DOE/FC/10066-T1(Vol.5)

LOW-RANK COAL STUDY

NATIONAL NEEDS FOR RESOURCE DEVELOPMENT

MASTER

RD&D PROGRAM EVALUATION

The United States has over 1 trillion tons of identified low-rank coal resources; the strippable reserve base exceeds 100 billion tons. Major lignite deposits exist in the Fort Union Region and the Gulf Coast Region. The largest subbituminous coal deposits are in the Powder River Region, the San Juan Basin, and Northern Alaska.

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LOW-RANK COAL STUDY
National Needs for Resource Development

Volume 5 - RD&D Program Evaluation

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Energy Resources Co., Inc.
Walnut Creek, California

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PREFACE

This is volume five of a six-volume "Low-Rank Coal Study." Overall, the report presents a comprehensive analysis of the technical, environmental, and economic constraints to expanded development of U.S. lignite, subbituminous coal, and peat resources. The primary objective of the study was to propose a comprehensive national research, development, and demonstration (RD&D) program focusing on technology development for enhanced utilization of these resources. The report is organized as follows:[a]

Volume 1 - Executive Summary
Volume 2 - Resource Characterization
Volume 3 - Technology Evaluation
Volume 4 - Regulatory, Environmental, and Market Analyses
Volume 5 - RD&D Program Evaluation
Volume 6 - Peat

This study was directed by the Grand Forks Energy Technology Center (GFETC), which has the lead mission within the Department of Energy for technology "applications for low-rank coals." G. H. Gronhovd (Director) and E.A. Sondreal (Deputy Director) of GFETC provided technical direction and review of all aspects of the study. The work was performed by Energy Resources Company, Inc. (ERCO) under a contract initiated on May 16, 1979, and completed on September 30, 1980. The study approach is summarized in Table P-1, which shows the eight major contract tasks and the approximate percentage allocation of funds to each. The study schedule is summarized on Figure P-1.

Because of the scope and complexity of the effort, GFETC enlisted a task force of recognized experts on the technical and regional issues germane to the study. These individuals are listed in Table P-2; their contributions to the quality and direction of the study were highly significant. The task force met with the study team at four critical points to review interim results and to lead working groups which established the emphasis, priorities, and methodologies for the analysis. Primarily through the efforts of the task force members, useful data inputs and critiques of working draft materials were received from a number of organizations as the study progressed.

Individual contacts and contributions made during the course of the study are too numerous to list. The following (in addition to the task force members) contributed significantly to the review of part or all of the document: G.H. Gronhovd, E.A. Sondreal, W.G. Willson, and H.H. Schobert of GFETC; W.R. Kube of the University of North Dakota and GFETC; S. Alpert, K. Clifford, S. Ehrlich, T. Lund, C. Aulisio, D. Giovanni, and R. Wolk of the Electric Power Research Institute; W. McCurdy, S. Freedman, L. Miller, M. Kopstein, L. Ludwig, E. Burwell, W. Schmidt, M.N. Rosenthal, J. Nardella, and J. Turner of DOE; W.R. Kaiser of the University of Texas at Austin; and P. Averitt (retired) of the U.S. Geological Survey.

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[a] Volumes 2 through 5 address lignite and subbituminous coal; Volume 6 addresses peat; and Volume 1 summarizes the conclusions and recommendations of the total study.

Figure P-1

Low-Rank Coal Study Schedule

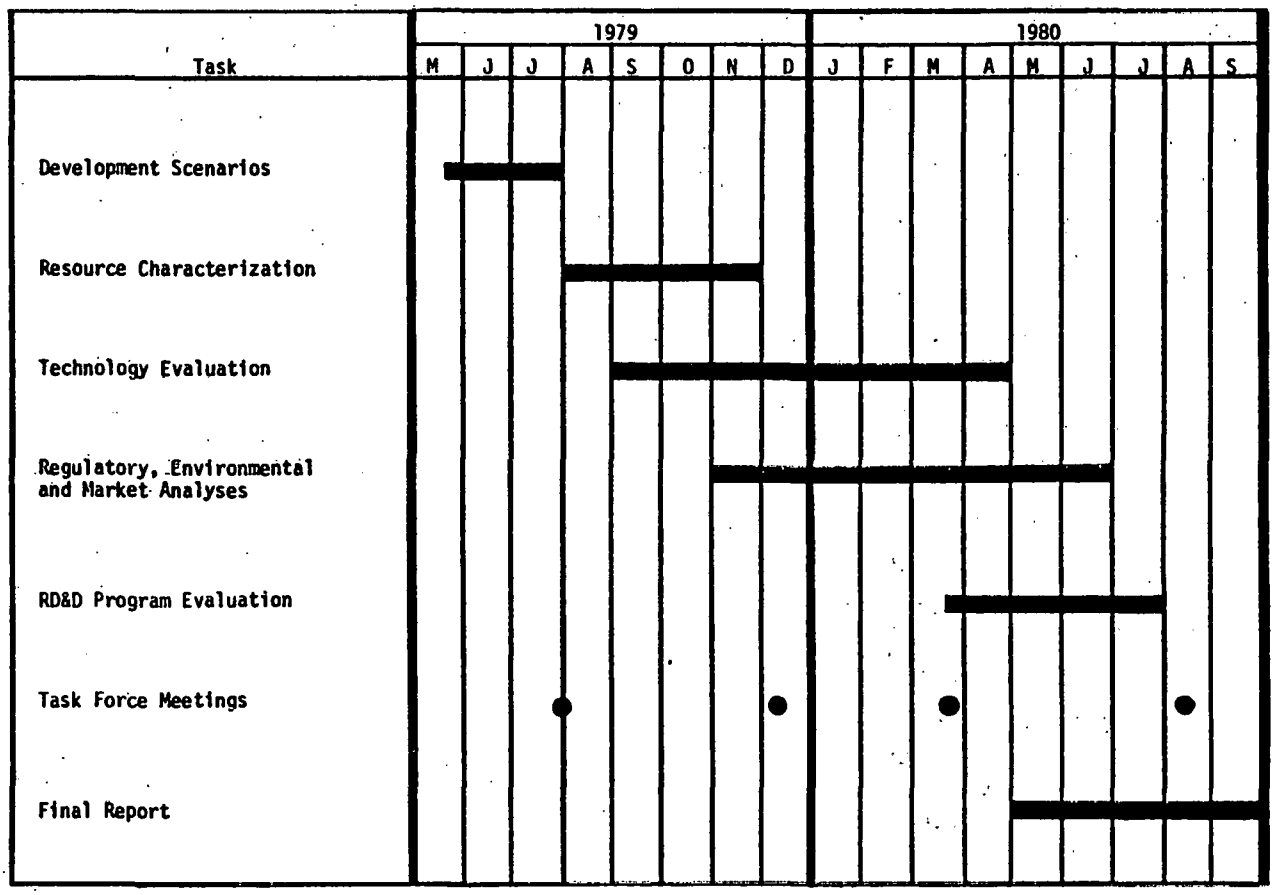


Table P-1

Major Tasks in the Low-Rank Coal Study

1. Low-Rank Coal Development Scenarios (6%)
   - 1.1 Literature Review
   - 1.2 Technology Definitions
   - 1.3 Regulatory/Environmental/ Market Definitions
   - 1.4 Low-Rank Coal Data Base

2. Resource Characterization (8%)
   - 2.1 Occurrence
   - 2.2 Properties/Characteristics
   - 2.3 Classification

3. Technology Evaluation (42%)
   - 3.1 Extraction
   - 3.2 Transportation Systems
   - 3.3 Preparation, Handling, and Storage
   - 3.4 Processing and Utilization
   - 3.5 Environmental Control Technology

4. Regulatory Requirements/ Constraints (4%)
   - 4.1 Definition
   - 4.2 Roadmap
   - 4.3 Effects on Development

5. Environmental Impact Analysis (3%)
   - 5.1 Land Use/Reclamation
   - 5.2 Air Quality
   - 5.3 Water Quality
   - 5.4 Ecological Effects
   - 5.5 Socio-Economic Effects

6. Market Analysis (6%)
   - 6.1 Existing Markets and Penetrations
   - 6.2 Potential Markets

7. RD&D Program Evaluation (11%)
   - 7.1 Definition and Priorities
   - 7.2 Review of Current RD&D Programs
   - 7.3 Cost and Impact Analysis

8. Task Force Utilization (20%)
   - 8.1 Development Scenarios Evaluation
   - 8.2 Technical Analysis Evaluation
   - 8.3 RD&D Program Definition
   - 8.4 RD&D Program Impacts and Recommendations

Table P-2

Low-Rank Coal Study
Task Force Participants

	Participant	Affiliation
1.	Dr. Martin A. Elliott Houston, Texas	Consultant, Texas Eastern Gas Transmission Co.
2.	Professor George R. Hill Salt Lake City, Utah	University of Utah Department of Chemical Engineering
3.	Mr. James Jonakin Birmingham, Alabama	Consulting Engineer (Retired from Combustion Engineering, Inc.)
4.	Mr. Paul W. Crutchfield and Mr. David J. Beecy Washington, D.C.	U.S. Department of Energy Office of Policy and Planning
5.	Professor Donald E. Severson Grand Forks, North Dakota	University of North Dakota Department of Chemical Engineering
6.	Mr. David M. White Austin, Texas	Texas Energy and Natural Resources Advisory Council
7.	Mr. Kurt Yeager and Dr. Charles R. McGowin Palo Alto, California	Electric Power Research Institute

The ERCO Program Manager on this effort was Dr. John Kotowski. Mr. George Wiltsee was the Assistant Program Manager and Technical Director. Other ERCO personnel who provided major contributions to the effort include Paul Goodson, Randall Smith, Wayne Simmons, Barbara Acker, Jeffrey Feerer, Timothy Buscheck, and Myron Burr. In addition, special thanks should be extended to Lydia Felix and Jennifer Spinello of the administrative staff for their support and assistance in the preparation of this report.

ABSTRACT

A national program is recommended for research, development, and demonstration (RD&D) of improved technologies for the environmentally acceptable use of low-rank coals. RD&D project recommendations are outlined in all applicable technology areas, including extraction, transportation, preparation, handling and storage, conventional combustion and environmental control technology, fluidized bed combustion, gasification, liquefaction, and pyrolysis. Basic research topics are identified separately, as well as a series of crosscutting research activities addressing environmental, economic, and regulatory issues.

The recommended RD&D activities are classified into Priority I and Priority II categories, reflecting their relative urgency and potential impact on the advancement of low-rank coal development. Summaries of ongoing research projects on low-rank coals in the U.S. are presented in an Appendix, and the relationships of these ongoing efforts to the recommended RD&D program are discussed.

5. RD&D PROGRAM EVALUATION

5.1 INTRODUCTION AND SUMMARY

The major emphasis in the Low-Rank Coal Study was on evaluation of individual technologies, resulting in listings of key issues relating to the use of low-rank coals with each technology. From analyses of these key issues (presented in the introduction to each technology section in Volume 3) and from Task Force recommendations, research needs were defined.

These research needs were then further evaluated to select only those of the greatest urgency in low-rank coal development. These remaining tasks were then classified into Priority I topics representing a zero-base program of essential RD&D, and Priority II topics representing additional highly relevant RD&D. Taken together, both priority areas compose a well rounded yet conservative program of research, development and demonstration which will support the greatly expanded use of low-rank coals.

The recommended research areas in extraction technology (including surface mining, underground mining, and underground coal gasification) are aimed at improving existing mining and reclamation techniques, reducing environmental impacts, and developing advanced extraction technologies for future, more difficult geologic conditions.

