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Base Program on Energy Related Research

**Quarterly Report
August 1 - October 31, 1997**

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For
U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
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TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	iv
EXECUTIVE SUMMARY	v
TASK 1.0 OIL AND GAS	1
Subtask 1.2 Miscible/Immiscible Gas Injection Processes	2
Subtask 1.3 Development of a Portable Data Acquisition System and Coalbed Methane Simulator	4
Subtask 1.4 Tank Bottom Waste Processing Using the TaBoRR® Process	6
Subtask 1.5 Bench-Scale Testing and Verification of Pyrolysis Concept for Remediation of Tank Bottoms	8
TASK 2.0 ADVANCED SYSTEMS APPLICATIONS	10
TASK 3.0 ENVIRONMENTAL TECHNOLOGIES	11
Subtask 3.2 Remediation of Contaminated Soils (Haz-Flote™)	12
Subtask 3.3 The Syn-Ag™ Process: Coal Combustion Ash Management Option ...	14
Subtask 3.4 The Maxi-Acid™ Process: In-Situ Amelioration of Acid Mine Drainage	15
TASK 4.0 ENVIRONMENTAL TECHNOLOGIES	16
Subtask 4.1 Heavy Oil/Plastics Co-Processing	17
Subtask 4.2 Fossil Fuel and Hydrocarbon Conversion Using Hydrogen-Rich Plasmas	19
CONTRACT STATUS REPORT (Current Year Subtasks Only)	20
CONTRACT STATUS REPORT (Contract to Date)	21
FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORTS	
(Active Subtasks Only)	22

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Summary of Base Funding for FY 1993–1997	vi
2. Subtasks Approved for Funding Through FY 97	x

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 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 (FETC) 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 \$7,511,884 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 1993-1997

Fiscal Year	Funding	Number of Projects	New Starts
1997	521,000	23	2
1996	780,000	21	2
1995	1,077,976	19	4
1994	3,132,908	15	5
1993	1,950,000	10	10
TOTAL	7,511,884		

Significant Accomplishments Under the Base Research Program

CROW™ Process Modeling

A numerical simulator was developed and compared with laboratory physical simulations of the Contained Recovery of Oily Wastes (CROW) process that was previously patented by WRI (U.S. Patent No. 4,848,460). The data were used to update the model in such a way that excellent predictability of the behavior of oily wastes during their remediation with the CROW process was achieved. This information greatly enhanced the utility of this technology.

Miscible-Immiscible Gas Injection Processes

WRI is currently developing a predictive model for miscible-immiscible gas injection processes with emphasis on the 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. Nine full-scale physical simulations were completed and data indicate that there would be a 5 to 12% increase in recovered oil using a gas trapping mechanism with proper immiscible injection of CO₂.

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 300-barrel per day demonstration has been designed, constructed, and operated with DOE JSR, cosponsor and Base Program funding. This includes the addition of a pyrolyzer designed to produce low-volume, benign solid waste for landfill as the only unusable product.

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 U.S. Patent No. 5,322,530. 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 try obtain cosponsorship for a pilot-scale demonstration of the technology.

Environmental Technologies

WRI has worked 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 task evaluated 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 related task determined the economic and technical feasibility of using power plant ashes to produce synthetic aggregate in the Syn-Ag™ process. Work on the Haz-Flote™ process is designed for ex-situ decontamination of materials with hydrocarbon content. It will be a valuable complement to CROW™. A patent attorney is currently evaluating whether to seek patent protection for inventions from the prior three subtasks. WRI's Maxi-Acid™ process addressed 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.

PEAC™

PEAC™ (Palmtop Emergency Action for Chemicals) is a technology for which WRI is seeking patent protection. WRI has recently heard that the U. S. patent has been approved, but it is not issued yet. The technology was developed under a variety of sponsorship including DOE (Base and JSR), EPA, and petroleum companies and organizations. The product is a self-contained, hand-held unit that aids emergency responders in evaluating the safety considerations related to chemical spills. The considerations include, but are not limited to, toxicity, dispersion characteristics, evacuation distance, and explosion hazard. The software in PEAC utilizes data bases developed by WRI from experiments at the DOE national Spill Test Facility in Nevada.

