the US. Over the years, large quantities of low-level radioactive waste, some in aqueous solution, have been accumulating at these sites in storage. Moreover, at some sites, this material has already leaked out and contaminated the soil over wide surface areas. In order to attack this problem, the DOE has expressed its desire to investigate new remediation techniques by promoting extremely applied and focused research programs. The work centers on the development of new procedures to remove and concentrate heavy metals and radionuclides from these low-level wastes. Most of the waste is in the form of aqueous solution and the new technique must be capable of reducing the concentration of contaminants down to parts per million (ppm) and in some cases parts per billion (ppb). Since the quantity of these wastes is large, the remediation procedure must be efficient and capable of being scaled-up in a predictable manner.

Industrial contacts have voiced a desire to remove several heavy metals from various aqueous streams. Heavy metal contaminants discussed include nickel, cadmium, copper, lead and chromium. Based on the standard reduction potentials, all of these metals should be excellent candidates for the technique developed in this program.

A technique which can be used to remove metal ions from solution is the electrochemical reduction or adsorption of the metal ions. In this procedure, a conductive surface acts as a electrode. A negative potential is applied to the electrode surface. The metal ions in solution are transported to the electrode surface via convection. Upon reaching the electrode surface, the metal ions are

adsorbed. If the potential is sufficiently negative the ions will be reduced and plated onto the electrode surface. In either case the metal ions are removed from the aqueous waste. While such a procedure is effective at lowering the concentration of the metallic species on the small scale, application at the large scale has been hindered due to the relatively small surface area of the metallic electrodes. This work assesses the performance of novel carbonaceous materials with large surface areas to remove radionuclides and heavy metal ions and their ability to be scaled up to applicable size.

Electrochemical techniques pertain to measurements involving the flow of electrons during a reduction-oxidation (redox) reaction. These measurements involve current, potential, charge and/or time as the primary variables. Electrochemical studies typically incorporate the use of a three-electrode system. This system includes a working, reference and auxiliary electrode. The redox reaction occurs at the surface of the working electrode as a result of the applied potential. Therefore it is critical to choose a suitable material for the working electrode. To be effective, the material must meet certain requirements. The electrode material should exhibit good electrical conductivity, be chemically inert over the potential region of interest, show favorable electrochemical behavior with the analyte(s), have a low background current and have an easily reproducible surface (1). Carbon materials are well suited for use as working electrodes. Graphite (2,3), carbon paste (4), glassy carbon (5) and reticulated vitreous carbon (RVC) (6) are a few examples of carbonaceous materials that have been used as working electrodes. A detailed discussion of carbon electrodes has been compiled by Dryhurst and McAllister (7).

Carbonaceous materials have been used to produce flow-through porous electrodes. Electrode materials have included graphite chips (8) or granules (9), glassy carbon grains (10), crushed graphite (11), screens of graphite (12) or carbon (13) and RVC (14). These porous flow-through electrodes have been used to remove metal ions from aqueous solutions. This is of major importance to industrial processes and environmental applications. The large surface area of porous flow-through electrodes makes them excellent candidates for the removal of metal ions from solution. Removal efficiencies approaching 100% can be achieved (14).

Discussions with METC personnel have ascertained the identity of several transuranics and radionuclides of concern. These metals include uranium, plutonium, cesium and strontium. Due to their large negative standard reduction potentials and the instability of the solid metals in water, electrosorption will be assessed for their removal. Due to the hazards of working with radioactive species, non-radioactive isotopes or surrogates will be employed. Strontium and uranium can readily be measured using polarography.

Once the metals have been removed from solution and accumulated onto the electrode surface, they can be recovered by reversing the applied potential. To recover selectively the metals, careful control of the applied potential is crucial. By applying a potential sufficiently negative to electroplate only one metal, it can be removed from the stream. Subsequent remediation cells with increasingly more negative potentials can be used in series to remove other metals. Each metal can thus be removed and recovered selectively.

The present work addressed the use of various carbon materials, including carbon fibers and porous carbon foams, to produce porous flow-through electrodes for the removal of metal ions from aqueous media. The resulting effluent was monitored downstream to assess the decrease in analyte concentration and hence the electrode efficiency.

EXPERIMENTAL METHODOLOGY

A schematic diagram of the apparatus used to carry out these experiments is shown in Figure 1. It was designed in the WVU lab and was produced by the WVU machinist. The carbonaceous material to be tested is placed between a platinum mesh screen and a filter. The platinum mesh is used to establish electrical contact to the carbon material. The purpose of the filter is two-fold. The filter prevents the carbon from flowing out of the cell and acts to distribute the solution evenly throughout the carbon bed. A predetermined potential is applied to the carbon material using a potentiostat. The sample solution is pumped through the carbon material and the unwanted metal contaminants are removed.

For the cathodic removal of metal ions, a potential more negative than the standard reduction potential of the metal ions of interest is applied to the working electrode (see Table I). This applied potential forces the plating of the metals onto the electrode surface thus removing the contaminant metal ions from solution.

Many metals can not be reduced at the electrode surface due to their large negative standard reduction potentials. The problem with these species is that their reduction potentials are more negative than that required to electrolyze water to hydrogen gas (H_2) and hydroxide ions (OH^-). Hence for aqueous solutions, water will be electrolyzed before these metals are electroplated onto the carbon surface. In these cases, electrosorption is applied. Electrosorption utilizes a negative potential which is more positive than the potential to reduce the metal ion. The positive charge of the metal ion is attracted to the negative charge on the electrode surface. The metal ions are loosely bound to the electrode surface due to electrostatic forces and are removed from the aqueous stream. Due to the neutralization of charge on the electrode surface, lower

removal efficiencies are expected. It is anticipated that most radionuclides will be removed by electrosorption since they generally have large negative standard reduction potentials (see Table I, for examples of Sr^{+2} and U^{+2}).

Experimental parameters require optimization to maximize the removal of these metal ions. These parameters include pH, electrolyte concentration, solution flow rate, applied potential and carbon bed thickness. Conversion efficiency, long-term stability and loading capacity must be assessed as well. Finally, the pressure drop and flow rate characteristics of the solution flowing through the carbon bed need to be evaluated.

CARBON SAMPLES

Several carbonaceous electrode materials have been obtained from a variety of sources for comparison. To date, the following samples have been obtained.

- Reticulated Vitreous Carbon (RVC) Foam (Duocel®, 3% density) from Energy Research & Generation, Inc. (ERG, Oakland, CA). 10, 20, 30, 45, 80 and 100 pores per inch (ppi).
- Vapor Grown Carbon Fibers (VGCF) (Pyrograf III, Lot ADNH, 104-107) from Applied Sciences, Inc. (ASI, Cedarville, OH).
- Vapor Grown Carbon Fibers (Pyrograf III, Lot AN-201, "as grown") from Applied Sciences, Inc.
- Vapor Grown Carbon Fibers (Pyrograf III, Lot AN-201, "oxidized") from Applied Sciences, Inc.
- Vapor Grown Carbon Fibers (Pyrograf III, Lot P-2, "pelletized", regular "AN" fiber) from Applied Sciences, Inc.
- "Coal-Derived" Carbon Foam (23 NMP, Sample # 001) from WVU (Morgantown, WV).
- "Coal-Derived" Carbon Foam (23 NMP, Sample # 001, crushed foam, 420-707 μm) from WVU.
- Carbon Nanofibers (#1094-A) from PSU (University Park, PA).
- Carbon Nanofibers (#1094-B) from PSU.
- Carbon Nanofibers (NF46, unsupported) from PSU.

- Graphite Fiber Mats from PSU.
- Carbon Nanofibers grown on Graphite Fiber Mats (#0295) from PSU.
- Graphite Felt (#0695-A) from PSU.
- Carbon Nanofibers grown on Graphite Felt (NF46, F100, CN37 and CF37 from PSU).

RETICULATED VITREOUS CARBON (15)

Reticulated Vitreous Carbon (RVC) is an open-pore material with a honeycomb (foam) structure (14). RVC is a form of carbon that combines some of the properties of glass with normal industrial carbon. RVC has a large void volume (97%) and a small surface area (0.09 m²/gram). It has a self-supporting rigid structure, a low resistance to solution flow and is resistant to temperatures up to 600 °F in air (16). A more thorough discussion of vitreous carbon is available in the literature (17-21). The samples obtained had various pore sizes. Sizes included 10, 20, 30, 45, 80 and 100 ppi (pores per inch). The 100 ppi RVC foam was tested in our study.

VAPOR GROWN CARBON FIBERS (22)

The VGCF manufactured by Applied Sciences, Inc. (ASI) is produced by a combination of catalytic and chemical vapor deposition processes which allow for control of the fiber dimensions, such as filament length and diameter. Lengths are available from 1 mm to tens of centimeters and diameters can vary from under 0.2 μm to over 100 μm. The resulting fiber has a lamellar morphology and is highly graphitic. Cross section and overall views of these samples were provided in the first year's quarterly reports.

"COAL-DERIVED" CARBON FOAM

These particular samples of carbon foam are made from coal-derived pitches produced at WVU by a novel solvent extraction process. By careful control of experimental parameters, an ultra-low ash foam precursor (pitch) is produced which upon careful heat treatment results in a low-density carbon foam structure. This "green" foam is then calcined at temperatures around 1000 °C and a highly conductive material results. The foam has an open-cell structure, enabling it to be used as an efficient carbon electrode.

