Base Program on Energy Related Research

Quarterly Report November 1, 1996 - January 31, 1997

Work Performed Under Contract No.: DE-FC21-93MC30126

For
U.S. Department of Energy
Office of Fossil Energy
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EXECUTIVE SUMMARY

Introduction

The Base Research Program at Western Research Institute (WRI) is planned to develop technologies to a level that will attract industrial sponsors for continued development under the Jointly Sponsored Research (JSR) Program. In many instances, a potential JSR cosponsor has been identified but additional laboratory or bench-scale data are necessary to assess the utility of the technology prior to cosponsor investment. Both peer and management review are employed prior to proposing Base projects to the U.S. Department of Energy (DOE).

The goals of the Base Research Program are in support of those of the JSR Program, which are designed to:

- Increase the production of United States and western energy resources, particularly low-sulfur coal, natural gas, oil, and renewable energy resources
- Enhance the competitiveness of United States and western energy technologies in international markets and assist in technology transfer
- Reduce the nation's dependence on foreign energy supplies and strengthen both the United States and regional economies
- Minimize environmental impacts of energy production and utilization.

The goals of the JSR and Base Programs are accomplished by focusing research, development, demonstration, and commercialization in three major technology areas:

- **ENERGY PROGRAMS** emphasize the increased production and utilization of domestic energy resources and include enhanced oil recovery, coal bonification and upgrading, coalbed methane recovery, and renewable energy resources.
- **ENVIRONMENTAL PROGRAMS** minimize the impact of energy production and utilization by providing technology to clean underground oily wastes, mitigate acid mine drainage, and demonstrate uses for Clean Coal Technology (CCT) and pressurized fluidized bed combustion (PFBC) waste solids.
- **TECHNOLOGY ENHANCEMENT** activities encompass resource characterization studies, the development of improved environmental monitors and sensors, and improved techniques and models for predicting the dispersion of hazardous gas releases.

Interactions between the Base and the JSR Programs are dynamic and continuous, as commercialization of promising new technologies is the driving force for both. The Base Program explores innovative concepts that will attract industrial cosponsors for continued development under the JSR Program. In many instances, a potential JSR cosponsor has been identified, but additional laboratory or bench-scale data are necessary to verify the process or product concept. Once done, the project moves to the JSR stage where the objective is to develop and demonstrate the technology sufficiently for sound and prudent commercialization decisions to be made.

Not infrequently the reverse occurs. A project will demonstrate considerable promise at the JSR stage but require a supplemental Base Program activity to complete the applied research required for process optimization and a thorough technical understanding of the phenomena being exploited. As a result, the two programs are tightly integrated and complementary components of the overall development process.

In a high-technology global economy, technology development is crucial to the preservation and growth of the American economy and standard of living. Much of this technology and growth will come from companies that were small or nonexistent just a decade ago. Unlike the large multinational companies with captive research and development facilities, these companies must rely on creative and innovative contractors such as Western Research Institute to assist with their process and product development activities. It is a tribute to the wisdom and the foresight of the United States Department of Energy and the Federal Energy Technology Center that activities such as the Cooperative Agreement Programs exist to meet this crucial national need.

The Base Cooperative Agreement (DE-FC21-93MC30126) was initiated on February 2, 1993. Since that time, total funding of \$6,990,884 has been authorized both through the original agreement and subsequent modifications.

A summary of funding and the number of projects is shown in Table 1.

Table 1. Summary of Base Funding for FY 1993–1996

Fiscal Year	Funding	Number of Projects	New Starts
1996	780,000	21	2
1995	1,077,976	19	4
1994	3,132,908	15	5
1993	1,950,000	10	10
TOTAL	6,990,884		

Significant Accomplishments Under the Base Research Program

Subtask 1.2 Miscible-Immiscible Gas Injection Processes

WRI is currently developing a predictive model for miscible-immiscible gas injection processes with emphasis on use of CO₂. Physical simulations are in progress using the GEM 96.00 simulator developed by the Computer Modeling Group. Personnel at FETC have made this simulator available for use by WRI researchers. Initial efforts with the simulator are encouraging. The GEM simulator has been leased by WRI, and the project leader was trained in its use. Physical simulations indicate that a 5 to 12% increase in recovered oil can be accomplished using a gas-trapping mechanism with proper immiscible injection of CO₂.

Subtask 1.4 Tank Bottom Waste Processing Using the TaBoRR® Process

WRI developed the Tank Bottom Recovery and Remediation (TaBoRR®) process to address the problem of tank bottom wastes. The method results in separation of water, a light hydrocarbon stream, a heavy hydrocarbon stream, and an inert, nonleaching, liquid-free solid. For this invention, WRI was granted U.S. Patent No. 5,259,945. Filings are proceeding under the Patent Cooperation Treaty in countries throughout the world. A process development unit (PDU) has been constructed to provide data for economic evaluation, numerical modeling of the process, and environmental analyses. The PDU is capable of processing 1 to 2 barrels per day of tank bottom wastes. This PDU is being used to support field mitigation work. A concurrent modeling effort was successful in development of operational parameters for the flash operation.

Subtask 2.1 Development and Optimization of a Process for the Production of a Premium Solid Fuel from Western U.S. Coals

WRI has developed technology that results in a dried coal with a decreased tendency to spontaneously combust. This technology, called COMPCOAL™ (Compliance Coal), is the subject of a patent, U.S. Patent No. 5,322,530. Recent evaluations under the Base Program have reaffirmed that the low-temperature ignition characteristics of the COMPCOAL products are similar to those of the raw coals. Work is continuing to obtain cosponsorship for a pilot-scale demonstration of the technology.

Subtasks 3.1–3.4 Other Environmental Technologies

WRI is working on four environmental technologies, each of which appears to have significant potential for application. WRI is currently assessing the patent position of these technologies, so this

is a sensitive time for detailed discussion of results. Invention disclosures have been written on all four.

One subtask (3.1) evaluates fundamental properties of solid wastes (conventional and clean coal technology ashes) from coal combustion to determine the economic and technical viability of their productive use in cement or other materials. A final topical report is being prepared for this subtask. A related subtask (3.3) determines the economic and technical feasibility of using power plant ashes to produce synthetic aggregate in the Syn-AgTM process. Work on the Haz-FloteTM process (under subtask 3.2) is designed for ex-situ decontamination of materials with hydrocarbon content. It will be a valuable complement to CROWTM. Patent applications are being prepared for all three subtasks. WRI's Maxi-AcidTM process (under subtask 3.4) addresses in-situ treatment of precursors to acid mine drainage to quickly mitigate and treat acid formation. A JSR application is planned for a project in Montana with the Montana Bureau of Mines and Geology.

Subtask 4.1 Heavy Oil/Plastics Co-Processing

WRI has developed a method to co-process plastic mixtures with a variety of heavy oils. This method not only reduces the volume of landfill material but also produces low yields of char plus gas and high yields of liquids that show potential for use as fuels. Based on this invention, WRI has applied for patents in the United States, Canada, and Mexico and has also filed under the Patent Cooperation Treaty (PCT) process. Work was recently completed to define scale-up parameters at bench scale for economic evaluation and improvement of process efficiency. These data are being used to seek industrial sponsorship.

The authorized subtasks and the corresponding funding is provided in Table 2. A summary of budgets, expenses prior to the quarter, expenses by month for this quarter, and remaining balances is provided in Table 3.