Key issues in transportation technology deal with rail, barge, truck, conveyor and slurry pipeline transportation, but recommended research topics in transportation address only slurry pipeline needs. Coal transportation problems in the other areas are better addressed by studies in Preparation, Handling and Storage. Research topics in slurry pipeline transportation are primarily oriented at resolving technical problems relating to water separation and treatment.

Recommended research in Preparation, Handling and Storage includes coal drying, cleaning, beneficiation, briquetting, and several other areas which have application in conventional transportation. Most of the research topics in this technology area are concerned with the development of basic data on coal properties, followed by the adaptation of conventional coal preparation systems to low-rank coals.

The area of coal utilization and conversion encompasses a broad variety of technologies including conventional combustion, fluidized bed combustion, gasification, liquefaction and pyrolysis. In addition, environmental control technologies have been considered for each area.

Several of the research topics in conventional combustion are aimed at predicting or reducing ash fouling problems. Direct ignition of pulverized coal (without oil) is also included because of its high potential for reducing oil consumption.

The recommended RD&D projects in environmental control technology for low-rank coal combustion are crucially important to the continued expansion of electric utility use of these fuels. To meet tightening standards, research is required in each type of individual control technology (e.g. electrostatic precipitators, fabric filters, wet and dry SO_2 scrubbers, NO_x control systems, etc.) for particulate, NO_x, SO_x, trace elements and solid waste.

In fluidized bed combustion of low-rank coals, research is recommended to determine optimal design configurations, evaluate in-bed control of SO_x, NO_x and particulate emissions, and resolve difficulties noted with low-rank coals in preliminary tests, such as bed agglomeration.

Low-rank coal gasification is an area with considerable potential, in which a vigorous research effort is justified. Recommendations in this area include adaptation of advanced processes to low-rank coals, effects of mineral matter and slag, health and environmental control technology, and mechanical design of solids feeding equipment.

As in fluidized bed combustion and advanced gasification technologies, optimal process adaptation is an issue of critical importance in liquefaction of low-rank coals. Other recommendations are to investigate the unique effects of low-rank coal mineral matter, moisture content and process generated recycle solvents. Special problems such as deposit formation, bottoms viscosity, catalyst deactivation, and corrosion are also unique to low-rank coals.

Due to the difficulty with yields and product quality in low-rank coal pyrolysis, evaluation of the feasibility of using Western coals as pyrolysis feedstocks is recommended. Health effects studies and improvement of analytical methods for pyrolysis products are also needed.

Topics in Basic Research are essential to developing a fundamental understanding of low-rank coal properties and performance in the various extraction, transportation, preparation and utilization technologies. A wide variety of basic research studies is recommended, including geologic and petrographic characterization of the coal, theoretical and laboratory investigations of reaction chemistry and catalysis, and detailed analysis of the properties and behavior of conversion products and by-products.

In developing the RD&D program, several topics of high priority were suggested which did not fit into any of the technology areas. These were studies of a regional nature, and address environmental, market/economic, and regulatory/policy implications of low-rank coal development. Resolution of social, economic, and political issues will strongly influence Western coal development, and will require research into topics that transcend technology.

5.2 OVERALL PROGRAM PLAN

5.2.1 Approach to Delineating the Recommended RD&D Program

The definition of the recommended RD&D program for low-rank coals involved a multi-step process. The overall approach was first to use Task Force input to identify major research topics, state their objectives and review their requirements. Supporting data and ongoing related research was then identified, and consideration was given as to how recommended research would be integrated with other work. Finally an overall RD&D program plan to advance low-rank coal development was delineated. This process, summarized in Table 5.2.1, was begun with the definition by the Task Force of a comprehensive category listing of technology areas to be considered in the overall analysis.

Table 5.2.1

Steps in the RD&D Program Definition

1. Technology Category Listing; Priorities
2. Technical Evaluation; Trade-off Analysis
3. Definition of "Key Issues"
4. Definition of RD&D Project Areas
5. Review of Current Low-Rank Coal RD&D
6. Delineation of Recommended RD&D Projects; Priorities
7. Integration of Recommended RD&D Program

Based on this category listing and initial judgments as to priorities, a detailed technical evaluation was conducted to determine which areas provided the greatest potential for application to or advancement of low-rank coal technology. This evaluation culminated in a trade-off analysis of low-rank coal properties and characteristics versus specific technology requirements and advantages or disadvantages. The results of this trade-off analysis were developed into a set of low-rank coal key issues; i.e., areas where additional research, development or demonstration data critical to the assessment and/or development of low-rank coals was required. These key issues were used as the basis to delineate low-rank

coal research areas. The research areas were then developed into a set of specific research topics. Each research topic was further defined in terms of its objectives, overall approach, presently available supporting data, and related current research. Although hundreds of research activities were reviewed as part of this definition, details of specific current research efforts are included in this volume only for those efforts presently ongoing or recently completed. A general overview of the state-of-the-art in each technology area is presented in Volume 3.

To indicate the general level of importance or urgency associated with each recommended project, a priority designation was assigned. This priority designation was based on a subjective evaluation of each project by the Task Force in terms of the criteria delineated in Table 5.2.2. The Priority I projects are are considered essential to the advancement of low-rank coal development. They are in essence the projects that form the zero-base budget program recommendation. Priority II projects are considered very important, and could greatly enhance the development of low-rank coals. Both Priority I and Priority II projects fall into the highest priority category designated for DOE's Fossil Energy program strategy; i.e. "Activities which will support greater direct use of coal in the near term."

Table 5.2.2

Criteria for Establishing RD&D Priorities

- Market Potential/Chance of Success
  - Is the potential market impact and the likelihood of success of the project high?
- Cost
  - Is the cost of the project within reasonable bounds
  - Does the risk/reward relationship appear favorable?
- Period of Performance

  Will the project produce results within a short period of time?
- Need
  - Is there a need in the private sector for developments in this area?
  - Are other important RD&D efforts dependent upon the results of this work?

5.2.2 Program Objective and Justification

The RD&D program recommended as part of this study forms the basis for initiation of a comprehensive national effort to accelerate the development of low-rank coals. The basic objective of this RD&D program is to provide an improved technology base for low-rank coal development. The major justifications for initiation of this type of program now are as follows:

1. Large quantities of economically recoverable reserves make coal one of the few indigenous energy sources capable of relieving our overdependence on imported oil during the next 20 years.

2. Expanding coal use rapidly enough to make a difference (e.g., tripling by the year 2000) will necessarily require Western low-rank coals to provide most of the new production.

3. Accomplishing this kind of explosive growth in coal production and use without damaging the environment will severely challenge the technical and financial capabilities of the industries (and governments) involved.

4. Very little attention has been paid to the special problems of low-rank coals in previous and existing national coal RD&D programs.

The accelerated development and commercialization of Western low-rank coal technologies has been identified as one of the highest priority items for DOE/Fossil Energy. Thus, implementation of an RD&D program in low-rank coals at this time is economically, environmentally and strategically essential.

5.2.3 Program Description

Brief descriptions of the recommended research, development and demonstration projects are presented in Section 5.3. All technology areas associated with low-rank coals are considered, including Extraction, Transportation, Preparation, Handling and Storage, Utilization, and Basic Research. In addition, other research activities are presented which address regional environmental, economic and regulatory issues. These topics are broad in scope and cannot be categorized by individual technology areas.

Although there are important issues in the areas of Extraction, Transportation and Preparation, the topics presented under Utilization are the most significant technology barriers to enhanced low-rank coal utilization. At the foundation of much of this work are the results of topics considered under Basic Research.

In Figures 5.2.3.1 and 5.2.3.2, the Priority I and Priority II research projects are categorized into the seven phases of research, development and demonstration evolution. Descriptions of these phases are given in Appendix A. The tables show that the great majority of projects fall into the three central categories (Exploratory Development, Technology Development and Engineering Development), indicating the predominantly developmental nature of the overall program.

Major elements of the program in each technology area are summarized in Figures 5.2.3.3 and 5.2.3.4, the overall program Work Breakdown Structures.

Figure 5.2.3.1

Matrix of RD&D Phases by Technology Area - Priority I

	Basic Research	Applied Research	Exploratory Development	Technology Development	Engineering Development	Demonstration	Commercialization, Production & Operation
EXTRACTION							
Surface Mined Land Reclamation				x	x		
Surface Mining							
Techniques for multiple thin seams, thick seams and deeper overburden				x			
Optimization of equipment specifications							x
Cost reduction through operations research and systems engineering							x
Underground Coal Gasification							
Aquifer disruption and groundwater contamination			x	x			
Subsidence and gas leakage				x	x		
Linking techniques					x	x	
Coal seam characterization and process monitoring					x		
TRANSPORTATION							
Slurry Dewatering							
Separation of coal fines			x				
Treatment of separated water			x				
Utilization of treated slurry water			x				
Slurry Pipeline Water Requirements			x				
PREPARATION, HANDLING, AND STORAGE							
Coal Drying for Conversion Processes			x	x			
Chemical Cleaning Processes for Low-Rank Coals				x	x		
Physical Cleaning Processes for Low-Rank Coals				x	x		
Coal Drying to Improve Transport Economics				x			
Optimized Crushing and Handling Equipment to Minimize Fines Generation		x	x				
DIRECT UTILIZATION AND CONVERSION							
Conventional Combustion							
Ash Fouling and Slagging Mechanisms				x	x	x	x
Control of Fouling and Slagging with Additives		x	x	x	x	x	x
Direct Ignition of Pulverized Coal without Oil					x	x	x
Environmental Control Technology for Conventional Combustion							
Integrated Environmental Control Systems				x			
Improved Spray Dryer and Dry Sorbent Systems				x	x	x	x
Improved Particulate Control Methods			x	x	x		
Fine Particulate Control Technology		x	x	x	x	x	
Solid Waste Disposal Procedures			x	x			
Improved Reliability of Ash Alkali Wet Scrubbing				x	x	x	
Trace Elements and Organic Compounds in Flue Gas			x	x	x		
Improved Procedures for NO_x Control					x	x	

	Basic Research	Applied Research	Exploratory Development	Technology Development	Engineering Development	Demonstration	Commercialization Production & Operations
Fluidized Bed Combustion							
Agglomeration of Solids in Fluidized Bed		x	x	x	x		
Sulfur Retention by Inherent Alkali in Low-Rank Coals		x	x	x			
Design Configuration of FBC Optimized for Low-Rank Coals				x	x	x	
Properties of Limestone-Deficient, Ash-Rich Fluidized Bed		x	x	x			
Hot-Gas Cleanup and Turbine Reliability for Pressurized FBC				x	x		
Materials Problems and Selection for Low-Rank Coal FBC				x	x		
Gasification							
Process Adaptation for Low-Rank Coal				x	x	x	x
Wastewater Treatment for Process Effluent			x		x		
Slag Behavior		x	x		x	x	
Catalytic Effects in Low-Rank Coal Gasification				x	x	x	
Slag, Ash, and Residue Leaching Characteristics and Immobilization		x			x		
Minimizing Health Effects of Coal Liquids			x		x		
Liquefaction							
Process Adaptation for Low-Rank Coal				x			
Recycle Solvent Studies				x	x		
Syngas and Hydrogen Effectiveness Studies				x	x		
Calcium Carbonate Formation in Reactors					x		
Coal Moisture Content and Drying					x		
Coal Mineral Catalysis in Recycle			x				
Bottoms Recycle				x	x		
Minimize Health Effects of Coal Liquids			x		x		
Pyrolysis							
Feasibility of Pyrolysis for Selected Low-Rank Coals				x			
Minimizing Health Effects of Coal Liquids			x		x		
BASIC RESEARCH							
Resource and Coal Seam Characterization	x	x					
Standard Low-Rank Coal Samples	x	x					
Petrographic Characterization	x	x					
Reactions Between Alkali Materials and Sulfur	x						
Surface Tension of Coal Slags	x	x					
Composition and Characteristics of Ashes and Slag from Low-Rank Coal & Peat	x	x					
Analytical Characterization of Liquefaction Solvents		x	x				
Coal Liquefaction Catalysis	x	x	x				
Oxidative Depolymerization of Low-Rank Coal		x	x				
Toxicity of Coal Liquids	x	x					