Heavy Oil/Plastics Coprocessing

WRI has developed a method to coprocess 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 completed to define scale-up parameters at bench scale for economic evaluation and improvement of process efficiency. An initiator is used to cause significant conversion of the waste plastics into liquid hydrocarbons that distill in the range of gasoline and diesel. This information is 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 August Through October 1997

Task 1.0

A total of 12 physical simulations have been completed to evaluate miscible/immiscible gas injection processes for oil production (Subtask 1.2). Three were done this quarter. Relative permeability waves for liquids were developed from the lab production data. These resulted in an improved match between physical simulation and the model.

WRI will complete development of its own coalbed methane simulator (Subtask 1.3). It can describe multicomponent sorption using both equilibrium (pressure-dependent) and psuedo-steady-state (average concentration and pressure-dependent) physics. Non-steady-state sorption was also added to the model.

Work on Subtask 1.4 (Tank Bottom Waste Processing using the TaBoRR® Process) included economic analyses for plants sized between 300 and 5,000 barrels per day. Operating costs for these plants were also estimated.

Two samples of refinery residue with pour points greater than 250 ° F (121 ° C) were processed in the TaBoRR unit (Subtask 1.5–Bench-Scale Testing and Verification of the Pyrolysis Concept for Remediation of Tank Bottoms). Excellent mass balances were obtained in each case.

Task 3.0

A patent application for the Haz-Flote™ (Subtask 3.2) process is still being considered. Preparation of a final topical report will be initiated during the quarter.

Under Subtask 3.3 (Syn-Ag™: Coal Combustion Ash Management), testing of various additives to produce lightweight aggregate was continued at lab scale. Work on patent applications continued.

Table 2. Subtasks Approved for Funding Through FY 97

Subtask	Project	Years 1-4 Funding	FY 97 Funding	Total Funding
1.1	CROW™ Process Modeling	471,163	0	471,163
1.2	Miscible/Immiscible Gas Injection	454,500	0	454,500
1.3	Coalbed Methane Simulator	316,841	0	316,841
1.4	Development of the TaBoRR® Process	748,275	120,750	869,025
1.5	Verification of the TaBoRR® Pyrolyzer Concept	0	135,750	135,750
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	195,000	0	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	175,000	0	175,000
3.8	PEAC™ Value-Added Project	0	145,750	145,750
4.1	Heavy Oil/Plastics Co-Processing	278,282	118,750	397,032
4.2	Fossil Fuel Conversion With Hydrogen Plasmas	131,447	0	131,447
6.1	North Site Cleanup	1,534,884	0	1,534,884
TOTALS		6,990,884	521,000	7,511,884

Under Subtask 3.4 (Amelioration of Acid Mine Drainage), evaluation of depletion of potential acidity under freeze/thaw cycles was completed.

A final topical report was completed on Subtask 3.8 (PEACTM Value-Added Project).

Task 4.0

Screening of reaction initiators that do not contain chlorine was addressed this quarter under Subtask 4.1 (Heavy Oil/Plastics Co-Processing). Both polyvinyl alcohol (PVA) and polyoxymethylene (POM) were effective in producing distillate hydrocarbons from decomposition of mixed plastics.

A final report was completed for Subtask 4.2 (Fossil Fuel and Hydrocarbon Conversion Using Hydrogen-Rich Plasmas).

Federal Assistance Management Summary Reports (Substitute DOE Form F 4600.5) are included for active subtasks on pages 20–32.

CONTRACT STATUS REPORT

Contract No. DE-FC93MC30126
 Contract Start: February 2, 1993
 Contract Complete: February 1, 1998
 Reporting Period: Through 3rd Quarter, 5th Year