Overview of Accomplishments During November 1996 Through January 1997

Task 1.0

A physical simulation testing protocol was completed to evaluate Miscible/Immiscible Gas Injection Processes for oil production (Subtask 1.2).

An evaluation of SIMED, a numerical model for coalbed methane recovery has shown it to be inconvenient to use (Subtask 1.3).

Several new and several continued industrial contacts were made relative to the TaBoRR[®] process (Subtask 1.4). Several more samples of tank bottoms were analyzed for chemical and physical

properties. A pyrolyzer unit is under construction. A modeling effort has successfully determined the operational parameters of the flash operation. An economic analysis of the process has been initiated.

Table 2. Subtasks Approved for Funding Through FY 96

Subtask	Project	Years 1-3 Funding	FY 96 Funding	Total Funding
1.1	CROW™ Process Modeling	471,163	0	471,163
1.2	Miscible/Immiscible Gas Injection	254,500	200,000	454,500
1.3	Coalbed Methane Simulator	316,841	0	316,841
1.4	Development of TaBoRR® Process	588,275	160,000	748,275
2.1	Premium Solid Fuel from Western U.S. Coals	127,835	0	127,835
2.2	On-line Alkali Monitoring Probe	107,250	0	107,250
2.3	Recycle Oil Process for Eastern Oil Shale	119,350	0	119,350
2.4	Support for COMPCOAL™	146,250	0	146,250
2.5	Eastern Oil Shale as an Asphalt Additive	66,145	0	66,145
2.6	Support for Koppelman Series C	108,405	0	108,405
2.7	Coal-Fired Gas Turbine	0	195,000	195,000
3.1	Solid Waste Management	691,998	0	691,998
3.2	Haz-Flote™ Remediation of Contaminated Soils	442,074	0	442,074
3.3	Syn-Ag™ Use of Coal Combustion Wastes	183,521	0	183,521
3.4	Maxi-Acid™ Treatment of Acid Mine Drainage	221,057	0	221,057
3.5	Spill Test Facility Data Base	186,539	0	186,539
3.6	Attenuation of Ammonium in Aquifer	16,400	0	16,400
3.7	Dense Gas Dispersion	0	175,000	175,000
4.1	Heavy Oil/Plastics Co-Processing	278,282	0	278,282
4.2	Fossil Fuel Conversion With Hydrogen Plasmas	81,447	50,000	131,447
6.1	North Site Cleanup	1,534,884	0	1,534,884
TOTALS		6,210,884	780,000	6,990,884

Task 3.0

Work on a final topical report on Subtask 3.1 (Solid Waste Management) continued. Patent applications are being prepared.

A patent application for the Haz-Flote™ (Subtask 3.2) process is being prepared.

Under Subtask 3.3 (Syn-Ag™: Coal Combustion Ash Management), invention disclosures have been written, and patent applications are being prepared. Disclosures were sent to the DOE patent attorney.

Under Subtask 3.4 (Amelioration of Acid Mine Drainage), preliminary work was completed to determine the impact of CO₂ on acid formation in low CO₂ environments.

The data base being developed under Subtask 3.7 (Evaluation of Dense Gas Dispersion) helps to establish a scientific and engineering basis for spill mitigation and to test regulations that will affect more than 100,000 sites. A draft final topical report was completed this quarter.

Task 4.0

Several experiments were completed using a stirred batch reactor for Subtask 4.2 (Fossil Fuel and Hydrocarbon Conversion Using Hydrogen-Rich Plasmas). Hydrogen plasma produces more distillate from heavy oils than does nitrogen plasma.

Federal Assistance Management Summary Reports (Substitute DOE Form F 4600.5) are included for active subtasks on pages 32–45.

CONTRACT STATUS REPORT

Contract No. DE-FC93MC30126

Contract Start: February 2, 1993

Contract Complete: February 1, 1998

Reporting Period: Through 4th Quarter, 4th Year

Subtask	Budget Prior years	Budget Yr 4	Total Budget	Expenses to 10/31/96	Expenses November	Expenses December	January	Total Expenses	Balance
4th Year Subtasks									
1.2	254,500	200,000	454,500	275,817	12,944	6,888	4,101	299,750	154,750
1.4	588,275	160,000	748,275	647,687	5,124	16,079	10,070	678,960	69,315
2.7	0	195,000	195,000	85	32	0	0	117	194,883
3.7	0	175,000	175,000	166,530	1,369	1,554	558	170,011	4,989
4.2	81,447	50,000	131,447	92,558	4,985	4,279	2,644	104,466	26,981
Subtotals	924,222	780,000	1,704,222	1,182,677	24,454	28,800	17,373	1,253,304	450,918
IX.									
1.3	316,841	0	316,841	169,085	9,617	5,023	6,500	190,225	126,616
2.1	127,835	0	127,835	124,832	246	0	0	125,076	2,757
3.1	691,998	0	691,998	687,494	270	4,109	15	691,988	10
3.2	442,074	0	442,074	429,434	924	1,887	35	432,281	9,793
3.3	183,521	0	183,521	104,985	890	1,312	11,408	118,595	64,926
3.4	231,057	0	231,057	112,099	4,210	24,683	4,599	145,591	85,466
3.6	16,400	0	16,400	1,952	272	1,221	1,180	4,625	11,775
6.1	1,534,884	0	1,534,884	1,464,212	16,250	11,487	9,317	1,501,266	33,618
Subtotals	3,544,610	0	3,544,610	2,994,077	32,679	49,722	33,155	3,209,633	334,977
Other ⁽¹⁾	1,742,052	0	1,742,052	1,741,630	0	0	0	1,741,630	422
Totals	6,210,884	780,000	6,990,884	6,018,384	57,133	78,522	50,528	6,204,567	786,317

⁽¹⁾ Completed subtasks (1.1, 2.2, 2.3, 2.4, 2.5, 2.6, 3.5, and 4.1)

TASK 1.0 OIL AND GAS

BACKGROUND

Conventional petroleum resources in the United States continue to diminish, resulting in our continued dependence on foreign sources. The development and application of methods to increase and support production from domestic resources is important to the nation's independence and well-being. A related area of environmental concern is the cleanup of oil waste materials. Numerous sites exist throughout the country where oily materials have been deposited and pose the threat of contamination to the environment. Effective methods for cleanup of these materials need to be developed for remediation of such sites.

LONG-TERM OBJECTIVES

The long-term objective of this task is to develop efficient processes that can be economically applied by independent, as well as major, oil producers. The present market for WRI-developed technologies appears to be with the independent operators.

Areas currently being targeted are:

1. Development of a predictive model for miscible/immiscible gas injection and verification of the model through physical simulations (Subtask 1.2)
2. Development of a portable data acquisition system and coalbed methane generator (Subtask 1.3)
3. Technology support, development of a lab process unit, numerical modeling, and economic analysis for the TaBoRR® process (Subtask 1.4).

Funding was approved for continuations of Subtasks 1.2 and 1.4 in the fourth year of Cooperative Agreement DE-FC21-93MC30126.