Figure 5.2.3.2

Matrix of RD&D Phases by Technology Area - Priority II

	Basic Research	Applied Research	Exploratory Development	Technology Development	Engineering Development	Demonstration	Commercialization Production & Operation
EXTRACTION							
Dewatering of Mine Area and Groundwater Control				x	x		
Underground Mining							
Mining thick seams					x		
Mining under unconsolidated overburden					x		
Dewatering and groundwater control					x		
TRANSPORTATION							
Slurry Pipeline Reliability							
Restarting slurry flow			x				
Freeze protection			x				
Ruptured slurry pipelines			x				
Distances over which coal suspension can be maintained		x	x				
PREPARATION, HANDLING, AND STORAGE							
Briquetting or Pelletizing			x	x	x		
Beneficiation and Preparation Techniques							
Applied to Slurry Pipeline System			x	x			
Waste Disposal from Coal Beneficiation			x	x			
Control of Dust, Oxidation, and Spontaneous Combustion					x	x	
Freeze Control					x	x	
Comminution Techniques					x	x	
DIRECT UTILIZATION AND CONVERSION							
Conventional Combustion							
Improved Boiler Cleaning Procedures			x	x			
Temperature Limitation vs. Boiler Corrosion				x	x	x	
Improved Stoker Furnace for Small Applications					x	x	x
Environmental Control Technology for Conventional Combustion							
Solid Waste Utilization					x		
Retrofit SO_2 Reduction Techniques Such as Lime/Limestone Injection			x				
Fluidized Bed Combustion							
Coal and Sorbent Feeding Distribution				x			
Staged Combustion for NO_x Control					x		
Temperature, Gas and Solids Distribution in Low-Rank Coal FBC			x		x		

Figure 5.2.3.2 continued

	Basic Research	Applied Research	Exploratory Development	Technology Development	Engineering Development	Demonstration	Commercialization Production & Operation
Gasification							
Effects of Pressure, Temperature, and Atmosphere on Evolution and Destruction of Volatile Matter			x				
Distribution Coefficients of Soluble Organics in Wastewater		x					
Slurry Feeding of Low-Rank Coal to High-Pressure Gasifiers					x	x	
Liquefaction							
Bottoms Viscosity Studies				x	x		
Effects of Staged or Continuous Removal of Gas				x	x		
Fate of Nitrogen				x	x		
Effects of Staged Temperature Exposure				x			
Disposable Catalyst Approaches				x	x		
Corrosion of Stainless Steel by Coal Liquids			x	x			
Erosion in Liquefaction Systems			x	x			
Mathematical Reactor Model to Account for Mixing and Turbulence Effects			x				
Pyrolysis							
Improved Analytical Methods for LRC Pyrolysis Studies		x					
Improved Pyrolysis Product Properties and Yields			x	x	x		
BASIC RESEARCH							
Surface Characteristics of Low-Rank Coal and Peat Fines	x	x					
Reactivity of Low-Rank Coals at 1200-1800°F in FBC		x	x				
Impacts of Drying Methods on Rheological Properties of Low-Rank Coal-Water Mixtures	x	x					
Kinetics and Reaction Mechanisms of Low-Rank Coals and their Chars with H_2O, H_2, CO, and CO_2	x	x					
Fate of Oxygen and Nitrogen Components in Coal and Peat Conversion Systems	x	x					
Reactivity of Peat in Various Atmospheres	x	x					

Figure 5.2.3.3

Work Breakdown Structure
Priority I RD&D Program

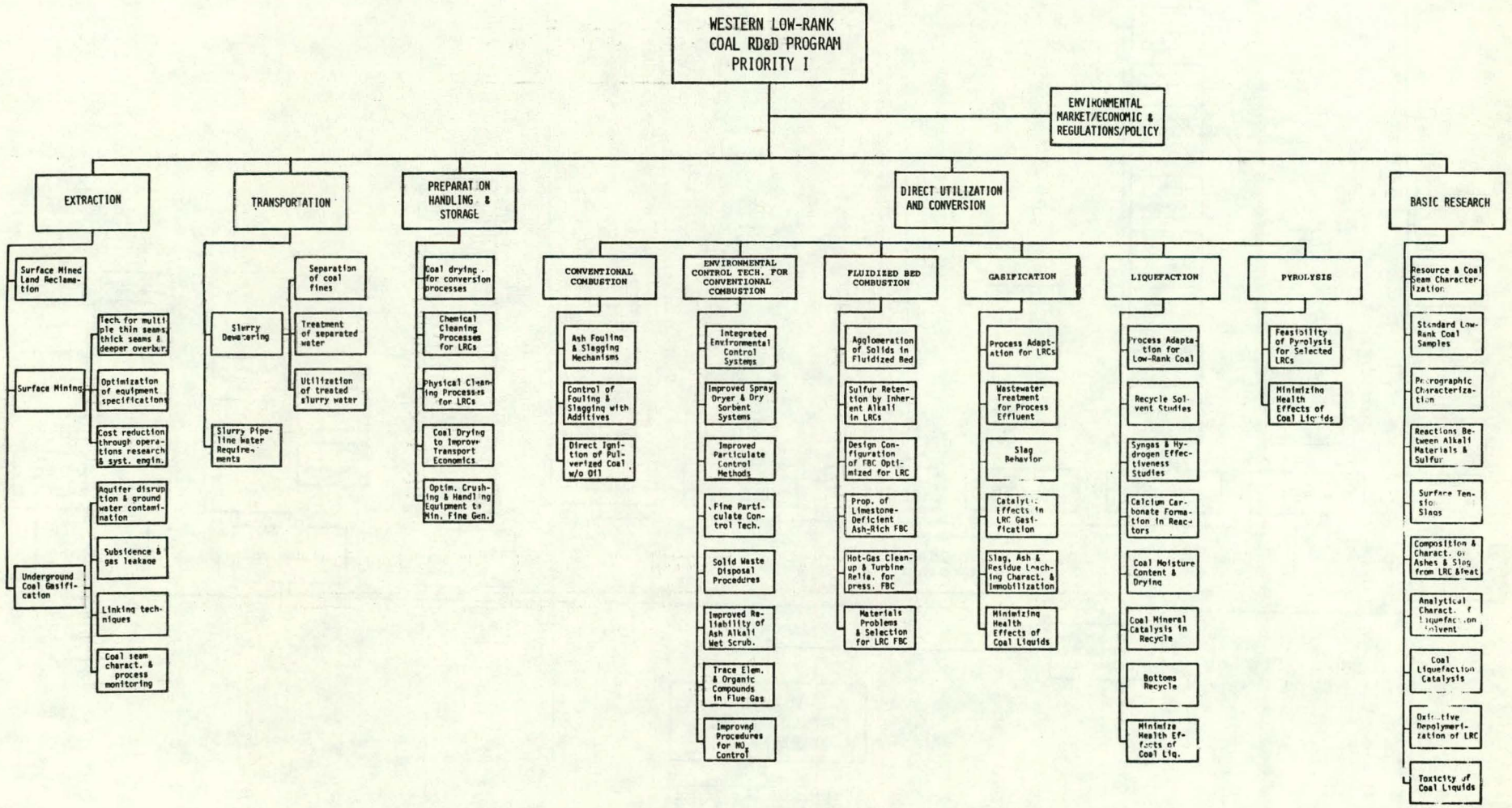
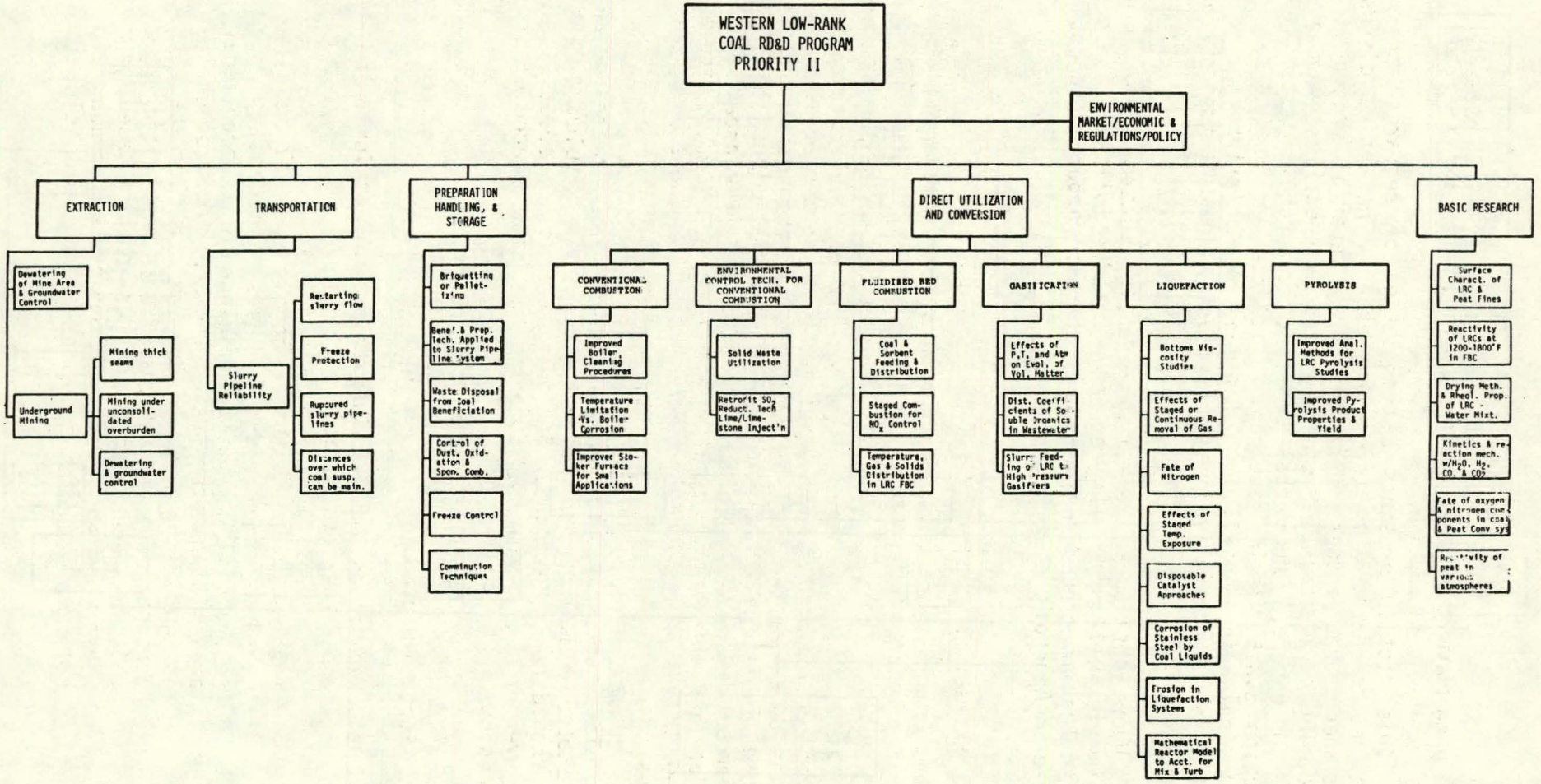


Figure 5.2.3.4

Work Breakdown Structure
Priority II RD&D Program



5.3 RD&D PROJECT RECOMMENDATIONS BY TECHNOLOGY AREA

This section presents a compilation of research and development project recommendations by technology area. The topics discussed below address needs and issues identified from material presented in Volume 3, Technology Evaluation. Projects listed by specific technology area are applied in nature; fundamental or basic research projects are discussed in section 5.3.5, Basic Research. Projects are ranked by priority (I and II), indicating a minimum program requirement (priority I topics) and a desirable, yet conservative program (priority I and II topics) for low-rank coal development.