CARBON NANOFIBERS

The carbon nanofibers were produced by our first year collaborators at The Pennsylvania State University (PSU). The nanofiber material is a microscopic version of a carbon fiber. It is produced by the metal catalyzed decomposition of certain hydrocarbons (23-24). Various degrees of graphitization are possible.

GRAPHITE FIBER MATS and GRAPHITE FELTS

Obtained commercially and supplied to WVU by Dr. Baker at The Pennsylvania State University.

All materials were treated with a dilute solution (10%) of nitric acid prior to use as the electrode material. If necessary to help activate or clean the surface, mild electrochemical or chemical methods were employed.

WORK PERFORMED THIS PERIOD

EXPERIMENTAL

Reagents:

Stock solutions of cadmium, lead, copper, uranium, strontium and nickel were prepared using atomic absorption standard solutions (Fisher Scientific, Fair Lawn, NJ) and deionized water. The deionized water used was further purified using a NANOpure™ ultrapure water purification system (Barnstead-Thermolyne, Dubuque, IA). These solutions were stored in polyethylene containers to avoid contamination. The 1.0×10^{-4} M mercury ion solution used for anodic stripping voltammetry was prepared from $\text{Hg}(\text{NO}_3)_2$ as needed. The mercury ion and sample solutions were prepared in 0.1 M KNO_3 (potassium nitrate) supporting electrolyte. The pH was adjusted using nitric acid. (All chemicals were certified ACS grade purchased from Fisher Scientific unless otherwise noted).

Surface Area Measurements:

The surface area of the samples has been determined and the data are shown in Table II. The surface areas were obtained at WVU using a Gemini III 2375 Surface Area Analyzer (Micrometrics Instrument Corporation, Norcross, GA). Standard operating procedures have been followed as outlined in the operator's manual.

A pre-weighed sample of the carbonaceous material was placed into a clean, dry sample tube. The sample was thoroughly de-gassed using nitrogen. The dewar was filled with liquid nitrogen and the system prepared for analysis.

The sample tube was connected to the analysis port and the balance tube was connected to the balance port. Care was taken to minimize exposure of the sample to air. The doors to the sample station were closed and the analysis initiated. Saturation pressure was set to 740.53 mm Hg and the evacuation rate to 599 mm Hg/min. The Gemini III 2375 performs automated analysis. It is capable of performing simultaneously BET multipoint and single point surface area, Langmuir surface area, t-method micropore and BJH adsorption/desorption distribution. The resulting data were recorded on an Epson plotter (Model P84FA).

Construction of the Remediation Cell:

The remediation cell (see Figure 1) was produced using a Lexan™ rod (5.0 cm diameter and 6.0 cm long). The flow channel (1.6 cm i.d.) was drilled through the Lexan™ body. A threaded Lexan™ plug was used to press the carbonaceous material between a platinum mesh and a piece of filter paper. The pressure on the carbon material can be easily adjusted by turning the threaded plug. The Ag/AgCl reference electrode (3M NaCl, Model RE-4, BioAnalytical Systems, Inc. (BAS) West Lafayette, IN) was introduced through a Lexan™ sleeve positioned 90 degrees to the flow channel. Leakage was prevented using an o-ring and compression fitting. A piece of coiled platinum wire inserted at the outlet of the cell was used as the auxiliary electrode. Contact to the working electrode was established via a platinum mesh.

Evaluation of Carbonaceous Materials:

The carbonaceous material to be studied was pretreated to clean, oxidize and assist in the wetting of the carbon surface. This was accomplished by placing the carbon material in a dilute solution (10%) of nitric acid overnight in a covered beaker. The material was then thoroughly washed using deionized water. The carbonaceous material was weighed and then positioned into the metal remediation cell using a clean glass rod.

The threaded plug is used to press the carbonaceous material between a platinum mesh and a piece of filter paper. The pressure on the carbon bed can be easily adjusted by turning the threaded plug. Rigid samples, such as RVC, were positioned using a snug fit. Electrical contact to the working electrode was established using the platinum mesh. The reference electrode was inserted into the sleeve and all three electrodes were connected to the potentiostat. The cell was connected to the pump using Tygon tubing and a 0.1 M KNO₃ electrolyte

solution was pumped through the flow cell. In order to help remove air bubbles and wet the electrode surface, a mild electrochemical pretreatment was used. The remediation cell was held at +1.00 V for 10 minutes followed by -1.00 V for 10 minutes.

The performance of the carbonaceous material under study was tested by placing a solution containing a known concentration of metal ions into the sample reservoir. The solution was then allowed to pass through the remediation cell at a known flow rate and applied potential. The potential of the remediation cell was controlled using a Power Module (Model PWR-3, BAS). The performance was assessed by measuring the metal ion concentration in the effluent and comparing it to the initial ion concentration. The percentage efficiency of the remediation cell is equal to the percentage of metal ions removed from the solution by the remediation cell. (For these studies, the effluent was collected in Nalgene bottles for subsequent analysis via voltammetry and/or atomic absorption).

Anodic Stripping Voltammetry:

The thin-layer flow cell was purchased from BAS (Model LC-44-01000). The working electrode was glassy carbon disk (0.3 cm diameter) over which the solution flows. Two 50 μm spacers were used to produce the flow channel and direct the sample solution across the carbon disk. Prior to use, the glassy carbon disk was polished using successive slurries of 1.0, 0.3 and 0.05 μm alumina until a mirror-like surface was obtained. The glassy carbon disk was then rinsed thoroughly with deionized water and assembled. All potentials were measured relative to the Ag/AgCl reference electrode (BAS, Model RE-4). Stripping voltammograms at the thin-layer flow cell were obtained using the BAS Model CV-27 Voltammograph in conjunction with a Hewlett Packard Model 7044B X-Y Recorder.

Polarography:

Polarographic data will be obtained using a Static Mercury Drop Electrode (SMDE) (Model 303A, EG&G Instruments, Princeton Applied Research, Princeton, NJ) in conjunction with a potentiostat (Model 263A, EG&G) and interface (Model 507, EG&G). This system has just been received and is currently be assembled. Upon assembly and calibration, this instrument will be utilized to measure the uranium and strontium ion concentrations in the effluent stream. (The 100 ppm solution being tested is below the detectable limits of Atomic Absorption. Polarography can be used to measure uranium concentrations down to 20 ppb).

Atomic Absorption:

Spectroscopic data were obtained using an Atomic Absorption Spectrophotometer (Model 2380, Perkin-Elmer, Norwalk, CT). Procedure and experimental conditions were outlined in the Perkin-Elmer "Analytical Methods of Atomic Absorption Spectrophotometry" Cookbook. All standards and samples were matrix-matched prior to analysis.

RESULTS and DISCUSSIONS

Several carbonaceous materials were examined for their performance as the cathode material. Each sample was tested to determine the effect of adsorption (no applied potential) and electroplating. Their performance was evaluated on their ability to remove the metal ions from solution.

To confirm minimal contribution from the platinum mesh to the metal removal, the system was first tested in the absence of any carbonaceous material. The response of the original feed solution was compared to the response of the effluent collected at -1.00 V. It was shown that the platinum mesh does not contribute significantly (<2%) to the removal of the metal ions. Therefore, the removal of the metal ions is due to their interaction with the carbonaceous material and is not significantly influenced by the platinum mesh.

In order to assess electrosorption, the carbon electrodes were tested for their ability to remove cadmium and lead at potentials more positive than that required to reduce the metal ions. The removal of cadmium was examined at various potentials above and below its theoretical reduction potential. Figure 2 shows the ASV response for a cadmium solution passed through the remediation cell at these potentials. Based on the initial cadmium feed concentration (100 ppb), the potential at which cadmium should be reduced is -0.58 V. Electrosorption removed 46% of the cadmium from the solution at -0.20 V and 78% at 0.40 V. At potentials more negative, electroplating removes 89% at 0.60 V, 91% at 0.80 V and nearly all (99%) at -1.00 V. The percentage of cadmium removed versus applied potential is also shown (inset).

Figure 3 shows the response for lead under the same conditions. The theoretical reduction potential for lead is -0.54 V. Removal of lead via electrosorption is shown also to occur at potentials more positive than the reduction potential. The removal efficiencies were 88% at -0.20 V and 92% at -0.04 V.

Continuous removal of lead from an aqueous stream using electroplating and electrosorption was used to demonstrate the long-term effectiveness of carbon nanofibers. The lead solution was passed through the remediation cell and the ions were removed by applying the desired potential to the carbon nanofibers. A potential of -1.00 V was applied to the remediation cell to remove lead ions via electroplating. Over a 72 hour period, removal efficiencies of 89% or greater were achieved for an inlet concentration of 100 ppm lead. Calculation of the lead removed over this period demonstrates a capacity of 1.025 g_{Pb}/g_{carbon fibers}, but it should be stressed that even at 72 hours, the carbon showed no signs of saturation (see Figure 4).

Removal of lead ions via electrosorption was carried out using a potential of -0.40 V. For an inlet lead ion concentration of 100 ppb, good removal efficiencies (90%) were obtained for the first 12 hours (see Figure 5). After that time a noticeable decrease in efficiency is evident. The removal efficiency drops to less than 50% after 57 hours. This decrease in removal efficiency is expected due to the neutralization of charge on the electrode surface. Regeneration of the carbon nanofibers would be required to maintain high removal efficiencies. For the first 12 hours of removal a capacity of $1.9 \times 10^{-4} \text{ g}_{\text{Pb}}/\text{g}_{\text{carbon fibers}}$ is obtained. At 57 hours this capacity increases to $7.1 \times 10^{-4} \text{ g}_{\text{Pb}}/\text{g}_{\text{carbon fibers}}$. Electrosorption of lead using a 100 ppm lead feed was attempted. Due to the smaller capacity of the carbon nanofibers when using electrosorption, the efficiency should drop off very quickly. As expected, within the first two hours the removal efficiency dropped to less than 20%.