SUBTASK 1.2

MISCIBLE\IMMISCIBLE GAS INJECTION PROCESSES

Lyle A. Johnson
Francis M. Carlson

November 1996–January 1997

OBJECTIVE

The objective of this subtask is to demonstrate a predictive model for the miscible\immiscible gas injection process with emphasis on the use of CO₂ as the injected gas. Data for the verification of the model will be obtained through the conduct of physical simulations designed with the use of the numerical simulator.

QUARTER OBJECTIVES

- Complete the physical simulation testing protocol.
- Continue matching of the physical simulation results with the CMG miscible\immiscible gas injection simulator.

ACCOMPLISHMENTS

The numerical simulator to be used in the subtask was selected based on availability and on the presence of the various capabilities desirable for the simulations. The simulator selected is the GEM 96.00 simulator offered by the Computer Modeling Group (CMG). A copy of this simulator resides at the Federal Energy Technology Center (FETC), and FETC personnel are familiar with it.

Agreements have been finalized with CMG to secure the executables of the GEM 96.00 simulator for use at WRI. The agreement includes a training session at CMG facilities for WRI personnel and access to CMG personnel for troubleshooting and modification of the computer code.

A literature survey has been conducted to assist in the design of the physical simulations. The emphasis of the survey was on nonintrusive capillary pressure and three-phase saturation

measurements during conduct of the physical simulations, methods to seal the core samples, and type of core to use.

A preliminary design for the physical simulation system has been developed, and the equipment specifications are being developed. Material for testing has been identified from information in the literature, and the availability of the material is being investigated. The method to seal the solid material, core, or sand in the reactor tubes is being evaluated. It appears that a bismuth alloy can be used with core material because of its low melting point and its expansion characteristic when cooled. Methods to prevent slippage around sand packs are also being evaluated.

The physical simulation apparatus has been constructed, and shakedown testing (10+ tests) has been completed. Methods for packing the reactor tubes with sand to produce various permeabilities have been evaluated for eight tube packings. Four full-scale physical simulations have been completed. Results from the initial simulations indicate that a 5 to 12% increase in the recovered oil is created by the gas-trapping mechanism when immiscible injection is properly conducted. Additional simulations using a more viscous hydrocarbon than the hexane used in the initial four tests are planned.

ACTIVITIES FOR NEXT QUARTER

- Conduct physical simulations using a second more viscous hydrocarbon.
- Continue matching the physical simulation results with those of the CMG miscible\ immiscible gas injection simulator.

PROCEDURES

This subtask is composed of four parts. The first part will be the selection of a numerical simulator followed by the acquisition or arrangements for use of the simulator. The second part will be the conduct of physical simulations to provide detailed data for the validation of the simulator. The numerical simulator will be used to develop the experimental plan and operational procedures for the physical simulations. Next will be the validation of the numerical simulator using history matching of the physical simulations. The model will be modified, if possible, to provide the necessary history matches. The final part will be the documentation of the numerical and physical simulations in a final topical report.

In a parallel effort, work is being conducted to evaluate the ability of the UTCOMP simulator to perform the required simulations for this project. A copy of this simulator is available for WRI use. The use of both the GEM and UTCOMP simulators is being considered for a comparative purpose.

RESULTS

The numerical simulator selected for use in this subtask is GEM 96.00 developed by CMG. The simulator was selected because of its capability to take into consideration the solubility of CO₂ in the aqueous phase and to allow for relative permeability hysteresis. Following discussions with personnel at FETC, the initial simulations using the CMG simulator were conducted by WRI personnel at the FETC facilities, since the simulator is available there. The initial experience using the simulator was positive. An experimental plan for the physical simulations is being developed using initial simulations conducted with GEM.

Agreements have been finalized with CMG for the use of the GEM 96.00 simulator at WRI's facilities during this subtask. The agreement also includes training for WRI personnel on the simulator at CMG facilities. This training has been conducted.

Literature surveys identified methods for the use of nonintrusive measurements of capillary pressure and three-phase saturations, but these methods appear to be cost prohibitive. A preliminary design for the physical simulator has been completed, as have the construction and shakedown of the apparatus. An outline for the testing procedure has been developed.

Methods to pack the reactor tubes with unconsolidated sand have been developed and tested for reproducibility. Shakedown testing of the reactor system has been completed. Four full-scale physical simulations have been completed with an increase in recovered oil of 5 to 12% of the initial oil in place. It appears that in addition to gas trapping, other mechanisms may be causing the increased production. Further testing is underway with a more viscous hydrocarbon to verify these results and evaluate other operating conditions.

CONCLUSIONS

From preliminary runs it appears that the GEM 96.00 numerical simulator is capable of performing the necessary simulations. However, the simulator has some problems handling an oil-wet system such as the one WRI is looking at. GEM 96.00 does not allow for the appropriate treatment of rock properties for oil-wet systems but does allow for hysteresis in capillary pressure and gas-oil permeability for water-wet systems. Consequently, the physical simulations will involve reversing the phases so that the wetting phase (water) will be displaced by the nonwetting phase (oil). In this manner, GEM 96.00 can be used to make predictions of the physical simulations which are consistent with its capabilities. CMG personnel have indicated that GEM 96.00 may be updated during the course of our work to permit more flexibility with rock properties.

Sand-packed reactor tubes have been evaluated to provide the desired range of contrasting permeabilities for the physical simulations. Initial tests indicate that an increase of 5 to 12% in oil

recovery can be expected from the immiscible gas injection method being used. It appears that the total increase in production cannot be attributed to gas trapping. History matching with the numerical simulator using data from the physical simulations will assist in identifying the contribution of individual processes.

Sand-packed reactor tubes have been evaluated to provide the desired range of contrasting permeabilities desired for the physical simulations. Preliminary testing has indicated that an increase in oil recovery can be expected from the immiscible gas injection method being used.

SUBTASK 1.3

DEVELOPMENT OF A PORTABLE DATA ACQUISITION SYSTEM AND COALBED METHANE SIMULATOR

Charles G. Mones

November 1996–January 1997

OBJECTIVES

WRI is currently participating in a Jointly Sponsored Research (JSR) program with Amoco Production Company (Amoco) regarding the enhanced recovery of methane from coalbeds by the injection of CO₂. Enhanced coalbed methane (ECBM) processes use an injected gas to stimulate the production of methane from coalbeds and potentially reduce the production of water. Part of WRI's responsibility in this program was to use Amoco's Generalized Compositional Simulator (GCOMP) to model the performance of a CO₂/ECBM pilot. Involvement with Amoco's leading edge, enhanced recovery technologies and GCOMP simulator have given WRI direct experience in the area of coalbed methane recovery.

WRI intends to market its expertise in coalbed methane recovery to commercial developers. Our marketability as reservoir engineers depends on having access to a coalbed methane simulator. Based on our experience with Amoco, a simulator is needed to perform proof-of-concept studies, evaluate reservoir design options, predict recovery, and determine process economics. WRI initially intended to develop its own coalbed methane simulator which would be capable of simulating both ECBM and primary (gas depletion) scenarios. However as an alternative, WRI is evaluating the performance of a commercially available model, SIMED, offered by the Australian Petroleum Cooperative Research Centre (APCRC).

QUARTER OBJECTIVE

The objective for the quarter was to perform N₂/ECBM modeling studies with SIMED to evaluate the effects of diffusion on predicted recovery.