Where applicable, on-going research related to a project recommendation is mentioned. The reference numbers following these statements refer to the numbered descriptions of current research projects which are included in Appendix B.

5.3.1 Extraction - Priority I Topics

1. Surface Mined Land Reclamation

Surface mining in general, and that which involves multiple thin seams, thick seams and deep overburden in particular, results in difficult reclamation problems. Studies are being conducted at two universities in Texas to determine both the aesthetic and chemical impacts on the soil which result from lignite mining.[2] Recommendations will be made to help avoid major damage to the visual character of these areas. Other research includes evaluation of chemical alterations to the clay minerals that are exposed to the atmosphere.[3] There are also others involved in related studies.

This work should be continued and expanded to include an evaluation of the other areas of the West affected by the problem. Different solutions should be investigated, including the use of specific plant species as rejuvenating groundcover. Emphasis should be placed on arid and semi-arid regions.

2. Surface Mining

a. Techniques for multiple thin seams, thick seams, and deeper overburden

These varying geologic conditions all require complex development efforts unnecessary for reserves which can be developed by conventional area mining techniques. The Department of Energy is sponsoring work to develop the "Terrace Pit" concept. The limitations of this mining technique will be identified during FY 1981. Based upon these findings, concepts for truck, scraper and conveyor haulage equipment must be developed.

b. Optimization of equipment specifications based on core analysis results

Because of the considerable cost of mining equipment, improved techniques are required for relating the results of core analysis to equipment specifications when developing new reserves. Mining and equipment engineers are beginning to make progress in this area through the increasing use of computer-aided analysis.

c. Cost reductions through operations research and systems engineering

In response to changing prices, labor costs, regulatory climate or other economic influences, changes in operating schedules or other facets of mine operation may be necessary. Depending upon the objective, which may be to reduce downtime, reduce costs or increase productivity, techniques for improving operating procedures and equipment utilization are needed.

3. Underground Coal Gasification

a. Aquifer disruption and groundwater contamination

In addition to the potential to disrupt groundwater flows (as in surface and underground mining), UCG could potentially contaminate groundwaters with a variety of harmful or toxic materials. The Lawrence Livermore Laboratory (LLL) is conducting field studies to investigate UCG groundwater contamination.[4] Work is also being performed in the laboratory and using computer models.

A field program of sampling and analysis should be initiated when pilot UCG facilities become operational.

b. Subsidence and gas leakage

Environmental impacts and lowered productivity from earth subsidence and gas leakage are concerns in UCG. Studies are being funded by national laboratories with subsidence models to determine whether such problems can be controlled.[4,5] Field work underway in this area will allow for model validation.

This work should be continued and expanded to determine the extent of gas leakage and other problems occurring from subsidence, and methods for control.

c. Linking techniques

Linking of feed and product boreholes is a critical step in UCG. Preferred techniques need to be developed for low-rank coals. There are a number of projects in progress to develop reliable, cost-effective linking techniques for UCG.[6] Reverse burn links have been completed and forward gasification conducted by several organizations. Forward and reverse combustion process models have been developed at the University of Wyoming and at the Laramie Energy Technology Center (LETC).[7,8] A joint DOE/GRI (Gas Research Institute) program includes demonstration of UCG by 1981.[9] This project entails well linkage by directional drilling and 100-200 foot well-spacing in deep level (3000-5000 feet) coal seams.

This research should be continued and evaluated following the UCG demonstration tests.

d. Coal seam characterization and process monitoring

Determination of coal seam characteristics is essential to determine its suitability for UCG and to establish an appropriate process design. Process monitoring faces special difficulties because of the remoteness of the reaction zone. Techniques to improve process monitoring are currently receiving attention.

The DOE is funding much of this work which includes steam-char kinetics, block pyrolysis experiments, and one-dimensional process modeling.[10,11,12] Related work includes pre-burn surveying and burn monitoring by in-situ and remote techniques. LLL is applying high-frequency electromagnetic detection of burn fronts.[6] Methods to improve coal seam characterization have been investigated in the form of studies dealing with mechanical and ion exchange properties of Texas lignite overburden and coal productivity measurements.[12,13]

Sandia Laboratories are supporting ongoing work at LETC to perform diagnostic instrumentation and interpretation of field test results.[14] Data generated from these studies will enhance the utilization of coal within the experimental area.

5.3.2 Extraction - Priority II Topics

4. Dewatering of Mine Area and Groundwater Control

Surface mining can disrupt groundwater flows, resulting in flooded mine areas and alterations in underground water flows. The Texas Energy Development Fund is currently sponsoring Texas A&M University to determine the regional influence of surface mining on groundwater quality and quantity.[1] This work will include identifying mining and reclamation management alternatives available to the state of Texas in order to protect groundwater quality and quantity.

This work should be continued and expanded to include other areas where strip mining of Western coal interacts with groundwater resources.

5. Underground Mining

a. Mining thick seams

Conventional underground mining technology has a practical upper limit to the thickness of seam which can be mined -- approximately seven feet. Western low-rank coal seams are commonly greater than 12 feet thick. Efficient extraction of these seams will require new or modified technologies. Considerable work is underway to develop techniques for mining thick seams. The DOE is currently funding studies of caving by pillar extraction, longwall caving and multi-slice longwall mining.[21]

Underground mining of Texas lignite is receiving funding by a number of sources. One project entails the application of a statistical methodology to improve drilling and deposit estimation strategies.[22]

The National Coal Board is evaluating the use of water jets to improve productivity, in application to relatively thick, dipping seams, where the water also transports the coal out of the mine.[25]

These or similar techniques will have to be refined and conditions for their optimum application to Western coals developed.

b. Mining under unconsolidated overburden

Roof collapse is a chronic problem in underground mining. When mining overburden is unconsolidated, roof collapse is more certain. Techniques for mining under these circumstances would increase the tonnage of recoverable resources in low-rank coal deposits. An understanding of the geological section related to the immediate roof strata is essential in order to determine the support requirements. Additional supports are required for unconsolidated overburden. New roofing support systems need to be developed. No work is currently being sponsored in this field.

c. Dewatering and groundwater control

Like surface mines, underground mines can collect surface waters or intersect groundwater flows causing mine flooding and aquifer disruption. Solution of these difficulties will lie in the perfection of existing techniques. Some synergism may be gained by coordinating work on the same issue for surface mining.

5.3.3 Transportation - Priority I Topics

1. Slurry Dewatering

a. Separation of coal fines

Both for environmental reasons and for efficient recovery of coal from the transport medium, the separation of coal fines from slurry water is an important issue. Centrifugation and pressure filtration are currently used to reduce the solids content of the water to 5 or 6 percent, which is followed by ponding and flocculation. New approaches or modifications to this technology are needed. The approach to developing acceptable slurry dewatering techniques for low-rank coals should be as follows:

(i) Review techniques which have been applied to existing or experimental slurry pipelines:

- centrifugation
- pressure filtration

(ii) Investigate novel techniques; incorporate results from Basic Research projects - studies on characterization of Slurry Components and Surface Characteristics of Fines. Evaluate the applications of colloidal chemistry, such as surface potential, to solids separation.

(iii) Investigate other transport media which would simplify the problem of phase separation, or allow the direct use of the slurry:

- oil
- methanol
- liquid CO_2

b. Treatment of separated water

Adequate techniques for use or disposal of slurry water may be decisive in slurry pipeline permitting. The use of coagulants, immiscible solvents and salts to promote solid-liquid separation should investigated.

c. Utilization of treated slurry water

Since disposal of slurry water is generally unacceptable, utilization of treated water at the pipeline destination may be a necessary alternative. Potential water uses should be identified and evaluated after use with a variety of low-rank coals. No research is ongoing in this area. Future research will depend upon accepted treatment techniques.

2. Slurry Pipeline Water Requirements

Water use in slurry pipelines is a political/environmental issue of prime significance, and can decisively affect pipeline projects. General techniques including return pipelines and other transport media need to be proposed and evaluated, and then applied in individual cases. No work is ongoing in this area.

5.3.4 Transportation - Priority II Topics

3. Slurry Pipeline Reliability

a. Restarting slurry flow

A decrease in fluid velocity or cessation of flow will cause coal particles to settle out of suspension. Reattainment of previous fluid velocity may be insufficient to restart slurry flow. The extent of this problem should be quantified for a variety of coals under different circumstances.

b. Freeze protection

Slow moving slurries are particularly susceptible to freezing which can not only plug the entire pipeline, but cause pipe breaks as well. Techniques for freeze prevention of low-rank coal slurries need to be developed.

c. Ruptured slurry pipelines

Environmental impacts, permitting rights and lost production are prime motivators for reducing the incidence and damage due to ruptured lines. This area is not currently being addressed.

d. Distances over which coal suspension can be maintained

Re-suspension at pumping stations or other midway points must occur before coal particles have a chance to settle out of the slurry. The maximum distance between stations will vary depending on coal type, slurry parameters and ambient conditions, and should be investigated for a representative sample of these variables.

A number of organizations are funding research at Texas A&M University to study the rheological properties of lignite suspensions.[24] This work should be continued and expanded to include other coal types.

5.3.5 Preparation, Handling and Storage - Priority I Topics

1. Coal Drying for Conversion Processes

High moisture contents found in low-rank coals generally detract from their performance in utilization systems. Three issues should be addressed in this area.

a. Drying techniques to limit moisture reabsorption

Drying to increase Btu levels in slurries, or for other purposes can be substantially negated by moisture reabsorption common to low-rank coals. Drying techniques which will limit this phenomenon are needed.

b. Complete drying for MHD applications

The extremely high temperatures required by MHD processes require coal with very low moisture levels (less than 5 percent). The basic feasibility of drying subbituminous coal to very low levels has been demonstrated in vendor tests sponsored by Montana College of Mineral Science and Technology with DOE funding. Incomplete drying might be offset by oxygen enrichment of combustion air; an engineering/economic tradeoff study should be conducted to determine the optimum procedure once the most efficient drying technology is selected.

c. Drying without deactivation for liquefaction

Several attempts to lower process pressures during low-rank coal liquefaction have employed coal pre-drying. Except where the coal was slurry dried, deactivation occurred, disrupting the liquefaction process. Investigation of methods, such as slurry drying to dry low-rank coals without deactivation, is necessary to their widespread acceptance as liquefaction feedstocks.

2. Chemical Cleaning Processes for Low-Rank Coals

High concentrations of sodium in some lignites are responsible for boiler tube fouling. GFETC and the University of North Dakota have performed bench scale experiments and process design studies of ion exchange processes that remove sodium from lignite and reduce fouling problems.[27] Scaleup studies and economic evaluations are needed to determine if this type of chemical cleaning is a viable option for utilities to consider.