The final desire is to recover the metals once they have been removed from the aqueous stream. It is possible to recover the metal ions plated on the electrode simply by reversing the potential. The metal ion concentration in the resulting effluent is more greater than that of the feed. Electrodeposition and the subsequent recovery from carbon nanofibers was demonstrated with a 100 ppm lead ion feed. The lead ions were removed from the aqueous stream using an applied potential of -1.00 V. Subsequent recovery of the lead at an applied potential of +1.00 V, produced an effluent stream more concentrated in lead. The lead concentration in the recovered effluent was 730 ppm, demonstrating a 7:1 concentration of the waste stream. Individual metal ions can be removed and recovered selectively by these means.

A summary of the electrodeposition removal efficiencies for the carbon samples tested to date are shown in Table III. These results demonstrate that carbonaceous materials are extremely effective for the removal of heavy metal ions from solution.

Industrial Application:

Contact has been established with Mr. Jim Zievers, President of Industrial Filter & Pump Mfg. Co. in Chicago, IL. Through his representative, Mr. Mel Siska, a Chicago-based metal plating facility has been identified as a cooperating partner for the immediate industrial application of this research. It has been proposed that the electrochemical method developed in this research be applied to their nickel-plating line for the removal and recovery of nickel. The final rinse stage produces an aqueous waste contaminated with nickel. The objective is to purify the rinse water for reuse and to recover the nickel for recycling back into the plating process.

Removal of nickel at the experimental conditions used for lead and cadmium resulted in low removal efficiencies. Due to the unique chemistry of

nickel, careful attention must be taken to increase the removal. Table IV demonstrates the need for tailoring the removal process of nickel. By applying a more negative potential (i.e. -1.60 V) enhanced removal efficiencies are obtained (97.9%). But at this potential the water is reduced and current is wasted due to the production of hydrogen gas. By simply pre-plating a small layer of copper or mercury, enhanced removal efficiencies are obtained. The removal efficiency is also dependent upon the pH of the contaminant solution. For a 100 ppm nickel solution at pH 7.0, a small layer of pre-plated copper and a remediation cell potential of -1.20 V, 89.1% of the nickel is removed.

Radionuclides:

Two metals have been identified that need to be removed from aqueous wastes generated at several nuclear production and processing facilities: strontium and uranium. Both of these metals are available in non-radioactive forms. Strontium can be easily measured by atomic absorption at all levels under study. Atomic absorption can not be used to determine uranium concentrations below 100 ppm. Therefore, polarography will be used to facilitate the measurement of uranium. Polarography can determine uranium concentrations between 20 ppb and 500 ppm. The "static mercury drop electrode" used for polarography was received this quarter and is currently being assemble and tested. Preliminary removal of strontium is discussed below.

No removal of strontium was observed using the untreated WVU foam. This was expected due to the relatively low surface area ($0.5 \text{ m}^2/\text{g}$) of the "non-activated" carbon foam. Activation of the foam surface could increase the surface area to values necessary for the electrosorption of strontium and such an activation is in preparation.

The improvement in removal efficiencies using the higher surface area carbon fibers is shown in Table V. Removal of strontium using carbon nanofibers resulted in 5.90 % of the strontium to be removed. Usage of the ASI carbon fibers improved this removal to 34.4%. This improvement is most likely due to differences in the surface properties of the two carbon fibers. Alternative removal schemes, similar to those used for nickel are currently being examined to improve even further the removal of strontium from the aqueous waste.

3-inch Prototype Remediation Cell:

Construction of the 3-inch prototype remediation cell has been completed. A schematic of the apparatus is shown in Figure 6. The assembled system will include a flowmeter to measure flow rates and a manometer to measure the pressure drop across the remediation cell. The remediation cell was produced by machining a 4-inch Lexan™ rod. The 3-inch diameter flow channel was drilled through the Lexan™ body. Via the threaded plug, the depth of the carbon

electrode bed can be varied between 0.5 and 4.0 inches. Electrical contact is established in the same manner used in the smaller cell. The prototype is currently being assembled and parametric studies will begin in the 2nd quarter.

Presentations:

During the last quarter, two presentations of this research were made. The first was at the 1996 METC Program Review on March 22, 1996 in the NRCCE Building on the West Virginia University Campus in Morgantown, WV.

The second was on 28 March, 1996 at the 211th National Meeting of the American Chemical Society in New Orleans, LA.

CONCLUSION

All proposed objectives have been met to date (see Table VI). An extensive search of the literature has been conducted in the areas of heavy metal removal, waste water treatment and water remediation. More than 150 papers have been amassed in these areas with special interest in the areas of electrochemistry and electrowinning using carbonaceous material. Further effort has been exerted in order to find applications of this technology to radionuclides.

The thin layer flow cell to be used as the detector for anodic stripping voltammetry has been assembled and has been thoroughly tested. This testing included characterization, calibration and verification. The flow cell will be connected "on-line" and used to monitor continuously the concentration of metal ions in the effluent stream.

The Atomic Absorption Spectrophotometer has been similarly tested. The testing has been performed using specific hollow cathode lamps specific for the individual metals under analysis. Spectrophotometric analysis was performed "off-line".

The performance of the commercially available RVC as a cathode was satisfactory. Improved removal efficiencies were obtained with the novel carbon materials utilized in this study. Loose carbon nanofibers with a relatively large surface area ($200 \text{ m}^2/\text{g}$) effectively removed over 90% of cadmium and lead from an aqueous sample. Vapor Grown Carbon Fibers supplied by ASI also worked well for the removal of cadmium and lead by electroplating. The "coal-derived" foam produced in the WVU laboratory was an excellent cathode material. The concentration of lead in the effluent dropped below detectable amounts after only 4 hours. This demonstrated removal efficiencies approaching 100%.

The current industrial application of this technology was for the removal of nickel from a rinse solution used in the plating industry. Upon selection of the proper experimental conditions, a removal efficiency of 89.1% was obtained. This was accomplished by adjusting the pH of the waste stream and by pre-planning a small amount of copper onto the carbon surface to help catalyze the reduction of nickel.

The removal of strontium was demonstrated using carbon fibers. Removal efficiencies up to 34.4% were obtained, but removal capacity was soon reached. Other removal schemes with similar metal reaction mechanisms to those used for nickel are being examined. Currently, no removal data has been obtained for uranium.

WORK PLANNED for NEXT PERIOD

In the next quarter, the following work will be conducted,

- The 3-inch remediation cell will be assembled and parametric studies will commence.
- The removal of strontium will be maximized via tailoring the electrosorption process.
- Calibration of the Static Dropping Mercury Electrode will begin for the measurement of uranium.
- Testing for the removal of uranium will commence using carbon fibers and carbon foams.
- Test the remediation cell's ability to remove nickel from "REAL" industrial samples.

Figure 1. Schematic of Electrochemical Remediation Cell.

Figure 2. Effect of Remediation Cell Potential on Cadmium Removal.

Figure 3. Effect of Remediation Cell Potential on Lead Removal.

Electroplating

Capacity @ 72 hours > 1.025 grams Pb/ gram of carbon
(***NOT at Saturation***)

Flow Rate = 3.1 mL/min/(gram carbon)

Figure 4. Long-Term (72 hr) Removal of Lead Using Carbon Nanofibers. ($E_{\text{CELL}} = -1.0 \text{ V}$)

REMOVAL of Pb USING CARBON NANOFIBERS

Figure 5. Long-Term (102 hr) Removal of Lead via Electrosorption.
(Conditions: $E_{\text{CELL}} = -0.40 \text{ V}$)

Figure 6. Schematic Diagram of the 3-inch Remediation Cell.
 (1-Flowmeter; 2-Cell; 3-Manometer; 4-Pump; 5- Auxiliary Electrode;
 6-Pt Contact to Working Electrode; 7-Reference Electrode.)