ACCOMPLISHMENTS

WRI evaluated the effects of diffusion and a dual-porosity reservoir description by performing simulations with SIMED. As a basis for modeling, WRI used a study that evaluated the economics of recovering methane from coalbeds by using N_2 as an injectant (Stevenson, 1993). Using the reservoir description of Stevenson, SIMED predicted an increase in methane production (over primary production rates) within one week of injection. In fact, the methane rate exceeded the N_2 injection rate by 10 to 15 vol% for the duration of the study. The simulation also predicted that the increase in methane production would be accompanied by an increase in N_2 percentage in the recovered gas. The immediate increase in methane production as a result of N_2 injection was observed by AMOCO in their N_2 pilot.

Based on our exposure to coalbed methane simulators that employ equilibrium sorption, WRI believes that equilibrium models would not have predicted the fast response nor the immediate appearance of N_2 in the product gas. WRI surmises that the differences in predictions between SIMED and models that employ equilibrium sorption result from the latter's assumption of instantaneous diffusion and the fact that equilibrium models are not formulated as a dual-porosity simulator.

WRI also used SIMED to predict methane recovery with CO_2 as an injectant. The modeling used the identical reservoir description as the N_2 economics study (Stevenson, 1993). Predicted methane recovery was less than predictions for N_2 for the one-year injection interval studied. However, the percentage of injected gas in the produced methane was lower with CO_2 than N_2 injection strategies. We presumed that the reduced recoveries were caused by the high sorption of CO_2 in comparison to N_2 .

WRI is currently negotiating a one-year lease of the SIMED model with APCRC. We have been pleased with SIMED's ability to predict the trends that were evident in AMOCO's N_2 pilot. SIMED's formulation includes diffusion within a dual-porosity description, which WRI believes is necessary to correctly model recovery from coalbed resources.

ACTIVITIES FOR NEXT QUARTER

Activities for next quarter are:

- Evaluate SIMED under conditions of multicomponent (i.e. N_2 and CO_2) gas injection.
- Evaluate SIMED with fractured reservoir description.

- If SIMED continues to perform well, enter into a one-year lease agreement.

REFERENCE

Stevenson, M.D., W.V. Pinczewski, and R.A. Downey, 1993, Economic Evaluation of Nitrogen Injection for Coalseam Gas Recovery. SPE Paper 26199, 1993 Gas Technology Symposium, Calgary, Alberta, 1993.

SUBTASK 1.4

TANK BOTTOM WASTE PROCESSING USING THE TABORR™ PROCESS

Robert M. Satchwell

November 1996–January 1997

OBJECTIVE

The objective of this project is to develop information for use in the successful deployment of WRI's patented TaBoRR® technology. To accomplish this objective, work is being conducted in areas of technology support, design and operation of a laboratory process unit, numerical modeling of the process, and economic analysis.

QUARTER OBJECTIVES

The objectives for the quarter were to:

- Locate and secure more samples of tank bottom wastes.
- Characterize and analyze the sampled tank bottom wastes.
- Compare numerical modeling results with those of the demonstration unit operations.

ACCOMPLISHMENTS

- Approximately 21 samples from Alaska, Kansas, California, Wyoming, New Mexico and Colorado have been received and analyzed for various physical and chemical properties.
- Delivery of the pyrolyzer was delayed but has been rescheduled.
- The modeling effort has been successful in determining the operational parameters of the flash operation.

OBJECTIVES FOR NEXT QUARTER

The following activities are planned for next quarter:

- Sample other sources of tank bottom wastes to add to the database
- Characterize and analyze the sampled tank bottom wastes
- Conduct further economic analysis of process operations.

TASK 2.0 ADVANCED SYSTEMS APPLICATIONS

BACKGROUND

Western U.S. coals and oil shale are quite different from their eastern counterparts. Eastern coals are typically higher in rank, heating value, and sulfur content than western coals. Conversely, western coals contain more moisture, higher volatile matter, and higher alkali and alkaline earth elements as ash. Therefore, combustion and conversion processes developed for eastern coals are often neither compatible with nor appropriate for the western coals.

Coal production is one of the most significant sources of revenue in the West. Over the last decade, the consumption of coal by electric utilities has grown at a faster rate than the consumption of either petroleum or natural gas. Energy development processes using coal are of interest to the state of Wyoming and the Rocky Mountain region.

Previous coal research at WRI has concentrated on the development and testing of coal drying and mild gasification technologies, as well as the tailoring and adaptation of advanced coal utilization concepts for low-rank western coals. These coals have several advantages over eastern coals. For example, because of their low sulfur content, they can be utilized in conventional PC boilers with relatively little emissions control equipment. Similarly, because of their low sulfur content, their use in advanced combustion systems requires less capital investment.

Current work at WRI is concentrating on design, assembly, and testing of a bench-scale fuel preparation and delivery system for pressurized application using coal fines. The results from this study will be used to design a fuel preparation and delivery system to be interfaced with WRI's solid fuel-fired gas turbine pilot unit.

LONG-TERM OBJECTIVES

The long-term objectives of this activity are to optimize and adapt the emerging coal-based technologies to Powder River Basin coals by exploiting some of the coals' unique properties while removing technical barriers.

A new subtask, Subtask 2.7 (Development and Testing of a Coal-Fired Gas Turbine) will be initiated later in the year.

TASK 3.0 ENVIRONMENTAL TECHNOLOGIES

BACKGROUND

Environmental issues in the United States have focused on ensuring clean air and water. The implementation of the Clean Air Act (CAA) and its amendments has indirectly resulted in an additional emphasis on solid waste management. The volume of solid waste is increasing from the fossil fuel production and consumption sectors, and the character of these wastes is also changing. The remediation of contaminated sites in the United States still remains a high priority. However, efforts to speed the cleanup of these sites are being hampered by the lack of effective high-volume treatment processes. Effective means of mitigating the environmental consequences related to energy development and utilization and the remediation of contaminated sites are needed today.

LONG-TERM OBJECTIVES

The Environmental Technologies task is designed to provide a range of environmental waste management services and research and development activities. The scope of the program includes developing waste management options for fossil fuel related industries and regulatory agencies. The long-term objectives of this task are to develop technologies that improve solid waste management practices, remediate hazardous waste and contaminated soils, and provide predictive models for environmental technologies.

Current areas of work include:

1. Solid waste management to evaluate conditioning and hydration reactions associated with clean coal technology ash disposal/utilization (Subtask 3.1).
2. Remediation of contaminated soils using the Haz-Flote™ process (Subtask 3.2).
3. Development and evaluation of the Syn-Ag™ process for coal combustion ash utilization (Subtask 3.3).
4. In-situ amelioration of acid mine drainage using the Maxi-Acid™ process (Subtask 3.4).
5. Attenuation of ammonium contaminate in an aquifer (Subtask 3.6). There was no appreciable activity on Subtask 3.6.
6. Evaluation of a series of dense gas dispersion tests (Subtask 3.7).

SUBTASK 3.1

CONDITIONING AND HYDRATION REACTIONS ASSOCIATED WITH CLEAN COAL TECHNOLOGY ASH DISPOSAL/UTILIZATION

Alan E. Bland
Terry H. Brown

November 1996–January 1997

OBJECTIVES

Project objectives are to generate the required fundamental data and to develop technologies that can be used by industry to assess and implement economically and technically viable ash management strategies and plans for CCT ashes.