High levels of uranium and other hazardous wastes suggest a high potential for improving the value of some low-rank coals by chemical removal of these contaminants. Current techniques should be reviewed, and the leaching of hazardous components studied. This research area is not currently under investigation. The above studies should be investigated at the laboratory scale.

3. Physical Cleaning Processes for Low-Rank Coals

a. Investigation of multisolvent approaches

Float/sink tests have been conducted at GFETC. Those coals investigated include Fort Union Region lignite, Texas lignite, and New Mexico subbituminous coal.[28] The results obtained in the analysis of Fort Union Region lignite indicate that most of the mineral matter is bound or finely dispersed in the coal matrix, and was not significantly reduced.

This work should be expanded to include miscible/immiscible and low boiling fraction solvent approaches. No work is currently sponsored in this area.

b. Assessment of trends toward extraction of lower grade coal

The degree to which lower grade coal is likely to be extracted and the end use of the coal will help indicate the potential for cost effectiveness and acceptance of coal cleaning techniques. This area is not currently under investigation.

4. Coal Drying to Improve Transportation Economics

Transportation economics are strongly affected by coal moisture content. GFETC and the University of North Dakota have conducted pilot plant work on the Fleissner Process, a steam drying technique using pressure with saturated steam. Wide variations in release of liquid water were attributed to possible differences in capillary shrinkage and/or the temperature dependent colloidal properties of lignite.

There are problems associated with the costs of drying, handling, and transporting low-rank coals. The properties of the dried product are a function of the particular drying process. The rail rate structures are also an important factor in evaluating which drying methods are economically attractive.

GFETC has also used a commercial scale dryer in order to study moisture reduction.[26] Two years after the drying procedure there was no indication of moisture penetration. The first step in technology development should involve a review of state-of-the-art methods, including thermal, gas and liquid phase techniques. Consideration should be given to the effect of drying, or other coal handling and storage requirement. The effects of moisture content on boiler design should also be considered.

Depending on the cost of the drying technology used and its effect on other coal properties, tradeoffs may be established in boiler and reactor design. Water clean-up and utilization potential from drying processes should also be evaluated.

5. Optimized Crushing and Handling Equipment to Minimize Fines Generation

It is well known that low-rank coals decrepitate upon drying to produce fines. However, other procedures which may result in fines are not well characterized in this respect. Methods for reducing fines generation through improved crushing and handling methods would considerably affect the marketability of low-rank coals.

5.3.6 Preparation, Handling and Storage - Priority II Topics

6. Briquetting and Pelletizing Techniques

a. Application of European techniques to U.S. coals

To determine the effectiveness of European briquetting techniques (which have been applied to brown coals for centuries), samples of U.S. low-rank coals should be sent to Bergbau-Forschung for tests. Work is in progress at the Pittsburgh Mining Technology Center to confirm laboratory results on successively large scale pelletizing equipment.[29] It has been learned that the mechanical properties of lignite pellets are enhanced when the mositure content is maintained at maximum possible levels. Related work has demonstrated that lignite can be agglomerated by briquetting and extrusion. This work should be expanded to include results from Basic Research work.

b. Market study of applications in industrial, consumer, and large scale conversion plants

Enhancement of physical and combustion properties is the primary reason for pelletizing or briquetting coal. A market survey to determine the extent of demand increase for low-rank coals would be useful in establishing economic potentials for development work in this area. Such a survey has not been conducted on the current market.

c. Incorporation of petrographic characterization data

It is likely that different coals will respond optimally under different conditions in briquetting procedures. Basic data would be a useful adjunct to this effort. Strength and wear resistance of finished briquettes have been improved by use of coatings. These polymeric and resinous coatings have also been useful for dust prevention. Briquette quality is strongly affected by coal moisture content, particle size, and hardness. Although the handling, storage, and utilization characteristics of low-rank coal pellets are improved relative to the raw coal properties, coal pellets or briquettes may still be subject to spontaneous ignition, oxidation, size degradation, changes in moisture content, and declines in heating value. By integrating the petrographic properties of low-rank coals, these problems can be better understood.

7. Preparation and Beneficiation Techniques Applied to Slurry Pipeline Systems

The objective of this research topic is to determine the most effective way to incorporate thermal, chemical, and mechanical beneficiation techniques into the slurry pipeline system. One problem is the high inherent moisture content of low-rank coals. When combined with the slurry water, the energy content of the fluid would be relatively low, suggesting the possibility of drying the low-rank coal prior to slurrying it. Different drying procedures produce different physical, chemical, and moisture reabsorption properties of the dried low-rank coals.

Other possibilities include incorporating coal washing or ion exchange steps into the low-rank coal slurrying system; or utilizing non-aqueous slurry media and accomplishing solvent refining or some other beneficiation reaction simultaneously with transport of the coal.

8. Waste Disposal from Coal Beneficiation

a. Scoping study to determine RCRA requirements on concentrates

Compliance with environmental control laws must be one objective of coal beneficiation development. This represents a first step in this direction, and is not currently being studied.

b. Leaching studies on wastes

For the same reasons that fly ash and scrubber sludge are examined for leachability, wastes from coal beneficiation processes must not contaminate disposal sites or groundwater supplies with harmful materials. Leaching studies provide the most efficient evaluation of the extent of control technology required, and are not being conducted on low-rank coal beneficiation wastes.

9. Control of Dust, Oxidation, and Spontaneous Combustion

Spontaneous heating may occur as a result of oxygen diffusion to a coal surface, particularly when available surface areas and ambient temperatures are high. The chemical mechanism of spontaneous heating requires the presence of water molecules, since atmospheric oxygen does not react directly with carbon at these temperatures.

High rates of windage loss can occur with dried lignite, because of the breakdown of the physical structure that accompanies the drying of low-rank coal. As in the case with spontaneous combustion or oxidation, this problem can be controlled by the proper use of storage pile compaction procedures, application of coatings, size segregations, and closed storage or transport facilities.

Although acceptable procedures to control these problems have been empirically developed by the low-rank coal industry, improved dust or oxidation control techniques might evolve if additional research were performed.

10. Freeze Control

Freezing of carloads or storage piles of coal is a nuisance problem that can require expensive delays and labor-intensive efforts to correct. Certain coal preparation and handling techniques have been identified by GFETC and others to alleviate these problems. Additional research might lead to more cost-effective preventive measures.

11. Comminution Techniques

Comminution methods include crushing and grinding processes used to achieve controlled size reduction of coal. Low-rank coals have physical properties that make optimal design of crushing and grinding equipment difficult. Additional research on these problems is required.

5.3.7 Direct Utilization and Conversion

5.3.7.1 Conventional Combustion - Priority I Topics

1. Ash Fouling and Slagging Mechanisms

The objective of this research topic is to improve boiler availability and reduce fouling and slagging of heat transfer tubes. Activities should include:

a. Development of design modifications to reduce boiler slagging and fouling

- furnace heat release rate per cubic foot and per foot of furnace perimeter
- burner location
- burner geometry
- aspect ratio (ratio of length to width for a given furnace volume)
- spacing of superheater and reheater tubes
- gas temperature and velocity

b. Development of modifications to boiler operating procedures from an understanding of their effects on slagging and fouling

- load and capacity factors
- cycling of boiler
- excess air
- fuel size consist
- combustion modification for NO_x control (overfire air and staged combustion)

c. Development of analytical techniques for predicting fouling and slagging potential of low-rank coals, taking into account the great natural variability of coal properties. EPRI has sponsored work which has led to the development of CONAC, a continuous on-line neutron activation counter.[34] The device has been proven in test runs to evaluate heating value, moisture and sulfur contents.

This work should be continued and expanded to evaluate slagging and fouling potential of low-rank coal based on the following coal characteristics:

- proximate analysis
- reactivity
- mineral matter composition (elemental analysis and mineral composition, especially sodium)
- ash content
- ash fusion temperature
- slag viscosity

2. Control of Fouling and Slagging with Additives

a. Mechanisms additive reactions in relation to slagging and fouling

GFETC is sponsoring a project at the Midwest Research Institute in which combustion and ash-forming processes can be observed in a laminar flame.[33] The ash particles produced from a North Dakota pulverized lignite showed significant visible differences from Eastern coal ash. Tests are continuing on a subbituminous coal from Montana. This work should be continued and expanded to examine the behavior of additives that reduce fouling in full-scale tests.

b. Additive selection based upon laboratory testing

EPRI has retained Battelle Columbus Laboratories to develop guidelines for utilities as to what additives will alleviate fuel-related problems in commercial boilers.[35] This study will compile the existing knowledge of effects related to fuel combustion additives, and relate predicted and observed additive effects to their composition and method of application. Battelle is also conducting laboratory and field tests to demonstrate the effectiveness of additives in fouling and slagging control.[36]

The results of these tests should be evaluated and continued, if necessary, to include other additives and/or other low-rank coals.

c. Demonstration of most promising additive candidates in commercial boilers

Additive candidates selected by the above studies should be evaluated in operating commercial scale boilers to demonstrate their potential.

3. Develop Methods for the Direct Ignition of Pulverized Low-Rank Coal Without Oil

For each coal of interest, the ignition energy should be determined as a function of particle size and other parameters as appropriate. The effect of coal upgrading procedures on east of coal stream ignition should also be evaluated. From a systems analysis of this operation, the most promising direct ignition procedure should be selected and demonstrated on a commercial or utility size boiler. Work in this area is not currently being sponsored.

5.3.7.2 Conventional Combustion - Priority II Topics

4. Improved Boiler Cleaning Procedures

a. Criteria for predicting ease of deposit removal and soot blower requirements.

It may be possible to integrate this task with tasks 1 and 2 above, predicting the type of cleaning method required based upon coal analysis. It may also be possible to predict cleaning requirements based upon deposit morphology. This area is not currently under investigation.

b. Improved methods for deposit removal during boiler outage

A systems approach should be taken, which would investigate, for example, the use of additives to simplify deposit removal.

5. Temperature Limitation Vs. Boiler Corrosion

The general objective of this development effort is to increase steam cycle efficiency by raising steam temperature.

a. Determine corrosion rates of metal alloys (currently in use and promising candidates) with probes by exposing them in operating boilers to metal temperatures up to 200°F greater than current practice.

b. Determine the potential for using additives to extend the upper temperature limitation of alloys for use in superheaters and reheaters.

Neither of these research topics is currently being addressed.

6. Improved Stoker Furnace for Small Applications.

Very little work has been done in the past 20 years to develop or improve small stoker furnaces to burn low-rank coals. There are, however, many potential applications for these small furnaces in residential, commercial, and small industrial facilities. It may therefore be beneficial to develop and demonstrate the use of these small stoker furnaces. In addition to furnace development, fuel improvement for these systems would be desirable.

5.3.7.3 Environmental Control Technology for Conventional Combustion - Priority I Topics

1. Integrated Environmental Control Systems

Future designs of low-rank coal-fired power plants should be based on a systems engineering analysis, integrating all waste discharge systems to effectively control potential effluents. Among those systems which should be integrated are:

- stack gas effluent controls (SO_2, particulate, and NO_x scrubbers)
- water treatment and discharge systems (cooling tower and boiler blowdown, overflow from ash ponds, runoff from coal piles, etc.)
- solid waste disposal systems (fly ash and scrubber residue ponds)
- boiler system itself (combustion modifications affecting emissions)

EPRI is constructing a pilot plant at the Arapahoe Station of the Public Service Co. of Colorado to assess the integration of air, water, and solid-waste techologies for pulverized-coal-fired plants. In this approach the control equipment is considered an integral part of the power generation system, allowing for the reduction of adverse effects and lowered costs.[46]

2. Improved Spray Dryer and Dry Sorbent Systems

Spray dryers offer advantages over conventional wet SO_2 scrubbing systems in power plants burning low-rank coals. Evaluation of their large scale potential will require:

a. Performance evaluations of the first full-scale spray dryer systems.

b. Full-scale tests of units using injection of dry sorbent in place of conventional slurry injection.

c. Continued laboratory and pilot scale testing to improve spray dryer and dry sorbent injection systems.