TABLE I: STANDARD REDUCTION POTENTIALS OF THE METAL IONS OF INTEREST

Reduction Reaction	E, V (vs. Ag/AgCl)

ELECTROSORPTION	
$\text{Sr}^{+2} (\text{aq}) + 2\text{e}^{-} \rightarrow \text{Sr} (\text{s})$	-3.108
$\text{U}^{+2} (\text{aq}) + 2\text{e}^{-} \rightarrow \text{U} (\text{s})$	-2.022

$2\text{H}_2\text{O} (\text{l}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-} (\text{aq})$	-1.050

ELECTROPLATING	
$\text{Zn}^{+2} (\text{aq}) + 2\text{e}^{-} \rightarrow \text{Zn} (\text{s})$	-0.986
$\text{Cd}^{+2} (\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cd} (\text{s})$	-0.624
$\text{Ni}^{+2} (\text{aq}) + 2\text{e}^{-} \rightarrow \text{Ni} (\text{s})$	-0.453
$\text{Pb}^{+2} (\text{aq}) + 2\text{e}^{-} \rightarrow \text{Pb} (\text{s})$	-0.348
$\text{Cu}^{+2} (\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$	+0.115

TABLE II: PROPERTIES of CARBON MATERIALS**Surface Areas**

Material	Surface Area (m ² /gram)	
	BET	Langmuir
Vapor Grown Carbon Fibers (ASi)		
Regular "AN" Fiber	76.78 (73.6)*	122.66
Oxidized "AN" Fiber	25.78	-
Pelletized "AN" Fiber	20.25 (20.77)*	-
WVU "coal-derived" Foam (23 NMP)	0.52	-
Carbon Nanofibers		
1094-A	115.13 (227.8)*	186.78
1094-B	182.77 (192.3)*	286.03
NF-46	43.28	-
Graphite Fiber Mats	0.59	-
Graphite Mat with Fibers	99.92 (112.8)*	-
Graphite Felt	0.17	-
Graphite Felt with Fibers		
NF46	55.41	-
F100	54.54	-
CF37	13.96	-
CN37	35.31	-
VGCF	76.78 (73.6)*	122.66
RVC		
100 ppi	0.092	-
80 ppi	44.80	-
Activated Carbon	784.32	-

TABLE III: Removal Efficiencies for Cd and Pb

<u>Cathode Material</u>	<u>Cathode Potential, V</u>	<u>Metal Removed</u>	
		Cd	Pb
Platinum Mesh	0.00	0%	0%
	-1.00	0%	9%
RVC	0.00	16%	0%
	-1.00	50%	8%
Nanofibers (1094-A)	0.00	0%	0%
	-1.00	91%	95%
Nanofibers on Graphite Mats	0.00	0%	0%
	-1.00	90%	92%
Graphite Felt	0.00	13%	7%
	-1.00	22%	97%
Nanofibers on Graphite Felt	0.00	0%	0%
	-1.00	46%	99%
ASI Carbon Fibers			
"pelletized"	0.00	-	0%
	-1.00	-	98%
"oxidized"	0.00	-	0%
	-1.00	-	99%
WVU "Coal-Derived" Foam			
"crushed"	0.00	-	0%
	-1.00	-	99%

TABLE IV: IMMEDIATE INDUSTRIAL APPLICATION

(REMOVAL OF NICKEL VIA ELECTROPLATING)

$$E^\circ = -1.050 \text{ V}$$

$$E^\circ = -0.453 \text{ V}$$

MATERIAL	SURFACE CONDITION	pH	E _{CELL} , Volts	TIME, hours	% REMOVED
WVU Foams	bare-crushed	3.5	-1.2	2	0.00
		7.0	-1.2	2	0.00
			-1.4	2	68.7
			-1.6	2	97.9
	w/ Cu	3.5	-1.2	2	49.0
				4	57.3
		7.0	-1.2	2	82.4
				4	89.1
	w/ Hg	3.5	-1.2	2	44.3
				4	47.6
				6	50.6

TABLE V: DOE APPLICATION
REMOVAL OF STRONTIUM VIA ELECTROSORPTION

$$E^{\circ} = -2.022 \text{ V}$$

$$E^{\circ} = -1.050 \text{ V}$$

MATERIAL	CONDITION	pH	E _{CELL} , Volts	TIME, hours	% REMOVED
Nanofibers	bare	3.5	-1.00	2	5.90
				4	5.60
				6	<1.00
			-1.20	2	5.70
				4	3.20
				6	3.10
WVU Foams	bare	3.5	-1.20	2	0.00
		7.0	-1.20	2	0.00
		11.0	-1.20	2	0.00
ASI	"pelletized"	7.0	-1.20	0.5	34.4
Nanofibers					

TABLE VI: PROJECT COMPLETION

ENVIRONMENTAL POLLUTION CONTROL DEVICES BASED ON NOVEL FORMS of CARBON

<u>Task #</u>	<u>WSB Code</u>	<u>Task Name</u>	<u>Duration</u>	<u>% Complete</u>
1	1.0	Identify Surrogates for Radionuclides.	JAN	100%
2	1.1	Provide List of Surrogates.	FEB	100%
3	2.0	Characterize Carbonaceous Materials.	JAN-OCT	20%
4	3.0	Use Small Remediation Cell to Test Other Carbonaceous Materials.	JAN-OCT	20%
5	3.1	Assess Carbon Material's Ability to Remove Heavy Metals and Radionuclides	JAN-DEC	20%
6	4.0	Construct 3-inch Remediation Cell	JAN-APR	90%
7	4.1	3-inch Remediation Cell Constructed	APR	90%
8	4.2	Engineering Parametric Studies on 3-inch Cell	APR-DEC	0%
9	4.3	Derive Correlations	JUN-DEC	0%
10	5.0	Test Metal Removal and Recovery Schemes	JAN-DEC	20%
11	6.0	Obtain "REAL" Samples from Industry.	FEB-DEC	0%
12	6.1	Test Removal Schemes Using Small Cell on "REAL" Samples.	JAN-DEC	20%
13	6.2	Apply 3-inch Prototype to "REAL" Samples	AUG-DEC	0%
14	7.0	Analysis and Reporting		
15	7.1	Analysis and Data Reduction	JAN-DEC	20%
16	7.2	Reports and Manuscripts	JAN-DEC	25%
17	8.0	Closure	DEC	
18	9.0	Overall Work Complete	DEC	

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**DEVELOPMENT OF INSTRUMENTAL METHODS
FOR CHARACTERIZATION AND ANALYSIS
OF NUCLEAR WASTES AND ENVIRONMENTAL CONTAMINANTS**

METC Task No. 2.5

Quarterly Technical Progress Report
Reporting Period: 1 January 1996 - 29 March 1996

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ABSTRACT

Technetium 99 (^{99}Tc) and Iodine 129 (^{129}I), common constituents of nuclear wastes at Hanford, Washington, and other DoE sites, are important target analytes in both the tank wastes themselves and in site aquifers. Characterization and chemical speciation of both of these radionuclides in tank wastes and aquifers therefore represents an important DoE research goal. The work described herein focuses on the development of new analytical strategies for the chemical speciation and quantitation of ^{99}Tc and ^{129}I in simulated nuclear waste tank and aquifer matrices. These tasks are being accomplished through the development of new methodologies in the area of capillary electrokinetic separations. Capillary zone electrophoresis (CZE) and open tubular capillary electrokinetic chromatography (OT-CEC) methods are being developed for each of the target ions. The CZE studies center on the determination of optimum separation parameters including: selection of operating buffer composition and ionic strength, optimization of buffer pH, selection of operating potential and injection conditions, and development of detection strategies (including UV, indirect fluorescence, and radiometric detection). The OT-CEC studies focus on the development of novel self-assembled monolayer stationary phases for ion exchange separations. This approach should provide higher loading capacities and therefore improved detection limits. Here, the novel detection strategies employed will include indirect fluorescence detection for the determination of small quantities of ^{99}Tc and ^{129}I , and radiometric detection for the analysis of ^{99}Tc . It is expected that these developments will lead to rugged, reproducible, cost-effective means for determining ^{99}Tc and ^{129}I forms and levels in various matrices.

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EXECUTIVE SUMMARY

The focus of this research effort is the analysis of technetium 99 (^{99}Tc) and iodine 129 (^{129}I), common constituents of nuclear wastes at Hanford, Washington, and other DoE sites. These species are important target analytes in both the tank wastes themselves and in site aquifers. Characterization and chemical speciation of both of these radionuclides in tank wastes and aquifers therefore represents an important DoE research goal.

This work focuses on the development of new analytical strategies for the chemical speciation and quantitation of ^{99}Tc and ^{129}I in simulated nuclear waste tank and aquifer matrices. Capillary zone electrophoresis (CZE) and open tubular capillary electrokinetic chromatography (OT-CEC) methods are being developed for each of the target ions. The CZE studies center on the determination of optimum separation parameters including: selection of operating buffer composition and ionic strength, optimization of buffer pH, selection of operating potential and injection conditions, and development of detection strategies (including UV, indirect fluorescence, and radiometric detection).

Later in the project (in the third and fourth quarters of this first project year), the OT-CEC studies will focus on the development of novel self-assembled monolayer stationary phases for ion exchange separations. This approach should provide higher loading capacities and therefore improved detection limits. Here, the novel detection strategies employed will include indirect fluorescence detection for the determination of small quantities of ^{99}Tc and ^{129}I , and radiometric detection for the analysis of ^{99}Tc .

It is expected that these developments in the field of microelectrokinetic separations will lead to rugged, reproducible, cost-effective means for determining ^{99}Tc and ^{129}I forms and levels in various matrices. Ultimately, these newly developed tools will be applied in the analysis of other target analytes.

1.0 INTRODUCTION

The development of several new tools for chemical analysis is proposed for the qualitative and quantitative determination of two important target analytes in Hanford site tank wastes and in site aquifers. Innovations in capillary zone electrophoresis and open tubular capillary electrokinetic chromatography will yield powerful methods for the separation of ^{99}Tc and ^{129}I from other components of simulated tank wastes and aquifer matrices. The use of novel detection strategies, including indirect fluorescence detection and radiometric detection, with the two separation methods will provide for the determination of trace quantities of ^{99}Tc and ^{129}I in small (pL to nL) volume samples, thus limiting human exposure to hazardous wastes. These advanced technology tools are expected to have commercial value, as evidenced by the interest and support of two firms which are active in the environmental analysis and remediation industry: Selective Environmental Technologies, Inc. (Selentec), a small business headquartered in Atlanta, GA; and Battelle Northwest, a research institute and US Department of Energy Contractor with offices in Richland, WA. The interest of Selentec in the project is indicated by the attached letter of endorsement. Battelle's interest is indicated by the provision of laboratory facilities, equipment, and personnel in several stages of the project. The support of these two entities bodes well for the success of the project and for the possibility of transfer of the technology to the marketplace after sufficient development.