QUARTER OBJECTIVES

The objectives for the quarter were:

- Prepare patent applications
- Prepare a final report for U.S. DOE FETC

ACCOMPLISHMENTS

WRI has initiated patent applications related to the results of the project. Work continued on a public version of the final report that does not compromise the patent applications

ACTIVITIES FOR NEXT QUARTER

- Continue with patent applications
- Prepare a final report for U.S. DOE FETC

PROCEDURES

Standard ASTM procedures for the geotechnical testing were used, including ASTM D-698 and 1557 for moisture-density relationship, ASTM C-109 (modified) for unconfined compressive strength, and ASTM C-157 for dimensional stability (expansion/shrinkage) testing. Chemical characterization used ASTM wet chemical methods, as well as standard ICAP, XRF, TGA, DSC, SEM and XRD techniques.

RESULTS

The results to date on the project are summarized below by project activity.

Activity 3.1.1 - Evaluation of the Chemical, Physical and Geotechnical Properties of Various CCT Ashes.

Four FBC ashes and two PFBC ashes were evaluated as part of the project. Geotechnical testing included moisture-density relationships (Proctors), unconfined compressive strength, and dimensional stability. Hydration reaction chemistry for the ashes has been completed. The geotechnical properties, such as strength and expansion, can be correlated with hydration reaction products in the ash.

Activity 3.1.2 - General Nature of Hydration Reactions

The reaction products from CCT ashes were examined, and they appear to be sensitive to a number of geochemical conditions. Methods for the identification and/or quantification of the appropriate hydration phases were also evaluated. Ettringite synthesized in the laboratory has been analyzed by a number of analytical techniques, of which advanced high-resolution TGA appears to be the most promising for quantification purposes.

restricted to US DOE and WRI only. Copies of the disclosures have been filed with the US DOE Patent Office. Activities are also under way to write and file the appropriate patent applications.

Activity 3.1.4 - Effect of Conditioning Media on Properties of Ashes.

The use of alternate water sources for conditioning CFBC ashes could provide relief to often scarce fresh water supplies. Testing was conducted on two ashes using two different water sources.

Activity 3.1.5 - Production of CLSFFM from CCT Ash.

Tests were completed using conventional and FBC ash-based controlled density flowable fill material (CLSFFM) designed at WRI. The FBC ash generator has asked WRI for assistance in the demonstration and marketing of the flowable fill under the JSR program.

ACTIVITIES FOR NEXT QUARTER

- Finish final topical report for U.S. DOE FETC and continue with patent applications.

SUBTASK 3.2

REMEDIATION OF CONTAMINATED SOILS (Haz-Flote™)

Terry H. Brown

November 1996–January 1997

OBJECTIVES

The primary objective of this subtask is to develop physical and chemical treatments to remove inorganic and organic compounds from contaminated materials. The project includes four areas of work:

- The acquisition of equipment and materials for the construction of the soil washing systems to be used in the remediation tests
- The preliminary evaluation of washing and remediation techniques for materials contaminated with metals and hydrocarbons
- The determination of physical and chemical treatment options for remediating mercury-contaminated soils associated with oil and gas pipelines
- Technical project management and reporting.

QUARTER OBJECTIVES

The objectives for this quarter were:

- Make a final decision on the patentability of the Haz-Flote technology
- Dispose of the mercury wastes
- Begin preparing the final report to DOE

ACCOMPLISHMENTS

- No work was done on this subtask this quarter

ACTIVITIES FOR NEXT QUARTER

- Begin preparing the final report to DOE

SUBTASK 3.3

THE SYN-AG™ PROCESS: COAL COMBUSTION ASH MANAGEMENT OPTION

Alan E. Bland

November 1996–January 1997

OBJECTIVES

Project objectives are to develop and demonstrate the technical process feasibility and economic viability of the Syn-Ag process for aggregate production using power plant ashes. The specific objectives are:

- Develop and document the Syn-Ag process
- Verify the properties of the aggregate produced from the Syn-Ag process
- Determine the process costs, including capital and operating costs, for the Syn-Ag process.

QUARTER OBJECTIVES

The objectives for the quarter were:

- Continue testing the production of the lightweight Syn-Ag product
- Continue with patent applications for Syn-Ag process configurations.

ACCOMPLISHMENTS

Disclosures have been written and patent applications are in being prepared. Copies of the disclosures have been supplied to the U.S. DOE Patent Office. Patent applications are in preparation. As a result, all information about the Syn-Ag process remains confidential to WRI, and therefore not available to the public and protected therein.

PROCEDURES

Standard ASTM procedures for the geotechnical testing were used, including ASTM D-698 and 1557 for moisture-density relationship, ASTM C-109 (modified) for unconfined compressive strength, and ASTM C-157 for dimensional stability (expansion/shrinkage) testing. LA abrasion resistance procedures follow ASTM C-131. Soundness testing followed ASTM C-88. Chemical characterization used ASTM wet chemical methods, as well as standard ICAP, XRF and XRD techniques.

ACTIVITIES FOR NEXT QUARTER

- Prepare for pilot-scale production runs and testing of lightweight Syn-Ag product.
- Continue with patent applications for Syn-Ag process configurations.

SUBTASK 3.4

THE MAXI-ACID™ PROCESS: IN-SITU AMELIORATION OF ACID MINE DRAINAGE

Terry H. Brown

November 1996–January 1997

OBJECTIVE

The objective of this subtask is to develop a method for the in-situ amelioration of acid mine drainage problems. The subtask includes the following work:

- Laboratory simulation and method development
- Design and modeling of the processes, including a containment system
- Application of the technology in a field trial.

QUARTER OBJECTIVES

The objectives for the quarter were:

- Continue evaluations of the influence of environmental conditions on acid and alkalinity production.
- Design and construct the leaching pad.

ACCOMPLISHMENTS

- Completed preliminary work on the impact of CO₂ on the formation of acid in a low O₂ environment.

OBJECTIVES FOR NEXT QUARTER

- Complete the construction of the leaching pad.
- Continue depletion studies.

SUBTASK 3.7

EVALUATION OF DENSE GAS DISPERSION

David Sheesley

November 1996–January 1997

OBJECTIVES

The objectives of this subtask are to:

- Archive spill test facility results from the U.S. Department of Energy Liquefied Gaseous Fuels Spill Test Facility (LGFSTF), at the Nevada National Test Site, hereinafter called Spill Test Facility (STF)
- Update the data base on chemical spill technology documents and data
- Make these data available to the public and industry.

QUARTER OBJECTIVES

- Archive Kit Fox data when \$500,000 funding for analysis has been allocated.
- Continues to seek funding to complete analysis in the related DOE NN-60 technology transfer project.
- WRI has also sought funding to complete the 1995 jointly sponsored Kit Fox research data processing and analysis as mandated by PL 101-549.

ACCOMPLISHMENTS

- A final report for the subtask was completed.

TASK 4.0 APPLIED ENERGY SCIENCE

BACKGROUND

In general, the reason alternative fossil fuels such as coal and oil shale have not found their way into the marketplace as sources for the production of transportation fuels is the high cost of recovery and conversion of these resources into useful products. In addition, the refining of crude oils to transportation fuels is becoming more costly because the amounts of heavy crude oils in the feedstock that must be refined is gradually increasing. Work on a different type of resource has recently been conducted that demonstrates that a light distillate can be produced that contains very little heteroatomic species. In addition, it is estimated that the cost of recovering this resource is not as great as producing a syncrude from oil or oil shale. The feedstocks for this process are waste motor oil and waste plastics that are normally discarded into landfills.