Pilot scale tests are in progress to improve dry sorbent systems for SO_2 removal from flue gases. KVB Engineering, Inc., is being supported by EPRI to study the effect of sorbent type, residence time, temperature, particle size, and stoichiometric ratio on SO_2 removal efficiency.[45] GFETC is investigating the use of dry sorbents for SO_2 removal.[47]

3. Improved Particulate Control Methods

a. Improved ESP performance

Tighter environmental standards for particulate emissions create new incentives for increasing ESP performance.

EPRI is sponsoring a project to produce the first complete characterization of ESP fractional efficiency using state-of-the-art installations.[48] The first tests are being performed with cold- and hot-side precipitation methods on Western coal fly ash.

The EPA is also testing ESP's to increase particulate control performance. Several advanced ESP designs show promise for performance improvements and cost reduction.

A number of companies are being funded by EPRI to improve particulate removal methods with advanced ESP's.[49] The objective of the program is to reduce the size and cost of the precipitator and increase reliability of the system.

Work is in progress at GFETC to develop new methods of fly ash conditioning in order to improve ESP efficiency.[50] Testing includes blends of New Mexico and Utah subbituminous coals and raw and cleaned Colorado subbituminous coal.

These tests should be continued and expanded to include advanced charging techniques, and improved fly ash removal techniques (new and retrofit).

b. Improved fabric filters

This development effort should proceed in several steps:

- determine effectiveness of state-of-the-art technology by pilot and full-scale tests
- develop improved bag cleaning methods
- evaluate fabrics and fabric finishes for ease of cleaning and life
- develop design modifications and operating procedures that will reduce overall size of the baghouse and reduce pressure drops through the system
- demonstrate performance downstream of wet scrubber and spray dryer systems

EPRI is supporting a consortium of companies to develop modifications which will reduce the overall size of the baghouse required for particulate control.[49] The Nebraska Public Power District is also performing a complete particulate and engineering evaluation of the fabric filter for EPRI.[51]

Kaiser Engineers is performing a program for the design, fabrication, and installation of a flexible, state-of-the-art, full-scale fabric filter test module.[52] Experiments are being conducted to determine optimum, cost-effective conditions for particulate control.

c. Advanced (novel) particulate control technology

Advanced techniques for particulate control would achieve more efficient collection or operation under severe circumstances. The list of novel techniques includes devices such as electrically augmented bag houses and granular filters.

4. Fine Particulate Control Technology

The regulatory climate for particulate control is becoming increasingly strict, especially for fine particulate. Increased collection efficiency for these particles should be sought through a program which includes:

- development of sampling and analytical methods
- methods for improving fine particle collection in existing devices
- application of novel devices and techniques, as developed in 3 above
- demonstration of fine particulate control on large scale operating systems

5. Solid Waste Disposal Procedures

A coordinated program in waste management must include:

a. Evaluation of current practices for disposal of solid wastes without fixation.

b. Determination of leaching characteristics of fly ash and solid materials produced by FGD systems (wet scrubbers, spray dryers and dry sorbents).

c. Development of improved methods for disposal of hazardous wastes:

- separation of hazardous and non-hazardous wastes
- concentration of hazardous species

Such work is not now being addressed adequately, and may be mandatory in the near future as a result of RCRA requirements.

6. Improved Reliability Of Ash Alkali Wet Scrubbing

This effort should be organized according to the following tasks:

a. Summarize current operating experience and develop explanations for reliability histories.

b. Develop guidelines for application of wet ash alkali systems.

c. Develop improved ash alkali systems by laboratory and pilot scale investigations.

The development of ash alkali systems is under investigation by a number of organizations. GFETC has pioneered the work in this area with laboratory and pilot plant studies.

7. Analysis of Trace Elements and Organic Compounds in Flue Gases

Data on the emissions of trace elements and organic compounds from low-rank coal-fired units are very limited. Several steps are necessary to provide an initial data base in this area of concern:

a. Development and verification of sampling and analytical procedures for condensed/solid and volatile organic materials and trace elements in flue gas.

Texas A&M University is developing sampling and analytical procedures to identify organic compounds and trace elements in stacks of lignite-burning facilities.[57] In a second but separate study, the same university is utilizing modern techniques to perform detailed investigations of the heavy trace element composition of Texas coal and lignite.[58]

b. Assessment of radioactivity of fly ash produced from combustion of low-rank coal.

Since low-rank coals demonstrate considerable variation in radioactivity, a representative cross-section should be tested to determine which coals, if any, represent radioactive environmental hazards.

c. Determine factors (design parameters, operating procedures, and fuel characteristics) that affect the emission of organic and trace elements. This task is a first step in understanding and developing effective control mechanisms.

8. Improved Procedures For NO_x Control

Increasingly tighter NO_x emissions standards are expected in the future, and satisfactory techniques to achieve these reductions are not available.

A comprehensive program for NO_x reduction in low-rank coal combustion should include:

a. Assessment of effectiveness of current combustion modifications used to reduce NO_x emissions.

b. Development of improved methods for the reduction of NO_x emissions by modifying combustion procedures.

c. Evaluation of the applicability of post-combustion techniques for NO_x emission control.

d. Study of low-rank coal-specific problems in NO_x control, such as the effects of overfire air on ash fouling.

5.3.7.4 Environmental Control Technology for Conventional Combustion - Priority II Topics

9. Solid Waste Utilization

The objective of this topic is to develop beneficial methods for the utilization of solid wastes produced by the combustion of low-rank coals.

a. Fly ash utilization

Current efforts at fly ash utilization should be continued. These include ash utilization for highway and road construction, in the manufacturing of cement, and in the manufacture of utility and lighting poles.

One of the major objectives of ash utilization research being performed at the University of North Dakota has been the ASTM acceptance of basic fly ashes for use in portland cement concrete.[56] Studies have been conducted to determine the effect of fly ash particle size on suitability of ash for mineral filler. Results demonstrate that the finer the fly ash the less desirable it is as mineral filler. Other investigations indicate the feasibility of producing excellent extruded brick containing 25 percent fly ash and 75 percent clay.

This work should entail the development of methods for extraction of useful components from fly ash. This may include radioactive elements such as uranium or other radioisotopes, or purification or extraction processes to prepare the fly ash for some other use. In a similar effort, EPRI is evaluating processes for the removal of hazardous trace metals from coal fly ash.

b. FGD waste utilization

Develop methods for the utilization of waste materials produced by flue gas desulfurization systems. Specify low-rank coal-specific problems.

- sodium based dry sorbents
- ash alkali process slags

10. Retrofit SO_2 Emission Reduction Techniques

The optimal method for achieving SO_2 emission reductions on retrofit installations will be specific to each location. The use of dry sorbent injection, and other techniques which may be especially applicable to low-rank coals, should be investigated.

5.3.7.5 Fluidized Bed Combustion - Priority I Topics

1. Agglomeration of Solids in Fluidized Bed

Agglomeration of bed materials can alter bed operation, and has been observed when burning low-rank coals. Two research topics need to be addressed in this area:

a. Determine the mechanisms and conditions that cause or prevent agglomeration.

b. Evaluate effects of bed materials and sorbents at the pilot scale.

2. Sulfur Retention by Inherent Alkali in Low-Rank Coals

Sulfur capture, with or without the use of sorbents when burning low-rank coals, is a fundamental advantage of the fluidized bed design. In order to take best advantage of this characteristic, a study should be initiated to determine the effects of coal and ash properties, operating conditions, bed materials and sorbents on sulfur retention in AFBC and PFBC designs.

A study is being performed at the University of Texas, Austin, to investigate the sulfur removal by natural sorbents.[68] There is little data on the amount of sulfur dioxides produced in FBC of Texas lignites. The extent of sulfur retention will need to be understood to quantify the costs of SO_2 control and the materials requirement for FBC.

This work should be expanded to include other low-rank coals, and should determine the effects of pressure on sulfur retention.

3. Design Configuration of FBC Optimized for Low-Rank Coal

Because of the unique chemical and physical properties of low-rank coals, different combinations of design variables and/or basic combustion design will be needed for low-rank coal feedstocks than will be used optimally for higher rank coals.

Fluidized-bed technology is currently evolving from the research and development stage to the demonstration project phase. Of the many facilities currently under development, there are four which have performed tests on low-rank coals. GFETC has the largest data base on Fort Union Region lignites and subbituminous coals.[63] GFETC is also supporting tests being performed by the Combustion Power Company.[66]

The Morgantown Energy Technology Center (METC) has the most AFBC performance data on Texas lignites and coal refuse.[64] The FluiDyne Engineering Corporation, unlike the others, is operating an air-cooled unit and is therefore well-suited for testing industrial process requirements.[65]

The Electric Power Research Institute (EPRI) has sponsored North Dakota lignite test burns in the Babcock & Wilcox AFBC unit at Alliance, Ohio, and in the Lurgi circulating bed system in Germany. The Westinghouse Electric Corporation is conducting design studies using a Gulf Coast lignite and a Wyoming subbituminous feedstock.

Evaluation of the optimal design and configuration for low-rank coal fluidized bed combustion should be based upon results from the above studies. The evaluation should proceed in the following order:

a. Evaluate results of EPRI- and DOE-sponsored tests, and TVA design studies.

b. Assess fluidized and circulating bed configurations as applied to (1) large-scale utility, and (2) small-scale industrial installations.

c. Identify combustor design differences required for AFBC and PFBC for low-rank coals: bed depth, velocity, heat transfer surface, etc.

d. Based upon above results, build and demonstrate optimized AFBC units for low-rank coals.

4. Properties of Limestone-Deficient, Ash-Rich Fluidized Bed

Certain low-rank coals may offer the possibility of combustor operation without the requirement of added sorbent (limestone or other material) because of favorable calcium-to-sulfur ratios. For this reason, the properties of low-rank coal fluidized beds (AFBC and PFBC) should be investigated.

The physical and chemical properties of ash-rich beds should be be determined. Particularly important are estimates of heat transfer coefficients and thermal diffusivity. The study should also include an evaluation of time-dependent changes in bed character.

5. Hot Gas Clean-up and Turbine Reliability for Pressurized FBC

The efficiency advantage obtained in a PFBC system is due largely to the use of a hot gas clean-up device which allows direct use of the hot gas for power generation.

Burns & Roe, under the sponsorship of EPRI, is performing engineering and economic evaluations based on the results of three projects, one of which entails the use of hot gas cleanup.[69]

Hot gas cleaning is still developmental in nature and there are still several issues to be resolved when this technology is being considered for use in conjunction with low-rank coals:

a. Determine effects of alkali on clean-up systems at pilot scale.

b. Determine need for additional clean-up; use of gettering.

c. Investigate use of multistage cyclones and/or ceramic filters.

One of the primary duties of a hot gas clean-up device is to protect downstream gas turbines from erosive particulate matter and corrosive chemical agents. A close relationship exists between hot gas clean-up performance and gas turbine requirements. An effort should be made to determine if economically attractive levels of particulate removal are compatible with advanced turbine blade requirements.