Subtask	Budget Prior years	Budget Yr 5	Total Budget	Expenses to 7/31/97	Expenses			Total Expenses	Balance
					August	September	October		
5th Year Subtasks									
1.4	748,275	120,750	869,025	688,483	119	1,501	7,689	697,792	171,233
1.5	0	135,750	135,750	42,368	15,440	38,398	26,502	122,708	13,042
3.8	0	145,750	145,750	140,894	2,069	247	1,001	144,210	1,540
4.1	278,282	118,750	397,032	325,075	3,770	5,856	13	334,715	62,317
Subtotals	1,026,557	521,000	1,547,557	1,196,820	21,398	46,001	35,205	1,299,425	248,132
Carryover Subtasks									
1.2	454,500	0	454,500	356,694	6,613	15,405	4,107	387,818	66,682
1.3	316,841	0	316,841	244,271	9,938	7,327	11,376	272,911	43,930
2.1	127,835	0	127,835	126,083	164	0	0	126,247	1,588
2.7	195,000	0	195,000	117	0	0	0	117	194,883
3.2	442,074	0	442,074	435,865	504	235	0	436,604	5,470
3.3	183,521	0	183,521	145,645	(520)	(6,463)	5,985	144,647	38,874
3.4	231,057	0	231,057	171,598	4,215	5,785	5,398	186,997	44,060
3.6	16,400	0	16,400	15,208	1,125	102	(55)	16,380	20
4.2	131,447	0	131,447	127,512	2,778	88	0	130,378	1,069
Subtotals	2,098,675	0	2,098,675	1,622,992	23,934	22,478	31,811	1,701,215	397,460
Other ⁽¹⁾	3,865,652	0	3,865,652	3,863,968	0	0	0	3,863,968	1,684
Totals	6,990,884	521,000	7,511,884	6,683,783	45,338	68,479	67,016	6,864,610	647,274

⁽¹⁾ Completed subtasks (1.1, 2.2, 2.3, 2.4, 2.5, 2.6, 3.1, 3.5, 3.7 and 6.1)

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. The present market for technologies developed by Western Research Institute (WRI) appears to be with the major oil and gas companies, as well as with 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).
4. Verification of the pyrolysis concept for TaBoRR (Subtask 1.5).

Funding was approved for continuation of Subtask 1.4 in the fifth year of Cooperative Agreement DE-FC21-93MC30126. Subtask 1.5 was initiated with fifth-year funding.

SUBTASK 1.2

MISCIBLE\IMMISCIBLE GAS INJECTION PROCESSES

Lyle A. Johnson

August–October 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

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

ACCOMPLISHMENTS

The numerical simulator used in the subtask was selected based on availability and on the presence of the various capabilities desirable for the simulations. The simulator is the GEM 96.00 simulator offered by the Computer Modeling Group (CMG). A copy of this simulator resides at the US Department of Energy (DOE) 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 design for the physical simulation system has been developed, with the physical simulations to be conducted in a sand-packed tube.

The physical simulation apparatus has been constructed, and shakedown testing (more than 10 tests) has been completed. Methods for packing the reactor tubes with sand to produce various permeabilities have been evaluated (8 tube packings). Twelve full-scale physical simulations have been completed, with one of the tests using only hexane and no gas injection for a baseline case. Results from the 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. Two of the simulations need a more viscous hydrocarbon than the hexane used in the other tests. Also included in the 12 tests are two duplicate tests to verify results.

ACTIVITIES FOR NEXT QUARTER

- Continue matching of the physical simulation results. Emphasis will be on determining if the gas trapping effect observed in the 1-D simulations can be extrapolated to a field situation.

SUBTASK 1.3

DEVELOPMENT OF A PORTABLE DATA ACQUISITION SYSTEM AND COALBED METHANE SIMULATOR

Charles G. Mones

August–October 1997

OBJECTIVES

WRI is currently participating in a Jointly Sponsored Research (JSR) project 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 OBJECTIVES

- Complete work on WRI's coalbed methane simulator giving the capability to select between equilibrium and pseudo-steady-state gas sorption.
- Perform operability tests with the model.

ACCOMPLISHMENTS

The coalbed methane simulator has been completed. The model has the ability to describe multicomponent sorption using both equilibrium (pressure-dependent) and pseudo-steady-state (average concentration and pressure-dependent) physics. Basic functionality testing has been conducted to verify that the model is operating correctly (numerically) and that the simulation results appear reasonable.

The ability to describe unsteady-state sorption was also added to the model during this quarter. An unsteady-state formulation relates the gas sorption rate to the time-dependent concentration gradient of sorbed gas within the coal's micropore (coal matrix). The unsteady state method potentially will result in more accurate predictions of recovery at early production times. In addition, the method more accurately describes transient performance and is potentially useful for evaluating well tests.