2.0 PURPOSE

Technetium 99 (^{99}Tc) and Iodine 129 (^{129}I), common constituents of nuclear wastes at Hanford, Washington, and other DoE sites, are important target analytes in both the tank wastes themselves and in site aquifers. [1] Characterization and chemical speciation of both of these radionuclides in tank wastes and aquifers therefore represents an important DoE research goal. The work proposed herein has as its purpose the development of new analytical strategies for the chemical speciation and quantitation of ^{99}Tc and ^{129}I in simulated nuclear waste tank and aquifer matrices. These tasks will be accomplished through the development of new methodologies in the area of capillary electrokinetic separations (both capillary zone electrophoresis (CZE) and open tubular capillary electrokinetic chromatography (OT-CEC)) and the use of novel detection strategies for the determination of small quantities of ^{99}Tc and ^{129}I . It is expected that these developments will lead to a rugged, reproducible, cost-effective means for determining ^{99}Tc and ^{129}I forms and levels in various matrices.

The proposed studies address DoE needs in the focus area of *Crosscutting Technologies and Supporting Programs*, specifically in the sub areas of both *Innovative Technologies/Supporting Programs* and *Industry Programs*.

This project will foster the development of a strong research partnership between the US Department of Energy's Pacific Northwest Laboratory and the Department of Chemistry at West Virginia University. Prof. Remcho's research program in microscale separations will make a unique contribution to the US DoE effort to measure, remediate, contain, and monitor wastes produced at the Hanford Reservation over the past half-century. This contribution will be facilitated and augmented through Dr. Ballou's research program at Battelle-Northwest. Dr. Ballou has directed environmentally relevant research projects for the US DoE for over 20 years, and his unique expertise and laboratory facilities will both support the project and ensure a consistent focus on Hanford needs. This collaborative approach offers the following benefits:

1. the infusion of new ideas and technology into the Hanford waste cleanup effort;
2. an enhancement of West Virginia University's research effort in environmental analysis and remediation;
3. reduced research and development costs for DoE; and
4. the development of a strong and mutually beneficial bond between the US DoE's Pacific Northwest Laboratory and West Virginia University.

The high efficiency and high peak capacity typical of capillary electrokinetic separation techniques [2], coupled with the high selectivity of radiometric detection and high sensitivity of indirect fluorescence detection, will provide a powerful set of tools for characterization and chemical speciation of Hanford waste tank constituents. The technology developed in this initial research effort will be extended and applied to other analytes and matrices in follow-on studies.

3.0 BACKGROUND

Instrumental methods are being developed for the determination of ^{99}Tc and ^{129}I in simulated nuclear waste tank and aquifer matrices. The use of simulated matrices in method development provides a wide margin of safety by minimizing/eliminating exposure to radioisotopes and by eliminating the need to transport radioactive species. The use of simulants also allows for rapid method development because of the increased simplicity of working with a non-radioactive, well-defined matrix. These combined benefits result in savings in both time and expense.

The target analytes, iodine and technetium, are primarily present in solution as iodide, iodate, and pertechnetate anions. These anions are the focus of the initial research. In the

interest of safety and practicality, a surrogate stable isotope of iodine (^{127}I) is being employed in developing both CZE and OT-CEC methods for iodine determination. ^{127}I , end product of the mass 127 decay chain, is also a component of tank waste and is present in a concentration similar to that of ^{129}I . ^{99}Tc will be handled in trace quantities using the unique facilities and expertise available at Battelle-Northwest.

4.0 METHODOLOGY

The separation technologies to be employed in conducting the work include both CZE and OT-CEC. CZE is conducted by introducing a small (~ 10 nL) sample into the open end of a 50 to 100 μm ID fused silica capillary, about 50 cm in length, whose ends are immersed in buffer-filled reservoirs. The sample is introduced either electrokinetically, by applying ca. 50 V/cm for 2-10 seconds; or hydrodynamically, by applying 3-10 psi for 2-10 seconds, while the inlet buffer reservoir is replaced with the sample reservoir. A potential gradient of 100-500 V/cm is then applied along the axis of the capillary, resulting in the separation of analytes according to differences in their charge and size. In addition to the electrophoretic movement of analytes induced by their charge, species are swept along the capillary via electroosmosis: bulk transport of solution in the capillary. Electroosmosis arises from the electrochemical double layer at the charged surface of the capillary when shear forces are generated by application of the high potential. Detection of the separated analyte zones is usually achieved using a UV detector, with a segment of the capillary itself serving as the optical flow cell. Here, the polymeric coating of the fused silica capillary is abraded or burned to produce a clear fused silica surface with excellent UV and visible optical transmission characteristics.

OT-CEC is a promising new technique for achieving microscale separations. [3] Essentially, OT-CEC represents the intersection of capillary electrophoresis and open tubular liquid chromatography. As such, it provides the unique benefits of each of these two techniques while overcoming some of the limitations of each. OT-CEC is conducted in open fused silica capillaries (~ 10 μm ID), though the walls of the capillary are modified by the application of a chromatographic stationary phase. This stationary phase may be either covalently attached to the fused silica capillary, or formed as a self-assembled monolayer of small molecules. In all other respects, the instrumentation employed in OT-CEC is identical to that used in CZE.

The detection strategies employed will include: 1) UV detection for development of a CZE method for the determination of iodine; 2) indirect fluorescence detection for sensitivity optimization in the determination of iodine and technetium by both CZE and OT-CEC; and 3) radiometric detection for the determination of ^{99}Tc by both CZE and OT-CEC.

5.0 WORK PERFORMED THIS PERIOD

5.1 Literature Search.

A thorough search of the chemical literature has been conducted in order to avoid duplication of effort and to provide the necessary background information for conducting these studies.

5.2 Development of CZE Methods for Analysis and Speciation.

0.01 M stock solutions of NaI, NaIO₃, and NaReO₄ (Sigma Chemical Co., St. Louis, MO, USA) were prepared in distilled, deionized water for use in method development. Serial dilutions of these were made in the appropriate buffer solutions as necessary for each stage of the experimental work. Unless otherwise noted, 50 µm ID fused silica capillary tubing (Polymicro Technologies, Phoenix, AZ, USA), 365 µm in OD, was used in all of the work described herein. Total capillary length (L_{tot}) was 65 cm, the effective length (length to detector, L_{det}) was 50 cm. All work was carried out using an ATI-Unicam (Boston, MA, USA) Crystal 310 CE system. Separations were conducted with the anode at the outlet reservoir due to the fact that $\mu_{\text{ep}} > \mu_{\text{eof}}$ for all of the analytes studied.

5.2.1 Analysis and Speciation of Ionic Iodine Species.

¹²⁹I and ¹²⁷I are most often present in solution as iodide (I⁻) and/or iodate (IO₃⁻). The charge/volume ratio for these two species in solution was found to be sufficiently different to allow for facile separation by capillary zone electrophoresis in standard operating buffer solutions. This technique entailed the axial application of a 100 to 500 V/cm potential gradient to the separation capillary using a high voltage power supply. The platinum electrodes used in this method were immersed into two small reservoirs filled with aqueous buffer solutions, one at each end of the fused silica capillary in which the separation is conducted. A window for optical detection was burned near an end of the capillary using a fiber optic fusion splicer (Alcoa-Fujikura, Atlanta, GA, USA). UV detection was employed in initial studies. Both I⁻ and IO₃⁻ absorb in the low UV (~200 nm), allowing for non-radioactive (¹²⁷I) iodide and iodate to be determined by CZE-UV when working at moderately high analyte concentrations. Initial experiments were conducted using a 25 mM β-alanine operating buffer at pH 3.5, and employed direct UV-Vis detection at 220 nm. Poor results prompted a shift to a 100 mM acetate buffer system, pH 4.5, which allowed for analysis of iodide with a limit of detection of approximately

10^{-3} M. Excessive analysis times led to the addition of 1 mM CTAB (cetyltrimethylammonium bromide) in an effort to increase the speed of the separation. Later work indicated that phosphate buffers would allow for optimal separation and detection conditions. These results are discussed in section 6.0, below.

Work also commenced on the construction of a fluorescence detector designed in-house. The necessary components have been ordered and assembly of the system has begun. It is anticipated that the detector will be operational in the second quarter of this project year. A schematic of the apparatus to be used in the CZE laser-induced fluorescence (LIF) studies is shown in Figure 1.

Figure 1. Schematic of CZE-LIF apparatus.

5.2.2 Analysis and Speciation of Ionic Rhenium and Technetium Species.

Technetium is most often present in solution as pertechnetate (TcO_4^-) ion. Since no stable isotope of technetium exists, the close and non-radioactive chemical homolog of technetium, rhenium, is being used initially to significantly simplify the experimentation. Perrhenate (ReO_4^-) ion is being used to determine appropriate operating and detection conditions. These conditions will then be validated first with standard solutions of ^{99}Tc and then with simulated tank waste solutions containing ^{99}Tc . ^{99}Tc is a beta emitter, and thus should be detectable at relatively low levels using a commercially available Raytest Steffi^{TM} radiometric detector (Raytest Inc., Wilmington, DE). [23] This detector is a component of the original budget, and has been ordered. Delivery is anticipated early in the second quarter of the current project year. Use of this highly sensitive, selective detector will minimize exposure to

radioactive sources and provide the trace level detection capability necessary for determination of ^{99}Tc in tank waste simulant and aquifer samples.