The EPA and Exxon Research and Engineering Company are co-sponsoring work to identify R&D needs of PFBC steam cycles using gas turbines.[70] One of the major conclusions is that advanced steam cycles using PFBC as the heat source are economically attractive as compared to other cycles when particulate removal requirements for turbine protection are relaxed.

6. Materials Problems and Selection for Low-Rank Coal FBC

The variation in temperature and chemical environment within a fluid bed combustor suggest that a variety of different metals or other materials of construction may be required. Corrosion/erosion studies are specifically needed for FBC's burning low-rank coals. This work should concentrate on in-bed, above-bed, cyclone, and air distribution locations within the combustor.

5.3.7.6 Fluidized Bed Combustion - Priority II Topics

7. Coal and Sorbent Feeding Distribution

The location of solids feeding ports in the fluidized bed combustor is an important design consideration. Two research tasks are needed to clarify optimum locations for various low-rank coals:

a. Determine effects of high coal reactivity on feeding and distribution system design, including number of ports, above or below bed, etc.

b. Incorporate basic coal science data on reactivity at the pilot scale.

8. Staged Combustion for NO_x Control

PFBC designs in particular seem to offer advantages for control of NO_x. For both AFBC and PFBC systems, the effects of high coal reactivity on staged combustion design should be evaluated, preferably at the pilot plant level.

9. Temperature, Gas and Solids Distributions in Low-Rank Coal FBC

Optimization and control of a fluidized bed system requires quantitative knowledge of in-bed and above-bed temperature profiles and gas and solids distributions. Laboratory or pilot scale studies are best suited to obtaining this knowledge under either atmospheric or pressurized conditions.

5.3.7.7 Gasification - Priority I Topics

1. Process Adaptation for Low-Rank Coals

There are many studies in progress which address conceptual process design optimization and engineering/economic analysis of low-rank coal performance in gasification systems.

EPRI is funding Fluor Engineers and Constructors to develop preliminary engineering and economic evaluations for a variety of coal gasification processes.[79] EPRI is also sponsoring a group of companies to evaluate a number of gasification concepts and the performance of novel power cycles integrated with gasification systems.[81]

A DOE-sponsored project at the University of Minnesota is investigating a state-of-the-art gasification system to heat the campus.[82] Tests entail the use of subbituminous coals and lignite. A co-sponsored project by DOE/GRI includes a number of advanced gasification processes. The goals include improvement of process efficiencies by as much as 10 percent over existing processes, reduction of capital costs compared to second-generation, and simplification of design and operations and increased reliability over second-generation processes.

The use of low-rank coals may prove to be advantageous in the HYGAS process.[83] A conceptual design for commercial scale demonstration is being completed by Procon, Inc. Studies of slagging fixed-bed gasification are being performed at the GFETC.[84] The DOE is also sponsoring work at the Oak Ridge National Laboratory, where Texas lignite and Wyoming subbituminous are included in the feedstocks under investigation.[85]

The Institute of Gas Technology is studying the economic and technical feasibility of the U-Gas (Ash Agglomerating) gasifier.[86]

Studies of this nature are essential in successfully applying low-rank coals in gasification systems. These topics should be continued and used as a basis for an overall technical and economic evaluation of low-rank coal gasification performance. The objective of such an evaluation is to suggest modifications and improvements to the most promising gasification systems for low-rank coals.

2. Wastewater Treatment for Process Effluent

The unique chemical composition of low-rank coals indicates that different methods or operating parameters will be required for treating gasification wastewater from low-rank coals, as compared to bituminous coals. Several research topics should be addressed to identify proper treating facility design:

a. Laboratory screening techniques for novel and innovative methods of wastewater treating

A simple yet effective standard for determining technical and preliminary economic feasibility of novel wastewater treating systems should be established.

b. Pilot plant demonstration of novel wastewater treating methods

Processes recommended for further analysis by the above screening technique should be demonstrated and evaluated at the pilot plant level. Of critical importance at this phase of process development is proof of the tar separation (emulsion breaking) system, and the determination of how the process parameters must be altered to account for coal specificity.

Both GFETC and METC have initiated gasification wastewater treatment studies.[84,87]

3. Slag Behavior

Proper design of high-temperature gasification processes requires knowledge of slag properties - viscosity, surface tension, and corrosivity - as a function of operation conditions. Properties of mineral matter, and therefore slags, are highly variable and need to be characterized for the low-rank coals.

The chemical corrosiveness of low-rank coal slags on refractory materials has been demonstrated on slag-tap linings at GFETC. These effects should be quantified for a number of coals so that refractory materials with acceptable lifetimes can be developed for gasifier use.

4. Catalytic Effects in Low-Rank Coal Gasification

It is known that the mineral matter present in low-rank coals is a catalytic agent in promoting gasification reactions. This property is potentially useful, and therefore, the conditions under which maximum catalytic activity occur should be quantified in a research program. The study should investigate a representative cross section of Western low-rank coals.

Gasification processes which rely on added catalysts may behave differently as a result of catalyst interactions with low-rank coal mineral

matter. In addition, mineral matter interactions could strongly influence the extent to which the added catalyst is recoverable, an economically critical variable.

For example, Exxon Research and Engineering Company is developing a Catalytic Coal Gasification process to produce substitute natural gas.[90] It is believed that the chemical composition of low-rank coal ash may have a different effect on catalyst activity or recovery than that associated with higher rank coals. Minerals such as sodium and calcium in low-rank coals may be recovered in the potassium recovery step.

5. Slag, Ash, and Residue Leaching Characteristics and Immobilization

Similar in scope to leaching tests on fly ash and bottom ash produced in direct combustion, the objective is to determine the extent of the problem to be faced in groundwater contamination from residue leaching.

6. Minimizing Health Effects of Coal Liquids

In assessing the risks to human health from coal processing emissions, the effects on the occupational, local, and general segments of the population must be considered. The most serious threat to industrial workers is exposure to potentially carcinogenic polycyclic aromatic hydrocarbons (PAH) or coal liquids. Although the PAH are considered a potential health hazard, perhaps the most critical hazard from coal conversion processes, less is known about them than other potential pollutants.

Although the products of different coal utilization technologies are not identical, many compounds known to be carcinogenic have been found in all these products and their process streams. Therefore, studies should be initiated to minimize the hazardous potential associated with gasification products.

5.3.7.8 Gasification - Priority II Topics

7. Effects of Pressure, Temperature, and Atmosphere on Evolution and Destruction of Volatile Matter

Coal volatile matter content is an important property in determining the wastewater composition in fixed bed gasification.

Therefore, one successful technique of wastewater treating may be to adjust gasification conditions to produce a more easily treated wastewater. The conditions for achieving best wastewater composition will vary depending on coal type and gasifier configuration and for any given coal may not correspond with conditions for best gasifier operation.

8. Distribution Coefficients of Soluble Organics in Wasterwater

The distribution of hydrocarbon compounds in the aqueous phase is dependent upon a variety of factors. Interactions occurring in a multiphase, multicomponent system prevent the use of simplified two-component solubility data. Experimental determination of wastewater composition for a variety of different coals is, therefore, a necessary part of designing an effective wastewater treating system for use in low-rank coal gasification plants.

9. Slurry Feeding of Low-Rank Coal to High-Pressure Gasifiers

Two major issues complicate the feeding of coal slurries to pressurized gasifiers: moisture content and line plugging. The problem of moisture reabsorption when slurrying dried low-rank coals compounds the problem of achieving an acceptable solids content in the slurry. Line plugging is a potential maintenance and reliability problem with any slurry feed system.

Gasifiers operating under pressure require that the coal (and any other solid such as a sulfur sorbent) be fed into the reactor at operating pressure. The ability to pressurize and feed dry solids eliminates disadvantages associated with slurry feeding. Reliability has been a problem with the lockhopper approach; one possible technique may be the use of pressurized pneumatic injectors.

5.3.7.9 Liquefaction - Priority I Topics

1. Process Adaptation for Low-Rank Coals

A large number of companies are jointly sponsoring coal liquefaction projects with DOE and EPRI. The most significant work has taken place with the Exxon Donor Solvent (EDS) process, which produces distillate fuels from a wide range of coals.[91] The subbituminous coals and lignites are more difficult to process, however methods are currently being developed to mitigate some of the problems associated with low-rank coals. To date, there has been very little work on low-rank coals in any of the major liquefaction projects.

The H-Coal Process is also being funded by a consortium of companies, and the DOE.[92] The H-Coal pilot plant is scheduled for start up in 1980. It is understood that higher reaction pressures will be required for subbituminous versus bituminous coal.

The SRC-I process was developed to produce a low-sulfur, low-ash solid fuel.[98] The SRC-II process is an extension of the first, generating a substantial yield of liquid, rather than solid product.

It is now understood that the unique properties of low-rank coals require a different set of process conditions than is optimum for bituminous coals. Economic and engineering evaluations of low-rank coal performance in processes optimized for other coals will not accurately represent their potential. Therefore, based on the results of on-going bench scale experimentation, such as the work at GFETC and UND, engineering/economic studies will suggest a direction for low-rank coal liquefaction development.

2. Recycle Solvent Studies

Recycle solvent composition and treatment is one variable process parameter which has an important effect on liquefaction performance. Results from this study will help to define optimum operating conditions for low-rank coal liquefaction systems.

a. Solvent composition effects on rate of hydrogenation

Solvent hydrogenation is a critical liquefaction process step which may or may not be accomplished catalytically. With the aid of sophisticated analytical techniques used in basic research, hydrogenation rates of solvents, and the extent and rate of hydrogen release should be determined as a function of solvent composition.

At the University of California, Berkeley, a DOE-funded investigation is underway of the hydrogen transfer between solvent and coal.[99] DOE is also sponsoring work at the University of Wyoming to study the effect of solvent characteristics on coal conversion, asphaltene formation, and nitrogen removal in hydrogenation of Wyodak coal (a Wyoming subbituminous coal).[95]

The Colorado School of Mines is performing a study of the kinetics and mechanisms of coal liquefaction in a pure donor solvent and a coal-derived solvent.[96]

Work continues at GFETC[97] and Exxon Research and Engineering[91] in order to better understand solvent hydrogenation and donor activity. Results should be collectively reviewed to determine optimum solvent characteristics.

b. Effects on product mix of recycling portions of solvent and heavy bottoms

One option for dealing with the high bottoms viscosity produced by low rank coals during liquefaction is to vary the reactor recycle to contain lesser quantities of solvent and greater amounts of heavy material. The desirability of this approach depends strongly upon its effect on product quality.

Work is in progress at GFETC and at Exxon Research and Engineering to determine the effect of recycling portions of the solvent and heavy bottoms on the product mix.[102]

c. Hydrogen content of solvent and product as a function of conversion and liquid yields

The relationship of product hydrogen content, conversion and liquid yield to solvent hydrogen content is an important process characteristic. In the SRC-II process, greater hydrogen addition to the feedstock is promoted by higher reactor temperatures and slurry recycle, thereby producing a substantial liquid yield. Pilot plant work being performed by the Pittsburg and Midway Company has encountered problems with solvent balance when operating on lignite.[98] An understanding of the solvent liquid yield as a function of solvent hydrogen content could

suggest process alterations which would correct this and similar steady state operational problems in other processes.

In addition to the SRC-II work, DOE and EPRI are funding investigations of liquefaction rates and product distributions for several liquefaction solvents.

3. Syngas and Hydrogen Effectiveness Studies

For bituminous coals, hydrogen has proven to be a superior reactant in liquefaction processes. However, low-rank coals have shown high liquid yields when reacted with synthesis gas, which has the added benefit of being cheaper than hydrogen. This tradeoff should be quantified for both lignite and subbituminous coals, and the economic incentive (if any) identified.