A potential shortcoming of the unsteady state formulation is excessive computation times that result from solving for sorbed gas concentrations within the coal micropore in addition to the usual macropore (coal fracture) transport equations. WRI has adapted a method of solution described by Ankle and Lambert (1980) to minimize computation times related to sorption. Ankle's approach decouples the calculation of sorption rate from the calculation of the concentration gradient within the micropore. The sorption rate is calculated within the model's implicit iteration loop and requires little computation time. The (time-consuming) solution for the concentration gradient occurs outside the iteration loop and is done after convergence has been achieved for the time step. Ankle's method does, in fact, achieve rapid execution speeds. Using a 2-dimensional, 2-component problem with an 11-by-11 grid system, the unsteady-state sorption required only 5% longer to execute than pseudo-steady-state sorption.

ACTIVITIES FOR NEXT QUARTER

- Continue testing the model to ensure proper operation.
- Compare model predictions with published results.

REFERENCES

Ankle, K.L. and Lambert, S., 1980, Analysis of the Coalbed Degasification Process at a Seventeen Well Pattern in the Warrior Basin of Alabama. SPE paper 8971 presented at the 1980 SPE/DOE Symposium on Unconventional Gas Recovery, Pittsburgh, PA, May 18-21, 1980.

SUBTASK 1.4

TANK BOTTOM WASTE PROCESSING USING THE TABORR® PROCESS

Robert M. Satchwell

August–October 1997

OBJECTIVE

Tank bottom wastes are being generated at a rate of about one million barrels a day. Disposing of these wastes costs production companies, pipelines, and refineries millions of dollars per year. Cost-effective treatment methods are needed to eliminate these wastes in an environmentally acceptable manner. The objective of this subtask is to develop information for use in the successful deployment of the TaBoRR® (Tank Bottoms Recovery and Remediation) technology developed and patented by WRI. WRI has generated a preliminary data base of tank bottom wastes that are created during oil production. The composition and physical properties of these samples vary widely. A data base will provide a basis for determining the most cost-effective and environmentally acceptable method of processing these materials.

QUARTER OBJECTIVES

- Sample other sources of tank bottom wastes.
- Characterize and analyze the sampled tank bottom wastes.
- Provide preliminary economics and scale-up economics for larger-sized units.

ACCOMPLISHMENTS

Samples from production and pipeline operations were obtained and analyzed. Laboratory experiments were conducted to determine yields from a Canadian sample. The results indicated that approximately 75% of the original feed material could be recovered as liquids. These liquids were highly upgraded compared to the original feed material.

Economic analysis was performed to determine the capital costs and debt service for various sized plants as shown in Table 1. These costs are based on \$1,000,000 for a 300 bpd plant and a 0.75 power law scaling. This assumes that the cost C_1 for a new capacity S_1 is related to a known cost C_0 for a known capacity S_0 by the following equation:

$$C_1 = C_0 * (S_1/S_0)^{0.75}$$

This scaling factor is very conservative for equipment of this size and may overestimate the capital cost of the larger units. The cost of debt service assumes 100% debt financing at an interest rate of 10% for five years. This debt is converted to a cost per barrel by assuming the plant operates at full capacity 300 days per year.

Table 1. TaBoRR Capital Costs and Debt Service

Size, Bpd	300	1000	3000	5000
Cost, \$MM	1,000	2,465	5,625	8,258
Annual Debt Service	\$254,965	\$628,488	\$1,434,176	\$2,105,497
Debt Service, \$/bbl	2.83	2.09	1.59	1.40

Operating costs were also estimated for various sized TaBoRR units as shown in Table 2. These costs consist of fixed and variable costs. Fixed costs include debt service, property taxes, insurance, maintenance, and operating labor. Variable costs include natural gas and electricity. In commercial practice, it can be expected that fuel gas will be reduced or eliminated, however this is not credited in this analysis. Operating costs include benefits and overhead and are computed at \$50/hr for 8760 hours per year. Maintenance costs are assumed to be 2.5% of capital investment. Taxes and insurance are assumed to be 5% of capital investment. Natural gas is priced at \$2.25/Mcf and electricity at \$0.05/kWh.

Table 2. TaBoRR Annual Operating Expenses

Size, Bpd	300	1000	3000	5000
Fixed Expenses, \$/bbl	8.53	4.17	2.55	2.11
Variable Expenses, \$/bbl	2.13	2.13	2.13	2.13
Total Expenses, \$/bbl	10.66	6.30	4.67	4.23

ACTIVITIES FOR NEXT QUARTER

- Testing of a concept to remove high concentrations of water from feed materials.
- Concentrated effort on shakedown operations of the pyrolyzer demonstration unit.