Preliminary results have also been obtained using hydrogen-rich plasmas to convert solid or high boiling fossil fuels to liquid products with low heteroatomic content.

Resources that can potentially be investigated under these subtasks include not only the more conventional resources, such as heavy crude oils, coal and coal-derived liquids, but also waste plastics and other streams that may potentially be converted into useful products. The successful conversion of the latter resources into useful products also has the potential of making a significant impact on our demand for foreign oil. In addition, the utilization of waste streams also helps resolve an impending problem with landfills in the United States. Legislation is being enacted in many states that will severely limit the types of wastes that can be disposed of in landfills.

LONG-TERM OBJECTIVE

The long-term objective of this task is to conduct basic science research to better understand and evaluate various applied energy technologies as they pertain to different feedstocks. This can be accomplished either through a better understanding of the nature and impact of the composition of different fossil fuels during the application of current processes or through the development of new processes.

Work continued on Subtask 4.2 (Fossil Fuel and Hydrocarbon Conversion Using Hydrogen-Rich Plasmas).

SUBTASK 4.2

PRELIMINARY EVALUATION OF A PROCESS USING PLASMA REACTIONS TO DESULFURIZE HEAVY OILS

Francis P. Miknis and Will Grimes

November 1996–January 1997

TASK OBJECTIVES

The objective of this task is to provide data needed to assess the viability of a process to desulfurize heavy oils through the use of plasma reactions.

QUARTER OBJECTIVES

The objectives for this quarter were to complete the experimental work, analyze the results and prepare a final report.

ACCOMPLISHMENTS

Samples from the exploratory tests of the previous quarter were analyzed to determine the extent of desulfurization. Additional experiments based on these results were conducted with an emphasis on higher conversions. Samples of the reaction products from these experiments are ready for analysis.

ACTIVITIES FOR NEXT QUARTER

Samples from the conversion experiments will be analyzed and a final report will be prepared.

PROCEDURES

Elemental analyses of the liquid products from exploratory plasma desulfurization experiments conducted in the previous quarter did not show significant sulfur removal. However, conversion to distillable liquid was minimal in all the tests, and these liquids were not analyzed separately. In the conventional hydrocracking of bitumen residuum, sulfur removal and distribution among the various

products has been shown to be a function of the degree of conversion (Sanford 1994). At low conversions most of the sulfur remains with the liquid reaction product. This seems to also apply to the plasma reactions. The exploratory experiments indicated that higher conversions would be needed to evaluate the concept of using plasma reactions to desulfurize heavy oils.

Two series of experiments were conducted using a batch reactor system and a high-sulfur asphalt obtained from the Strategic Highway Research Program Materials Reference Library (Cominsky et al. 1989). The first series of four tests was conducted to explore the effects of sample temperature and location of the sample with respect to the discharge on conversion to distillable liquids. After each test, the reactor was washed with methylene chloride. The methylene chloride was filtered, and the insoluble material was washed and weighed. Distillate samples from these tests were analyzed by simulated distillation.

A series of eight tests was conducted in which the distance from the end of the interior plasma tube to the sample was varied. Four different reactor geometries were used for these tests. Tests were conducted with hydrogen and nitrogen plasmas with each geometry. After the plasma exposure, the reactor was washed with methylene chloride and the resulting mixture was filtered. Samples of the methylene chloride insoluble material were saved for elemental analysis. Samples of the methylene chloride soluble residual material and the distillate from the cold trap were saved for simulated distillation and elemental analysis.

One experiment was conducted in which the asphalt was placed within the plasma rather than downstream of the discharge. This experiment was conducted using a regular kitchen-type microwave oven and a 250-ml round-bottom quartz flask configured to maintain a flow of hydrogen at a pressure of ~6 mm Hg. The asphalt was coated around the circumference of the flask then exposed to a hydrogen plasma for 15 minutes. The reaction flask outlet was connected through a dry ice/methanol-chilled cold trap to a vacuum trap and vacuum pump. Inlet gas flow rate was set by a mass flow controller.

The batch reactor shown schematically in Figure 1 was used for most of the experimental work. The reactor consisted of two coaxial quartz tubes. The 19 mm o.d. outer tube was sealed at one end to form an elongated test tube that served as the sample holder. The 9 mm o.d. interior tube provided a flow path for the inlet gas stream so that it was directed toward the surface of the sample. The interior tube was attached to the outer tube by a stainless steel fitting with O-ring seals. The axial adjustment provided by this arrangement allowed the distance from the end of the interior tube to the sample to be varied. Distillate was collected in a dry ice/methanol-chilled cold trap. Inlet gas flow rate was set using a mass flow controller.

Figure 1. Schematic Diagram of Batch Reactor System

RESULTS

In the previous quarter, a series of exploratory experiments was conducted on the use of microwave-induced plasmas to desulfurize heavy oils. In these experiments, asphalt samples were exposed to H₂, He, CH₄, or CH₄/H₂O plasmas. In each test, the sample was heated to 120° C, gas flow was established at 36 sccm (~100 mMol/hr.), and microwave power was set at ~ 200 watts. Samples were exposed to the plasma for 165 minutes. Reactor pressure was 6 mm Hg (0.8 kPa), except for one test with hydrogen plasma in which reactor pressure was 15 mm Hg (2.0 kPa). After each test, the cold trap and reactor were rinsed with methylene chloride. The liquid from the cold trap and reactor were combined, and the solvent was evaporated to provide samples of the liquid reaction products for elemental analysis. Table 1 lists product distribution and conversion to distillable liquids and gas for these tests. Table 2 shows the results of elemental analysis of the original asphalt and the liquid reaction products.

Table 1. Conversion and Product Distribution for Exploratory Plasma Desulfurization Tests

test #	gas	total	distillate		gas	
		% feed	% feed	% prod.	% feed	% prod.
1-1	H2	0.2	0.0	0.0	0.2	100.0
1-2	He	4.3	0.2	5.3	4.1	94.7
1-3	H2	17.0	2.4	14.3	14.5	85.7
1-4	CH4	11.8	5.1	43.4	6.7	56.6
1-5	CH4/H2O	11.6	4.4	37.8	7.2	62.2
1-6	H2	10.7	0.2	2.2	10.4	97.8

Table 2. Elemental Analyses of Total Liquid Products for Exploratory Plasma Desulfurization Tests

test #	C	H	N	S	H/C
feed	81.42	10.21	0.08	7.31	1.5
1-1	80.69	10.53	0.06	7.72	1.57
1-2	81.18	10.86	0.04	6.93	1.6
1-3	81.68	10.17	0.07	7.09	1.49
1-4	81.98	10.3	0.05	6.68	1.15
1-5	81.96	10.19	0.1	6.75	1.49
1-6	80.73	11.17	0.07	7.03	1.68

Elemental analyses of the original asphalt and the liquid reaction products show no significant reduction in sulfur after exposure to the plasmas. From these data it does not appear that reactive species in the plasma selectively abstract sulfur from the hydrocarbon matrix. Instead, it appears that carbon, hydrogen, and sulfur are abstracted nearly stoichiometrically in the product gas. For these tests, conversion was calculated as: (weight of distillate + weight of gas)/(weight of feed) x 100.