Initial work on perrhenate analysis has begun. Detection is by UV-Vis at 190 nm and buffer solutions are as described in section 5.2.1, above. This should allow for analysis of iodide, iodate, and perrhenate in a single step.

6.0 RESULTS AND DISCUSSION (Current Period)

6.1 Literature Search.

Several useful references on ion separations [4-11], indirect detection [12-14], radiometric detection [15], and self-assembled monolayer formation [16-22] were found. These references have aided in experiment design and facilitated rapid method development.

6.2 Development of CZE Methods for Analysis and Speciation: Analysis and Speciation of Ionic Iodine Species & Ionic Rhenium and Technetium Species.

6.2.1 Operating Buffer Composition Study.

Several operating buffer compositions were employed in an effort to identify a buffer which provided for high efficiency and resolution, and which allowed for facile UV detection. The four systems studied included:

1. β -alanine (25 mM, pH 3.50)
2. acetate (100 mM, pH 4.5)
3. acetate/CTAB (100 mM / 1 mM, pH 4.5)
4. phosphate (25 mM, pH 2.9)

β -alanine (25 mM, pH 3.50):

A 10^{-4} M mixed standard containing iodide, iodate, and perrhenate prepared in distilled, deionized water was introduced to the separation capillary using a hydrodynamic injection of 0.05 min. duration at 25 mbar. UV detection at 220 nm and at 200 nm were employed. Applied

potential was -20 kV for 30 min. No separation was obtained for the three component test mixture in > 10 trials.

acetate (100 mM, pH 4.5):

A 10^{-4} M mixed standard containing iodide, iodate, and perrhenate prepared in distilled, deionized water was introduced to the separation capillary using a hydrodynamic injection of various durations at 25-50 mbar. UV detection at 220 nm and at 200 nm were employed, and other wavelengths in the 190-230 nm range were also studied. Applied potential was -20 kV for 30 min. Conditions were roughly based on reference [7]. A separation of iodide and perrhenate was achieved when a 10^{-4} M mixed standard sample was used. Efficiencies in excess of 83,000 theoretical plates were realized for iodide. Iodide and iodate were not resolved using this operating buffer system. These results were the best obtained for the three component test mixture in > 15 trials.

acetate/CTAB (100 mM/1 mM, pH 4.5):

A 10^{-3} M mixed standard containing iodide, iodate, and perrhenate prepared in distilled, deionized water was introduced to the separation capillary using a hydrodynamic injection of 0.25 - 0.37 min. duration at 50 mbar. UV detection at 200 nm was employed, other wavelengths in the 190-260 nm range were also studied. Applied potential was -20 kV for 30 min. A separation of iodide and iodate was achieved when a 10^{-3} M mixed standard sample was used, though a peak for perrhenate was not observed. It is possible that the peak shape for perrhenate is so poor (broad and low) that it is lost in the baseline noise. Efficiencies in excess of 380,000 theoretical plates were realized for iodate. Efficiencies of this magnitude for very small species with high diffusion coefficients are unprecedented. It is likely that a "sample stacking" (preconcentration/zone focusing) effect is responsible for providing this excellent performance. Detection at 190 nm was determined to result in an order-of-magnitude improvement in detection limit for the two analytes resolved in this study. These results were the best obtained for the three component test mixture in > 15 trials.

phosphate (25 mM, pH 2.9):

A 10^{-3} M mixed standard containing iodide, iodate, and perrhenate prepared in distilled, deionized water was introduced to the separation capillary using hydrodynamic injections of 0.15 to 0.35 min. duration at 50 mbar. UV detection at 190 nm was employed. Applied potential was -20 kV for 30 min. A separation of iodide, iodate, and perrhenate was achieved in under 10 minutes. Efficiencies in excess of 80,000 theoretical plates were realized for perrhenate ($t_m = 5.4$ min.), while 129,000 theoretical plates were realized for iodide and iodate ($t_m = 3.5$ min. and 7.6 min., respectively). These results were the best obtained for the three component test mixture in > 15 trials. A typical result is shown in figure 2, which also indicates the limit of detection for the three target analytes. The phosphate buffer system was selected for further study as described below.

Capillary: I.D. = 50 micron, O.D. = 365 micron, L_{tot} = 55 cm, L_{det} = 40 cm

Sample: I^- , IO_3^- ($1.95\text{E-}5\text{M}$) and ReO_4^- ($3.9\text{E-}5\text{M}$)

Runbuffer: phosphate 25 mM, pH 2.9

Injection: -6 kV, 0.02 minutes

Separation: -25 kV

Detection: UV absorbance @ 190 nm, 0.0005 AUF

Figure 2. Determination of detection limit (LOD) for each of the three analytes.

6.2.2 Operating Buffer pH Study.

The 25 mM phosphate buffer was selected for use in an operating buffer pH study. The lowest pK_a for phosphate is ~ 2.2 , making its useful range of buffering capacity ~ 1.2 to 3.2 . The use of operating buffers outside of their buffering ranges is not unprecedented, however, and may not pose problems when the analytes studied are not sensitive to changes in solution pH during the separation. For this reason, pH's of 2.4, 2.9, 3.4, and 4.5 were deemed suitable for further study. The pH 2.9 phosphate buffer provided the best results, yielding a relatively rapid separation and improved peak shape for perrhenate relative to the separation achieved at pH 3.4. When a shorter separation capillary (L_{tot} = 55 cm and L_{det} = 40 cm) was used, separations were achieved in under 2 minutes with resolutions in excess of 2.0. Even faster separations should be possible with shorter capillaries. During the conduct of these studies, difficulties with the micro syringe pump used in sample introduction prompted a switch to electrokinetic sample injection. This methodology introduced no ill effects other than slight sample discrimination, which is

easily overcome through the use of a reasonable method of standardization. Figure 3 illustrates the decrease in analysis time achievable through buffer pH optimization.

Capillary: I.D. = 50 micron, O.D. = 365 micron, L_{tot} = 65 cm, L_{det} = 50 cm

Sample: I^- , IO_3^- ($1.0\text{E-}4\text{M}$) and ReO_4^- ($5\text{E-}4\text{M}$)

Runbuffer: phosphate 25 mM, pH 2.9

Injection: -6 kV, 0.02 minutes

Separation: -25kV

Detection: UV absorbance @ 190 nm, 0.0005 AUF

Figure 3. Effect of pH on the separation of I^- , IO_3^- , and ReO_4^- .

6.2.3 Separation Step Field Strength Study.

The field strength of the potential gradient applied during the separation has profound effects on the speed and efficiency of electrokinetic separations. High field strengths increase the migration velocities of charged species, and increase the electroosmotic flow velocity. Excessively high field strengths lead to resistive heating, which in turn promotes zone spreading and decreases efficiency. This indicates that an optimum range of field strengths exists in which efficiency is maximized while analysis time is minimized. In an effort to ascertain this range of field strengths, a study was conducted in which the applied potential (hence field strength) was varied between -20 kV and -30 kV (the upper limit of the power supply used in these

experiments). A separation of iodide, iodate, and perrhenate was achieved in roughly 2 minutes at an applied potential of -30 kV, with no zone distortion due to resistive heating. Three representative separations are shown in figure 4.

Capillary: I.D. = 50 micron, O.D. = 365 micron, $L_{\text{tot}} = 55$ cm, $L_{\text{det}} = 40$ cm

Sample: I, IO_3^- ($1.0\text{E-}4\text{M}$) and ReO_4^- ($5\text{E-}4\text{M}$)

Runbuffer: phosphate 25 mM, pH 2.9

Injection: -6 kV, 0.02 minutes

Separation: -20, -25, -30 kV

Detection: UV absorbance @ 190 nm, 0.0005 AUF

Figure 4. Effect of field strength on the separation of I^- , IO_3^- , and ReO_4^- .

6.2.4 Generation of Calibration Curves for Quantitative Analysis.

External standard calibration curves for quantitation of iodide, iodate, and perrhenate were generated for the 1.95×10^{-5} to 1.25×10^{-3} M concentration range. The curves generated are shown in figure 5. It is likely that the linearity of these plots is poor due to the disparity in ionic strength between the various standards and the operating buffer.

Figure 5. Calibration curves for quantitation of I⁻, IO₃⁻, and ReO₄⁻.

7.0 CONCLUSIONS (Current Period)

The project is on schedule and results are encouraging. A CZE-UV method has been developed for the analysis of iodide, iodate, and perrhenate in standard solutions. Room for improvement exists, however. In particular, the following problems should be and will be addressed in the coming months:

1. preparation of all samples in the operating buffer to improve calibration curve linearity;
2. variation of injection conditions to elucidate the effect of sample introduction on calibration curve linearity;

3. elucidation of the effects of field-amplified sample injection on sensitivity, efficiency, and calibration curve linearity.

Work will also focus on improvement of detection limits through LIF detection and on the analysis of simulated "real-world" samples.

8.0 WORK PLANNED FOR NEXT PERIOD

Final assembly of an in-house constructed in-capillary fluorescence detector will allow for method development to proceed with the indirect fluorescence detection of non-radioactive (^{127}I) iodide and iodate. The completed detector will be comprised of a Xe-arc lamp for excitation of the fluorescent marker and a sensitive (cooled) photomultiplier tube. In this detector, the fluorescent buffer additive will produce a constant high background signal when no analyte species are in the detection zone. The absence of a fluorescence signal will indicate the presence of iodide or iodate. This methodology will provide for detection sensitivity which is ~ 2 orders of magnitude better than that achieved in the earlier UV studies.