SUBTASK 1.5

BENCH-SCALE TESTING AND VERIFICATION OF PYROLYSIS CONCEPT FOR REMEDIATION OF TANK BOTTOMS

Robert M. Satchwell

August–October 1997

OBJECTIVES

WRI is developing, testing, and marketing its patented TaBoRR® (Tank Bottoms Recovery and Remediation) technology to treat tank bottom wastes. However, WRI's preliminary survey of the composition and physical properties of tank bottom wastes being generated has shown that some contain large amounts of solids. These wastes cannot be handled by the TaBoRR process and hence require special treatment schemes. Some of the early work performed at WRI has shown that through relatively mild thermal processing (pyrolysis) in a screw reactor, wastes containing high solids content, including those generated by the TaBoRR process as stripper bottoms, can be converted into a safe, disposable, carbon-rich solid waste form.

The goal of this subtask is to establish the viability of the pyrolysis concept for the ultimate disposal of TaBoRR stripper wastes and some unique tank bottom wastes containing high concentration of solids by defining the operating conditions (temperature, residence time) under which wastes are rendered into a carbon-rich, landfillable form.

Specific objectives of the proposed work are to:

- Modify an existing 6-in. twin-screw setup by installing a product collection train and upgrading the instrumentation.
- Determine the residence time and temperatures required to process the stripper bottoms created from the demonstration unit.
- Test and evaluate the pyrolysis concept using difficult and unique materials not suited for full TaBoRR processing.
- Characterize the gaseous and liquid products and establish disposal characteristics of produced solids.

QUARTER OBJECTIVES

- Continue to perform tests and evaluate the pyrolysis concept using difficult and unique materials not suited for full TaBoRR processing.

ACCOMPLISHMENTS

Two different samples of refinery residue (coker feed materials) were initially tested using the same reactor setup. The feed materials were solid in nature with pour points greater than 250°F (121°C). After an initial test, feed and mechanical problems occurred. Modifications to the reactor were employed to remedy the operations problems. The system was modified to:

- Upgrade the feed system to handle solid feeds that liquefy
- Modify the product collection system to prevent fouling and allow for the collection of light hydrocarbon products
- Reduce the angle of inclination of the reactor to match the demonstration plant.

Tests of the refinery samples were performed after reactor modifications were completed. Excellent mass balances were achieved for both materials. Exact product distribution and analytical results are confidential.

ACTIVITIES FOR NEXT QUARTER

- Efforts will focus on shakedown operations of the pyrolyzer demonstration unit.

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.

Subtask 2.7 (Development and Testing of a Coal-Fired Gas Turbine) will be initiated when work is completed on wood firing using the same equipment.

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. Remediation of contaminated soils using the Haz-Flote™ process (Subtask 3.2).
2. Development and evaluation of the Syn-Ag™ process for coal combustion ash utilization (Subtask 3.3).
3. In-situ amelioration of acid mine drainage using the Maxi-Acid™ process (Subtask 3.4).
4. Attenuation of ammonium contaminate in an aquifer (Subtask 3.6).

SUBTASK 3.2

REMEDIATION OF CONTAMINATED SOILS (Haz-Flote™)

Terry H. Brown

August–October 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

- Make a final decision on the patentability of the Haz-Flote™ technology.
- Prepare the final report for the DOE.

ACCOMPLISHMENTS

- A decision to pursue a patent application has not been made.
- Work on the final report has been initiated.

ACTIVITIES FOR NEXT QUARTER

- Prepare the final report for the DOE.
- Seek additional funding to address issues associated with the removal of Hg and other elements from various environments and the acidic nature of the remediated materials.

SUBTASK 3.3

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

Alan E. Bland

August–October 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

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

ACCOMPLISHMENTS

- Testing of various additives for lightweight aggregate production was conducted at the laboratory scale.
- A Syn-Ag production trial using CFBC ash was conducted, and the product is being tested.
- Work on the patent applications continued. An update of the proprietary components of the Syn-Ag process was supplied to the patent attorney.

ACTIVITIES FOR NEXT QUARTER

- Conduct pilot-scale lightweight aggregate production runs and testing of 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

August–October 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 (ongoing).
- Design and modeling of the processes, including a containment system (not initiated).
- Application of the technology in a field trial (not initiated).