Four tests were conducted to explore the effects of sample temperature and location of the sample with respect to the discharge on conversion to distillable liquids. The apparatus shown schematically in figure 1 was used for these experiments. Hydrogen flow was maintained at 36 sccm for all four tests.

In test 2-1, the asphalt sample was preheated to 160° C and exposed to hydrogen plasma for 270 minutes. There was a small leak at the O-ring seal on the interior plasma tube during the first 125 minutes of this test. When this leak was repaired, the interior tube slipped, moving its outlet end closer to the asphalt. In test 2-2, the sample was preheated to 188° C and exposed to hydrogen plasma for 166 minutes. The outlet end of the interior tube was fixed ~8 mm above the surface of the asphalt. For test 2-3, the asphalt was moved closer to the microwave applicator so that the surface of the asphalt was just below the bottom of the wave guide. The asphalt was preheated to 180° C and exposed to the hydrogen plasma for 25 minutes. In test 2-4, the asphalt was preheated to 180° C and exposed to the hydrogen plasma 746 minutes. During the first 660, minutes the end of the interior plasma tube was fixed at 8 mm above the asphalt surface. The cold trap was weighed at intervals as the test progressed. After 660 minutes, the cold trap weight was recorded. The interior tube was then lowered so that its outlet end was about even with the surface of the asphalt and the exposure was continued for an additional 86 minutes.

Table 3 lists the conversions and product distributions for these tests. Conversion was calculated as [(weight of feed) - (weight of MeCl_2 soluble resid)]/(weight of feed) x 100. It is interesting to note that methylene chloride insoluble solids were formed in similar amounts in all the tests and that there was no apparent correlation between solids formation and degree of conversion. The first test seemed to form the most distillate, but this result is suspect because of a leak in the reactor during the first half of the test. In the last test, 0.11 grams of distillate was produced during the first 660 minutes of exposure to the hydrogen plasma with the outlet of the interior tube 8 mm above the asphalt. Nearly twice this amount (0.20 grams) was produced in the final 86 minutes with the end of the interior tube lowered to just above the surface of the asphalt.

Table 3. Conversion and Product Distribution for Series 2 Exploratory Plasma Desulfurization Tests

test #	total	distillate		solids		gas	
	% feed	% feed	% prod.	% feed	% prod.	% feed	% prod.
2-1	31.3	8.2	26.2	3.6	11.3	19.5	62.4
2-2	32.7	6.1	18.5	4.5	13.7	22.2	67.8
2-3	29.7	5.9	20.0	4.6	15.6	19.2	64.4
2-4	45.3	7.0	15.3	3.6	7.9	34.8	76.7

Figure 2 shows the results of simulated distillation of the liquid from the cold trap for the four tests. For each test about 50% of the distillate was light gas oil (195-340° C). Test 2-3 in which the asphalt was placed near the discharge produced more heavy distillate (>340° C), while lower boiling liquids were favored in test 2-2 with the sample farther from the discharge.

Figure 2. Results of Simulated Distillation of Distillate Product from Series 2 Tests.

Table 4. Experimental Conditions for Series 3 Plasma Desulfurization Tests

#	gas	pressure	power	position	
		mm Hg	watts	begin	end
3-1a	H	5	250	+8	+8
3-1b	N	6	250	+8	+8
3-2a	H	8	200	+2	-8
3-2b	N	7	200	+2	-8
3-3a	H	17	250	+2	-8
3-3b	N	6	250	+2	-8
3-4a	H	5	250	+8	-8
3-4b	N	6	250	+8	-8

Table 5. Conversion and Product Distribution for Series 3 Exploratory Plasma Desulfurization Tests

test #	total	distillate		solids		gas	
	% feed	% feed	% prod.	% feed	% prod.	% feed	% prod.
3-1a	54.00	10.50	19.44	10.00	18.52	33.50	62.04
3-1b	37.62	4.95	13.16	8.91	23.68	23.76	63.16
3-2a	60.70	26.87	44.26	5.97	9.84	27.86	45.90
3-2b	58.33	18.63	31.93	8.33	14.29	31.37	53.78
3-3a	67.00	29.06	43.38	9.36	13.97	28.57	42.65
3-3b	83.74	19.70	23.53	17.24	20.59	46.80	55.88
3-4a	93.50	26.00	27.81	17.00	18.18	50.50	54.01
3-4b	83.00	17.00	20.48	20.00	24.10	46.00	55.42

Table 5 lists conversion and product distribution for the final test series. All the tests produced more distillate with hydrogen plasma than with nitrogen plasma. In all the tests in which the interior tube was lowered toward the asphalt as the test progressed, more solids were produced with the nitrogen plasmas than with hydrogen plasmas. Overall conversion was higher with hydrogen plasmas for all but one test. Results of elemental analysis and simulated distillation of the various products were not available at the time of this writing.

Table 5. Conversion and Product Distribution for Series 3 Exploratory Plasma Desulfurization Tests

test #	total	distillate		solids		gas	
	% feed	% feed	% prod.	% feed	% prod.	% feed	% prod.
3-1a	54.00	10.50	19.44	10.00	18.52	33.50	62.04
3-1b	37.62	4.95	13.16	8.91	23.68	23.76	63.16
3-2a	60.70	26.87	44.26	5.97	9.84	27.86	45.90
3-2b	58.33	18.63	31.93	8.33	14.29	31.37	53.78
3-3a	67.00	29.06	43.38	9.36	13.97	28.57	42.65
3-3b	83.74	19.70	23.53	17.24	20.59	46.80	55.88
3-4a	93.50	26.00	27.81	17.00	18.18	50.50	54.01
3-4b	83.00	17.00	20.48	20.00	24.10	46.00	55.42

REFERENCES

- Sanford, Emerson C., Influence of Hydrogen and Catalyst on Distillate Yields and the Removal of Heteroatoms, Aromatics, and CCR over a Wide Range of Conversions, Energy and Fuels, 1994, 8, 1276-1288.
- Cominsky, R.J., J.S. Moulthorp, W.E. Elmoreand, T.W. Kennedy, SHRP Materials Reference Library Asphalt Selection Process: Rept. No. SHRP-IR-A-89-002, Strategic Highway Research Program, Washington, DC, 1989, 31pp.

TASK 6.0 REMEDIATION

Task 6.0 has Subtask 6.1 as the only activity. This subtask was not anticipated in the original work plan for Cooperative Agreement DE-FC21-93MC30126 but was included for convenience.

SUBTASK 6.1 NORTH SITE REMEDIATION

Norm Merriam

November 1996–January 1997

OBJECTIVES

The overall objectives of this subtask are to clean up the WRI north site in a cost-effective and environmentally sound manner. The objectives for the individual phases are:

Phase I– Definition of waste streams

Phase II–Disposal of hazardous wastes

Phase III–Disposal of nonhazardous wastes

Phase IV–Sampling of soil and removal of buried wastes

Phase V–Decontamination and removal of equipment

Phase Va–Groundwater monitoring

Phase VI–Preparation of a materials inventory data base

QUARTER OBJECTIVES

Objectives for this quarter were to:

- Revise final report as necessary
- Arrange for removal of low-level radioactive materials

ACCOMPLISHMENTS

- Phase I is complete.
- Phase II is complete. Low-level radioactive materials were removed.
- Phase III is complete.
- Phase IV is complete.
- Phase V is complete. A draft of the final report was submitted to DOE during last quarter.
- Site revegetation and surface water control are complete.
- Phase VI, materials inventory database, is complete.
- Monthly reports were submitted.
- Topical reports were prepared as phases were completed.