The second stage of the iodine work will be conducted at the Battelle-Northwest facilities in Richland, WA. This portion of the project will require that Prof. Remcho travel to Richland to work directly with Dr. Ballou at Battelle's Atomic and Molecular Sciences laboratory. The investigators will make use of Battelle's 3 mW 488 nm air-cooled Argon Ion laser for enhanced LIF detection sensitivity. This instrument will provide a detection sensitivity which is approximately one order of magnitude greater than that achieved at WVU.

Initial experimentation with radiometric detection of ^{99}Tc will commence in the second quarter. In addition, the applicability of indirect laser-induced fluorescence detection to perhenate analysis will be studied. This technique will allow for the possibility of simultaneous analysis of ionic iodine and a technetium surrogate (Re) to be explored. Initial ^{99}Tc work will be conducted using the facilities and expertise of Battelle-Northwest, until such time that any necessary preparations and authorization are arranged for work to be conducted at WVU.

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**WVHTC Foundation's
Environmental Technology Support Program**

Quarterly Technical Progress Report
Reporting Period: January - March 1996

Work Performed Under Contract
No.: DE-FC21-92MC29467

For:
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:
West Virginia High Tech Consortium Foundation
200 Fairmont Ave, Suite 100
Fairmont, WV 26554

April, 1996

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ETI - First Quarterly Report January 1996 - March 1996

Executive Summary

The first quarter of 1996 was focused upon the creation of a formal business plan for the incubator, setting up of the infrastructure to administer the incubator, the performance of several efforts to determine feasibility of business plan components, the acceptance of AE Environmental under a "pre-admission" status as a means of dealing with the current list of clients, and the completion of traditional incubator admission through graduation procedures document. On 29 January, a board meeting was held to formally announce the director selection and initiation of this activity. A second board meeting is being planned for 30 May to review the business plan and related projects underway and to review the admission through graduation procedures document.

During the first quarter, METC through the coordination of Dr. Cook, graciously consented to loaning the ETI eight sets of office furniture that is being used for both administration staff and incubator clients. We wish to extend our appreciation for the use of these resources.

1.0 Introduction

The West Virginia High Technology Consortium (WVHTC) Foundation's Environmental Technology Support Program was funded in July 1995. The support program involves an advanced concept for the accelerated commercialization of environmental technologies. The program also will help establish an Environmental Technology Incubator in Morgantown, West Virginia. A total of \$187,000 in funds for FY '95 and FY '96 has been awarded to the WVHTC Foundation from the Department of Energy to support the management and operation of the Environmental Technology Incubator which has been established in Morgantown, West Virginia. Funds from the U.S. Small Business Administration and the Environmental Protection Agency have also been used to further this initiative. Phase 1 of the project was completed and Phase 2 of the program began on January 1, 1996.

2.0 Purpose

The WVHTC Foundation's mission is to create a high technology business sector in north central West Virginia. This mission will be supported through the efforts of the new environmental support program. The new program will enhance the development and growth of the environmental industry in our region. Further, the Foundation's Environmental Technology Support Program will facilitate technology transfer and the commercialization of Department of Energy Technology.

3.0 Background

The WVHTC Foundation is currently working with government, business, and educational entities to facilitate the pursuit of economic development. The Environmental Technology

Incubator (ETI) will foster this effort in the area of environmental technology related business activity. The ETI will serve as a catalyst organization for change linking entrepreneurs with technology, capital and academic resources in an effort to sustain new high technology environmental business development.

4.0 Methodology

The methodology for the establishment of the Environmental Technology Incubator includes a three phased approach:

Phase 1 - Planning and Start-up (July 1995 - December 1995)

Phase 2 - Implementation (January 1996 - June 1996)

Phase 3 - Continued ETI Development (July 1996 - December 1996)

The tasks being performed during Phase 2 are the following:

Task 1: Start-up Activities

- Form an Advisory Board of DOE staff, community leaders, business experts, and academic representatives.
- Hire the ETI Director
- Define the ETI business plan and exercise key strategies to determine feasibility inclusive of incubator services to be offered
- Admit the first cycle of ETI clients
- Begin to build a regionally-based capital network
- Assess DOE technologies
- Develop brochures and other marketing communications products

Task 2: Infrastructure Development

- Obtain and install computer/communications equipment and e-mail and Internet access
- Furnish the ETI

Task 3: Operating Policies

Develop a comprehensive set of policies, procedures, and metrics for the selection and graduation of incubator clients

5.0 Worked Performed this Period

During the first quarter of 1996, the WVHTC Foundation completed work on each of the tasks defined in the previous section. This is more fully explained below:

Task 1: Start-up Activities

- An advisory board was formed and the first board meeting held on 29 January
- The ETI Director was selected from among the program manager ranks at the WVHTC Foundation
- The ETI Program Team consisting of the ETI Director and project team, (Cy Logar, Tom Ponzurik, and John Spears from the WVU business school) developed a draft of the ETI business plan and exercised key strategies to determine feasibility; review of the business plan and a review of activities undertaken will be shared at the May 30 Advisory Board meeting
- The ETI Program Team has defined a tentative list of incubator services to be offered
- AE Environmental Services, Inc. was admitted to the ETI in the Grand Central Station location under a "pre-admission" status until formal procedures are defined and approved by the Advisory Board

Task 2: Infrastructure Development

- Five Apple Macintosh computer systems and a hub connector were provided by the WVHTC Foundation and moved to the NRCCE ETI office
- One Macintosh has been hooked up to the NRCCE communications hub at this time with Internet access
- Additional hardware has been ordered to facilitate the connection of the ETI's hub connector and connection of the remaining Macintoshes
- A laser printer was purchased as a resource for the ETI

6.0 Results and Discussion - *not applicable*

7.0 Conclusions - *not applicable*

8.0 Work Planned for Next Period

The following activities will be performed during the next period:

Task 1: Start-up Activities

- A second Advisory Board meeting will be held to review progress and approve the business plan and admission/graduation procedures
- A regionally-based capital network will continue to be developed
- A review will be performed of DOE technologies and SBIR activities
- Brochures and other marketing communications products will begin to be developed
- Several WVU graduate students will be hired to support the administrative and functional support needs of the ETI
- An announcement will be made in the region (Charleston to Pittsburgh) seeking input by entrepreneurs or companies interested in incubator services to determine level of interest and types of services of interest

Task 2: Infrastructure Development

The computers network, Internet access, and e-mail capability will be completed

Task 3: Operating Policies

The comprehensive set of policies, procedures, and metrics for the selection and graduation of incubator clients will be completed and reviewed by the Advisory Board

Budget Summary

As an overall strategy, the METC budget will be conserved as much as possible for pursuing ETI development type activities by the sharing of costs where appropriate by other WVHTC Foundation contracts. For example, the ETI Director is the current program manager for a NOAA sponsored grant and has off-set his direct labor charges to this specific contract. It is anticipated that his role will be reduced to a project manager function in order to devote more time to the ETI development once a replacement program manager is hired in the next reporting period.

As shown below, the final Phase 1 monies expended under the FY '95 budget total \$52.3K out of a possible \$68K budget. For Phases 2 and 3, the approved budget totals \$119K of which, \$12.4K was spent during the current reporting period. The direct labor can be attributed to work performed by a part-time graduate research assistant. In other categories, expenses were incurred by typical phone or office expenses. It is expected that these will increase dramatically once the computer resources become operational, the summer interns are hired, and the ETI Program Team spends more time at the ETI facility. The \$3K plus expenditure was for a laser printer to complete the computer equipment resource needs of the ETI.

Please note that the general and administrative rate has changed for WVHTC Foundation beginning 1 January. A letter from the WVHTC Foundation Finance Director will be included in the next period billing and reconciliation of the difference from the current period will be assigned to the budget.

ETI Phase 1 Funding Summary

ETI - Phase 1 1995 Funding

Total Direct labor	\$	13,085.69	
Overhead Rate (80.84%)		10,578.48	
			23,664.17
ETI - Public Information Service	\$	2,485.53	
ETI - Office Supplies		2,949.40	
ETI - Technical/Facilities Support		17,995.38	
ETI - Travel		2,381.60	
			25,811.91
Total Cost Input			49,476.08
G&A Rate (5.75%)			2,844.86
Total Expended	\$		52,320.94

ETI Phase 2 Funding Summary

ETI - Phase 2 1st Quarter 1996 Funding

Total Direct labor	\$	5,203.54	(estimated)
Overhead Rate (80.84%)		<u>2,984.78</u>	(estimated)
			8,188.32
ETI - Public Information Service	\$	10.00	
ETI - Office Supplies		342.88	
ETI - Technical/Facilities Support		3,190.38	
ETI - Travel		<u>27.40</u>	
			<u>3,570.66</u>
Total Cost Input			11,758.98 (estimated)
G&A Rate (5.75%)			<u>676.14</u> (estimated)
Total Expended		<u>\$</u>	<u>12,435.12</u>

ETI Spendplan

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
per month	4145	4145	4145	4145	8290	16000	16000	16000	13000	13000	13000	7130
			12435									
percentage	3%	3%	3%	3%	7%	13%	13%	13%	11%	11%	11%	6%
cumulative	4145	8290	12435	16580	24870	40870	56870	72870	85870	98870	111870	119000

SMALL BUSINESS SUPPORT PROGRAM

SMALL BUSINESS INTERACTION OPPORTUNITIES

SUBTASK 3.2

Quarterly Technical Progress Report
January 1 through March 31, 1996

Work Performed Under Contract
No.: DE-FC21-92MC29467

For

U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880, 3610 Collins Ferry Road
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March 1996

EXECUTIVE SUMMARY

The Environmental Technology Incubator (ETI) has preadmitted two small businesses into the incubator. A team effort between the Institute of Gas Technology and WVU researchers in the Department of Civil & Environmental Engineering has resulted in a proposal to the WVU Cooperative Agreement. The team will develop and evaluate biosorbents and cleaning solutions and their separation by the SpinTek centrifugal membrane technology for decontaminating and decommissioning USDOE facilities.