QUARTER OBJECTIVES

- Continue evaluations of the influence of environmental conditions on acid and alkalinity production.
- Construct columns and initiate the chemically aided depletion studies.

ACCOMPLISHMENTS

- Completed the depletion of potential acidity using humidity cells.

ACTIVITIES FOR NEXT QUARTER

- Continue the depletion studies.

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 was reinitiated under fifth-year funding to complete bench-scale analysis of Plastics/Heavy Oil Co-Processing (Subtask 4.1).

A final report is in preparation for Subtask 4.2 (Fossil Fuel and Hydrocarbon Conversion Using Hydrogen-Rich Plasmas).

SUBTASK 4.1

HEAVY OIL/PLASTICS CO-PROCESSING

Frank D. Guffey

August–October 1997

OBJECTIVES

The objectives of the subtask are to address the areas in our data base that do not have sufficient supporting data:

- Identify an initiator other than polyvinyl chloride (PVC) that does not contain halogens in an effort to eliminate the possibility of introducing chlorine into the products.
- Demonstrate the applicability of heavy oils other than used motor oil as coprocessing oils
- Generate additional processing data to demonstrate the technical feasibility of the concept with a different initiator and other heavy oils.

QUARTER OBJECTIVES

- Complete screening of the four initiators identified from the literature search.
- Begin evaluation of additional processing oils.

ACCOMPLISHMENTS

The screening of potential initiators that do not contain chlorine was addressed this quarter. Two oxygen-containing polymers have been identified that appear to have activity comparable to PVC. Obligations to another project diluted the efforts on Subtask 4.1. Therefore, the coprocessing of oils other than used motor oil with the waste plastics was not addressed.

A series of experiments was conducted to evaluate potential free radical initiators. The experiments were conducted to compare the activity of polyvinyl alcohol (PVA) and poly(oxymethylene) (POM) with that of polyvinyl chloride (PVC) and thermal decomposition without

the use of an initiator. The experiments were conducted using the same mass of each of the initiators as the mass of PVC used in earlier experiments.

Results from these experiments are listed in Table 1. The results provide the mass balance closure and distillate yield and plastics conversion as weight percentages for each initiator. Evaluation of the results shows that each of the initiators increases the distillate over thermal decomposition without an initiator. However, POM is not as active in producing distillate as in PVC. These results show PVA has the greatest effect on increasing distillate yield.

Table 1. Results Comparing the Activities of PVC, PVA, and POM on an Equivalent Mass Basis

Reaction Temperature (°C)	Initiator	Mass Closure (%)	Distillate Yield (%)	Plastics Conversion (%)
390	None	97.0	18.5	3.4
390	PVC	99.8	29.4	2.8
390	POM	98.9	21.6	8.2
390	PVA	99.0	33.8	5.4

Examination of the plastics conversion provides a different insight into the activity of the initiators. Polyvinyl chloride does not provide as much plastics conversion as thermal decomposition without the use of an initiator. However, POM shows the highest plastics conversion of all cases studied. This observation is interesting and will be further investigated in future efforts.

ACTIVITIES FOR NEXT QUARTER

- Activities will address the use of oils other than used motor oil for coprocessing waste plastics.

REFERENCES

Thayer, A.M., 1989, Solid Waste Concerns Spur Plastic Recycling Efforts. *Chemical and Engineering News*, January 30, 7-15.

SUBTASK 4.2

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

Francis P. Miknis
Will Grimes

August–October 1997

OBJECTIVE

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

QUARTER OBJECTIVES

- Complete the final report for the DOE.

ACCOMPLISHMENTS

- A final report has been written and is undergoing review.

ACTIVITIES FOR NEXT QUARTER

- Submit final report to FETC.

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:	3rd Quarter, Year 5

CUMULATIVE ACCRUED EXPENDITURES, YEAR 5 (\$)

	<u>Quarter 1</u>	<u>Quarter 2</u>	<u>Quarter 3</u>	<u>Quarter 4</u>
Approved Budget	170,000	335,000	440,000	521,000
Expenditures (Cumulative)	82,818	229,544	329,371	—
Remaining Budget	438,182	281,456	100,629	—

EXPENDITURES VERSUS APPROVED BUDGET