OBJECTIVES FOR NEXT QUARTER

- Revise the final report as necessary

CONTRACT STATUS REPORT

Contract No:	DE-FC21-93MC30126
Client:	U.S. Department of Energy
Contract Start:	February 2, 1993
Contract Complete:	February 1, 1998
Reporting Period:	4th Quarter, Year 4

CUMULATIVE ACCRUED EXPENDITURES, YEAR 4 (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget	137,000	387,000	607,000	780,000
Expenditures (Cumulative)	2,839	171,629	258,455	329,082
Remaining Budget	777,161	608,371	521,545	450,918

EXPENDITURES VERSUS APPROVED BUDGET

CONTRACT STATUS REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Reporting Period: Cumulative Through 4th Quarter, 4th Year

APPROVED BUDGET

Year 1 (3/93)	Year 1 (12/93) Cleanup	Year 2 (4/94)	Year 2 (9/94) Cleanup	Year 3 (2/95)	Year 3 (9/95) Cleanup	Year 4 (4 - 9/96)
\$ 1,950,000	\$ 828,000	\$ 1,750,000	\$ 604,908	\$ 976,000	\$ 101,976	\$ 780,000

Total Approved Budget: \$ 6,990,884
 Total Expenditures Through 1/97: \$ 6,204,567
 Remaining Budget: \$ 786,317

EXPENDITURES VERSUS APPROVED BUDGET

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Johnson, L.
 Project Title: Subtask 1.2 - Miscible-Immiscible Gas Injection Processes
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address

Western Research Institute
 365 North Ninth Street
 Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Year - 254,500)	264,500	334,500	404,500	454,500
Expenditures (Prior Year - 97,907)	71,047	40,975	65,888	23,933
Remaining Budget	289,549	244,571	178,683	154,750

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Sm Donence</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Carlson, F.
 Project Title: Subtask 1.3 - Development of a Portable Data Acquisition System and Coalbed Methane Simulator
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
 Western Research Institute
 365 North Ninth Street
 Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years)	316,841	316,841	316,841	316,841
Expenditures (Prior Years - 157,522)	1,417	471	9,675	21,140
Remaining Budget	157,902	157,431	147,756	126,616

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Sm Doname</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Satchwell, R.
 Project Title: Subtask 1.4 - Tank Bottom Remediation
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
Western Research Institute
 365 North Ninth Street
 Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years - 588,275)	593,275	668,275	713,275	748,275
Expenditures (Prior Years - 486,719)	30,903	99,127	30,138	31,273
Remaining Budget	230,453	131,526	100,588	69,315

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Sm Doneme</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Sethi, V.
 Project Title: Subtask 2.7 - Development and Testing of a Coal-Fired Gas Turbine System
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
Western Research Institute
365 North Ninth Street
Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget	67,000	112,000	157,000	195,000
Expenditures	0	67	18	32
Remaining Budget	195,000	194,933	194,915	194,883

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Sm Dorence</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Bland, A.
 Project Title: Subtask 3.1 - Solid Waste Management
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
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Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years)	691,998	691,998	691,998	691,998
Expenditures (Prior Years - 636,017)	49,107	(4,321)	6,691	4,494
Remaining Budget	6,874	11,195	4,504	10

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>SM Doname</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4800.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Brown, T.
 Project Title: Subtask 3.2 - Remediation of Contaminated Soils (Haz-Flote)
 Reporting Period: November 2, 1996 - February 1, 1997

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 Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years)	442,074	442,074	442,074	442,074
Expenditures (Prior Years - 341,301)	37,657	36,881	13,595	2,847
Remaining Budget	63,116	26,235	12,640	9,793

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date

Sm Donenue

2/27/97

Signature of USDOE Reviewing Representative and Date

Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Bland, A.
 Project Title: Subtask 3.3 - Syn-Ag Process: Coal Combustion Ash Management Option
 Reporting Period: November 2, 1996 - February 1, 1997

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EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years)	183,521	183,521	183,521	183,521
Expenditures (Prior Years - 63,992)	11,037	5,832	24,124	13,610
Remaining Budget	108,492	102,660	78,536	64,926

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Jim Donence</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Brown, T.
 Project Title: Subtask 3.4 - Maxi-Acid Process: In-Situ Amelioration of Acid Mine Drainage Problems
 Reporting Period: November 2, 1996 - February 1, 1997

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Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years)	231,057	231,057	231,057	231,057
Expenditures (Prior Years - 85,116)	8,155	3,956	14,882	33,492
Remaining Budget	137,796	133,840	118,958	85,466

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Sm Donenue</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Brown, T.
 Project Title: Subtask 3.6 - Attenuation of Ammonium Concentrate in an Aquifer
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
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 365 North Ninth Street
 Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years)	16,400	16,400	16,400	16,400
Expenditures (Prior Years - 0)	1,259	0	693	2,673
Remaining Budget	15,141	15,141	14,448	11,775

EXPENDITURES VERSUS APPROVED BUDGET

Milestones	Planned	Actual	Progress	Scheduled	Delivered
96-3.6 Attenuation of Ammonium Concentrate					
96-3.6A Final Topical Report					
96-3.6B Quarterly Report					

Feb 1 May 1 Aug 1 Nov 1 1996 Feb 1 1997

Signature of Recipient and Date

Sm Doneme 2/27/97

Signature of USDOE Reviewing Representative and Date

Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Sheesley, D.
 Project Title: Subtask 3.7 - Evaluation of Dense Gas Dispersion
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
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 Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget	40,000	85,000	130,000	175,000
Expenditures	2,839	140,249	23,442	3,481
Remaining Budget	172,161	31,912	8,470	4,989

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>SM Dorence</i> 2/21/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-458E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Miknis, F.
 Project Title: Subtask 4.2 - Fossil Fuel and Hydrocarbon Conversion Using Hydrogen-Rich Plasmas
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
Western Research Institute
365 North Ninth Street
Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years - 81,447)	96,447	111,447	126,447	131,447
Expenditures (Prior Years - 78,231)	2,190	348	11,789	11,908
Remaining Budget	51,026	50,678	38,889	26,981

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Sm Doname</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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Substitute DOE Form F 4600.5 replacing Form EIA-459E

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

Contract No: DE-FC21-93MC30126
 Client: U.S. Department of Energy
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Subtask Manager: Merriam, N.
 Project Title: Subtask 6.1 - North Site Remediation
 Reporting Period: November 2, 1996 - February 1, 1997

Name and Address
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 Laramie, Wyoming 82070

EXPENDITURES (\$)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Approved Budget (Prior Years)	1,534,884	1,534,884	1,534,884	1,534,884
Expenditures (Prior Years - 1,142,253)	95,898	160,705	65,356	37,054
Remaining Budget	296,733	136,028	70,672	33,618

EXPENDITURES VERSUS APPROVED BUDGET

Signature of Recipient and Date <i>Sm Donehue</i> 2/27/97	Signature of USDOE Reviewing Representative and Date
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