Negotiations are underway for GENESYST to develop a white paper for METC on their supercritical water oxidation system known as the Supercritical Gravity Pressure Vessel (SGIV).

Interaction between Intera Corp and WVU researchers has begun with the USDOE Portsmouth facility to study using bioremediation as a polishing step following Intera's surfactant flush of a TCE contaminated site on the Portsmouth facility.

The Kanawha River Voluntary Assessment project was restarted after a period of inactivity.

The WVU Cooperative Agreement Review was conducted and deemed a tremendous success.

1.0 Introduction

Subtask 3.2 "Small Business Interaction Opportunities" was initiated to address the technical problems or barriers to commercialization of innovative site remediation technologies. Through METC, a very large percentage of the USDOE innovative remediation technologies being developed is done by small businesses. Small business owners are creative thinkers usually technically competent beyond their resource base. At times they find technical problems and their lack of highly technical personnel creates an unsurpassable barrier for the small business to get their innovative technologies developed and commercialized. By ferreting out these problems, this program will allow teaming of a faculty member with the small business to solve the problem allowing further development of the innovative technology to occur.

2.0 Purpose

The Small Business Interaction Opportunities program was initiated to explicitly address the problems and barriers to commercialization of the innovative site remediation technologies developed by the small businesses funded by METC.

3.0 Background

Over the past three years the WVU Cooperative Agreement has funded numerous projects at WVU and Marshall University. This has resulted in defining at least three areas of core competencies at WVU which may be called upon to provide assistance to the small businesses that METC funds in the area of site remediation.

The core competencies include:

- * Remediation processes such as surfactant flushing of soils and chemical and biological destruction of polyaromatic chlorinated hydrocarbons
- * Confinement Barriers such as the Circulating (Desiccation) Air Barrier and Chemical Grouting Barriers
- * Fluid Recirculating Systems such as the Drain Enhanced Soil Flushing using Prefabricated Vertical Drains (PVD's)
- * Separation processes using novel membranes and novel forms of carbon

4.0 Methodology

By attending the kickoff meetings and other periodic meetings of the small businesses funded by METC an understanding of the project is obtained. During the presentations, value

added opportunities for collaboration between the small businesses and university researchers are carefully watched for. Discussions with program managers also provide opportunities for interaction. The Environmental Waste Management Technical Product Team also provides opportunities to determine needs of the small businesses and resulting research opportunities. For the long range research opportunities, the initiative at USDOE HQ level bringing together elements from DOE, DOD, NASA, Commerce and others to coordinate interagency site remediation capabilities and needs will be very helpful.

Also, attendance at various meetings and conferences on site remediation provides insights to research needs.

From all of the previous sources, research opportunities are ferreted out and projects are developed with university faculty to carry them out.

5.0 Work Performed This Period

The Environmental Technology Incubator (ETI) Advisory Committee met to discuss the progress of the incubator. Six candidate small businesses were nominated for inclusion into the ETI. Two were preadmitted (pending advisory committee approval) into the ETI and others will be considered at the next advisory committee meeting scheduled for May 30, 1996. The two preadmitted were both successful in obtaining challenge grants for start up funds from a grant to the College of Business & Economics from the Small Business Administration. The two companies are A & E Environmental Services Inc. out of Wheeling, WV and Global Concepts Inc. out of Bridgeport, WV.

At present there are six offices available for the ETI on or near the WVU campus. Two offices are in the NRCCE building where the associate director of the ETI, Dr. John Spears, will have his office. Four other offices are located at Grand Central Station. METC has provided (on loan) the office furniture required to make the offices functional.

Interaction was continued with the Institute of Gas Technology (IGT) resulting in a proposal being submitted for funding through the WVU Cooperative Agreement. The project is a joint effort between IGT (Dr. John Kilbane) and Dr. Brian Reed of WVU, Department of Civil and Environmental Engineering. It will become Subtask 2.6 A & B. The Institute of Gas Technology (IGT) will prepare and evaluate biosorbents and cleaning solutions that may be useful in the decontamination and decommissioning (D & D) of USDOE facilities. WVU researchers will investigate the feasibility of using SpinTek centrifugal membrane technology to separate the IGT sorbents/cleaning agents used in the D & D of USDOE facilities.

Interaction was initiated with Mr. Don Bogner of GENESYST which has a supercritical water oxidation system (SCWO) known as a Supercritical Gravity Pressure Vessel (SGPV). They have been asked to write a white paper comparing their technology

to other competing SCWO technologies and providing materials for presentation. These materials would be used to help make others in USDOE & USDOD aware of the technology and its advantages. A meeting is planned in early May to discuss details with Mr. Bogner and Dr. Jerry Rappe of GENESYST.

Contact was made with INTERA Corp., a small business sponsored by METC. They are developing a surfactant flush of a TCE contaminated site at the Portsmouth USDOE facility. Researchers from the department of Civil & Environmental Engineering at WVU are proposing that bioremediation be used as a polishing step following the surfactant flush. Initial contacts with Intera and the Portsmouth facility were fruitful and all seem amenable to pursuing the idea. Portsmouth indicated that their contact on bioremediation was Dr. Janet M. Strong-Gunderson at Oak Ridge and she needed to be a part of the program. Discussions have occurred with Dr. Strong-Gunderson. A proposal for funding through the WVU Cooperative Agreement will be submitted in the near future to begin work on this project.

The Kanawha River Voluntary Assessment project which did not get completed last year was provided its remaining carryover funds to continue the project to fruition. It involves working with companies in the Kanawha Valley through Clean Sites Inc. And the National Institute for Chemical Studies (NICS) to voluntarily clean up their contaminated sites. USDOE/METC's interest in this project is to hopefully obtain sites on which some of the innovative site remediation technologies developed by METC sponsored small businesses can be demonstrated and evaluated.

During the last week of March the WVU Cooperative Agreement Program Review was conducted. The review featured the interaction being accomplished by the WVU researchers with small businesses developing innovative site remediation technologies for METC. In attendance were 7 individuals from METC, 11 industrial partners cooperating in the research and numerous others. Total attendance exceeded 35 and the review was a tremendous success.

6.0	Results and Discussion	N/A
7.0	Conclusion	N/A

APPROACH FOR ASSESSING POTENTIAL VOLUNTARY ENVIRONMENTAL PROTECTION, KANAWHA VALLEY AREA

Quarterly Technical Progress Report
for Period January 1 through March 31, 1996

Work Performed Under
Contract No.: DE-FC21-92MC29467

METC SubTask No.
OLD 3.4

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
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April 1996

ABSTRACT

This project concerns investigation of the feasibility of establishing voluntary remediation programs in the Kanawha Valley, WV.

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Abstract

Executive Summary

1.0 Introduction

2.0 Work Performed this Period

3.0 Work Planned for Next Period

4.0 Technical/Administrative Difficulties

EXECUTIVE SUMMARY

The United States contains numerous hazardous waste sites. Many sites are on private land near operating units of various companies. An effort is being made to determine the conditions under which such sites can be remediated voluntarily. Such voluntary remediation would result in an accelerated clean-up of U.S. sites and a significant cost savings. Meetings are being held with U.S. companies to evaluate the potential for actually initiating voluntary clean-ups.

1.0 INTRODUCTION

The objective of the project will be to first assess the interest and willingness of industry in the Kanawha River Valley to participate in discussions that would lead toward voluntary cleanup activities. The second will be to implement the activities agreed upon by the interested parties. The project will first involve individual discussions with the industrial, government, and other organized groups in the area. These discussions will help determine the feasibility of organizing voluntary efforts. If the discussions indicate that conditions may be favorable for developing individual or group voluntary cleanup projects, a working group will be convened to establish the environmental goals of the project as well as the technical approach for achieving those goals.

2.0 WORK PERFORMED THIS PERIOD

The final meetings with the chemical companies were held.

A report was made to METC regarding the project. At that time, interest was expressed by METC in implementing DOE technologies at private sites, dovetailing with the chemical company interests.

A meeting with Region III of the U.S. Environmental protection Agency was held to ascertain the depth of interest in the voluntary program. EPA was very interested, given the enactment of a Brownfields/Voluntary program by the West Virginia legislature. A groundwork was laid for the discussion of a memorandum between the EPA and the state regarding voluntary cleanups. Subsequent discussions with WVDEP officials revealed a like interest.

3.0 WORK PLANNED FOR NEXT PERIOD

Establishment of a memorandum of understanding between EPA and West Virginia to facilitate voluntary cleanups. Establishment of contact with the DOE to begin discussions of using DOE developed technologies at sites to provide verification of performance.

4.0 TECHNICAL/ADMINISTRATIVE DIFFICULTIES - None.