4. Calcium Carbonate Formation in Reactors

It is known that the high calcium content of low-rank coals leads to the formation and deposition of calcium carbonate in the liquefaction reactor in the form of wall scale and oolites.

The EDS coal liquefaction project is investigating the circumstances under which oolite formation occurs.[91]

This work should be continued and expanded to determine the effects of pressure and the conditions under which coke formation and wall scale deposition occur.

5. Coal Moisture Content and Drying

High coal moisture content increases the reactor pressure required to maintain the minimum desired partial pressure of reducing gas. On the other hand, certain drying processes deactivate low-rank coals for liquefaction reactions by collapsing the pore structure of the coal and reducing the surface area available. The incentives for drying should be quantified, and processes (such as hot slurry drying) should be developed if justified by need and performance.

6. Coal Mineral Catalysis in Recycle

The catalytic role of low-rank coal mineral matter in liquefaction reactions is still ill-defined. Recycle of mineral matter provides the possibility of a greater catalyst charge in the reactor, but the properties of the mineral matter after passing through the liquefaction system must first be determined.

7. Bottoms Recycle

The practice of recycling portions of solvent in coal liquefaction is currently under investigation. Heavy bottoms recycle is a second option which has not received much attention. The effects of heavy material recycle on conversion and product yields need to be evaluated.

8. Minimizing Health Effects of Coal Liquids

Coal-derived liquids contain polycyclic aromatic hydrocarbons, considered the most serious hazard from coal conversion processes. These and other products are believed to be potential carcinogens, cocarcinogens, mutagens, or teratogens. Rigorous qualitative data relating to human exposure with health effects are still sparse. Therefore, studies are required to obtain such data, in order to better quantify the associated risks and hazards. These studies will lead to subsequent work dealing with the minimization of known health effects.

5.3.7.10 Liquefaction - Priority II Topics

9. Bottoms Viscosity Studies

Many tests on low-rank coals have shown them to produce high viscosity bottoms. Several areas of investigation should be pursued as possible means for alleviating the problem:

a. Determine the effect of coal analysis and solvent properties on bottom viscosity

The EDS coal liquefaction studies are investigating the effect of coal analysis and solvent properties on bottoms viscosity.[91] The difficulty of processing lower rank coals is reflected in higher viscosities of EDS liquefaction bottoms derived from various coals. Generally, these higher viscosities can be reduced with longer reactor residence times under typical EDS conditions.

This work should be continued and expanded to include other processes which have shown high bottoms viscosity with low-rank feedstocks.

b. Determine the nitrogen, oxygen and hydrogen content of the bottoms, as related to the coal analysis.

c. Determine the effect on bottoms viscosity of the THF- and benzene-soluble fraction degree of coal conversion and hydrogen content.

d. Determine the effect of hydrotreated distillate cuts on heavy bottoms viscosity.

DOE is sponsoring a project at GFETC to optimize distillate yields in order to balance the depolymerization of heavy ends and the coincident formation of gaseous products.[99]

10. Effects of Staged or Continuous Removal of Gas

During liquefaction, low-rank coals evolve large amounts of CO_2 and water vapor. Since a certain partial pressure of reducing gas (H_2 or synthesis gas) is required, the evolution of these components raises the total pressure, requiring thicker (more expensive) process vessels. The issue is further complicated by the fact that small amounts of CO_2 appear to be beneficial in promoting liquefaction. Therefore, two areas of investigation are warranted:

a. Determine the preferred method (staged or continuous) of removal of CO_2 and water vapor from the liquefaction reactor.

b. Determine optimum levels of CO_2 in the liquefaction atmosphere, and determine if this concentration can be produced in steady state without continuous or staged CO_2 removal from the reactor.

11. Fate of Nitrogen

Because nitrogen acts as a precursor to NO_x formation and as a catalyst poison in liquid fuel upgrading processes, the distribution of coal nitrogen in the gaseous and liquid products of liquefaction is important. Two topics should be studied to address the fate of heteroatomic nitrogen:

a. Determine the relative retention of nitrogen in product liquids as compared to bituminous coal.

b. Compare denitrogenation in synthesis gas vs. H_2 liquefaction of low-rank coal.

12. Effects of Staged Temperature Exposure

It is hypothesized that preasphaltene yield is determined by the highest temperature seen during the course of the reaction. Since control of preasphaltenes is important, this question should be resolved by a laboratory study of the effect of staged temperature on yield. Pressure and residence time at each temperature should also be noted.

13. Disposable Catalyst Approaches

Catalyst cost can be a critical factor in determining the economic viability of a liquefaction process. Use of a very cheap catalyst would obviate a catalyst recovery system and allow the catalyst to be used for one pass only, being discarded with the solid waste from the process.

The disposable catalyst hydrogenation process is part of DOE's Third Generation Processes Program.[100] The process employs inexpensive single pass catalysts, avoiding costly catalyst recovery and regeneration steps. The effects of low-rank coals in this process are expected to be similar to those in other liquefaction systems. The catalyst selection must be compatible with the mineral matter present in low-rank coals.

14. Corrosion of Stainless Steel by Coal Liquids

Corrosion rates for metals in coal liquefaction service must be known before process equipment can be accurately specified. In particular, corrosion coupon tests should determine corrosion rates as a function of water content, dissolved (free) oxygen content, mineral matter composition and coal rank. The mechanism of phenolate formation may also be important, and should be considered after it is identifed as a result of work in basic research.

15. Erosion in Liquefaction Systems

The presence of solid materials (particularly in SRC) can be a source of erosion in liquefaction systems. The role of mineral matter and agglomerate formation may be particularly important. These effects should be quantified.

16. Mathematical Reactor Model to Account for Mixing and Turbulence Effects

Mixing and turbulence effects are important factors in determining mass transfer and conversion rates in liquefaction reactors. A quantitative understanding of these hydrodynamic effects would aid reactor optimization efforts.

5.3.7.11 Pyrolysis - Priority I Topics

1. Feasibility of Low-Rank Coal Pyrolysis

An incentive for the use of low-rank coals in pyrolysis (and other utilization methods) is the low feedstock cost. However, high yields of gas and relatively low yields of liquid and char products establish a tradeoff with feedstock cost. Poor chemical and physical properties further reduce the incentive of cost.

A DOE-sponsored study at the Massachusetts Institute of Technology (MIT) is in progress to determine the operating characteristics and economic feasibility of directly producing gaseous and liquid fuels by coal pyrolysis.[107] High- and low-sulfur coals are being evaluated.

The FMC Corporation and the United States Steel Corporation are currently developing a process to produce a metallurgical formed coke.[108] The feedstock is a Wyoming subbituminous coal.

Based on a review of yield and market data for low-rank coal pyrolysis, a process design and engineering/economic tradeoff analysis should be initiated to quantify the incentives for pursuing low-rank coal pyrolysis.

2. Minimizing Health Effects of Coal Liquids

Although the products of coal combustion and coal pyrolysis are not identical to those of coal conversion, many compounds known to be carcinogenic have been detected in all these products or their process streams. Exposure to carcinogenic PAH is the most serious threat to industrial workers. Therefore, investigations of the similarities of various products will assist in evaluating the effects on human health.

5.3.7.12 Pyrolysis - Priority II Topics

3. Improved Analytical Methods for Low-Rank Coal Pyrolysis Studies

A special analytical technique is needed to quantitatively evaluate char reactivity and a standardized method for evaluation of pyrolysis liquids produced from various processes is desirable.

4. Improvement of Pyrolysis Product Properties and Yields

High oxygen content, acidity, corrosiveness, and pyrophoric nature are among the negative characteristics of low-rank coal pyrolysis products. The desirability of low-rank coals as pyrolysis feedstocks could be improved significantly (assuming yields are sufficient to justify the process economically) if physical and chemical product deficiencies could be corrected or improved.

As the major economic impediment in low-rank coal utilization, a shift from high gas yields to higher liquid or char yields could significantly improve low-rank coal pyrolysis incentives. Techniques for achieving this include:

- hydropyrolysis
- flash hydropyrolysis as an approach for maximizing yields of BTX chemical feedstocks

In addition to these possibilities, a number of projects are currently in progress investigating methods to increase pyrolysis yields of liquids and char when operating on low-rank coals. Project COED (Char-Oil-Energy Development) is a process for converting coal to char, oil, and gas by reacting the coal in a multi-stage, fluidized bed system.[109] The feedstock to the pilot plant has included Wyoming subbituminous coals and North Dakota lignite.

The Toscoal process, developed by The Oil Shale Corporation (TOSCO) upgrades low heating value coal (low-sulfur Western coal) through pyrolysis.[110] The pilot plant is currently in operation.

In the Garrett (now Occidental) Flash Pyrolysis process direct yields of methane and other hydrocarbons are obtained by rapid pyrolysis of coal.[111] The objective of the rapid heating is to minimize the production of gas. Product yield data are available for the pyrolysis of a Western subbituminous coal.

A study is also in progress at the University of Houston to investigate a pyrolysis process which takes advantage of the high volatility and other properties of Texas lignite to produce a clean burning char, and clean gaseous and liquid fuels.[112]

The Australian company, CSIRO, will begin pilot plant operations in 1980 for a flash pyrolysis process in which the primary product will be char.[113]

The National Science Foundation and the DOE are co-sponsoring work at MIT which entails small-scale experiments on the pyrolysis of a dried Montana lignite.[114] These tests will analyze those parameters affecting the yield of light hydrocarbon gases, oil, liquid tar, and char.

5.3.8 Basic Research - Priority I Topics

1. Resource and Coal Seam Characterization

A detailed delineation of the properties of low-rank coal reserves and resources should include:

- characterization of mineral matter and organic salts
- development of washability data
- variability studies on coal seams (such as sodium content, for example)

2. Standard Low-Rank Coal Samples

The purpose of this work is to standardize those feedstocks used in the various technologies (i.e., combustion, FBC, gasification, etc.). This could be accomplished by collecting the known coals and storing them all under identical conditions which would reduce product degradation, spontaneous combustion, and fugitive dust emissions. This standardization process allows for more meaningful comparisons among experiments conducted at different laboratories on different utilization technologies.

3. Petrographic Characterization

Improved petrographic techniques for evaluation and classification of low-rank coals are needed. According to petrography researchers at Pennsylvania State University, the techniques and classification systems used in this country for petrographic studies of bituminous coals do not apply to U.S. low-rank coals. The applicability of European brown coal petrography systems to U.S. low-rank coals is unclear. Pioneering work in the field of U.S. low-rank coal petrography should be initiated.

4. Reactions Between Alkali Materials and Sulfur

The mechanism and conditions of sulfur capture by alkali components of low-rank coal mineral matter is of specific interest in fluidized bed combustion, conventional combustion, wet and dry flue gas desulfurization and coal gasification systems. A basic understanding of this phenomenon would assure its optimum exploitation in each of the technology areas.

5. Surface Tension of Coal Slags

The behavior of coal slags is an important characteristic when designing a slagging gasifier or wet bottom combustor. Surface tension as a function of temperature should be determined for a representative cross section of low-rank coals.

6. Composition and Characteristics of Ashes and Slags From Low-Rank Coals

The development of a data base to characterize important properties of low-rank coal ashes and slags would be of considerable importance in fluidized and conventional combustion, gasification, liquefaction, pyrolysis, and projects oriented at ash utilization development.

7. Analytical Characterization of Liquefaction Solvents

Proper evaluation and comparison of liquefaction systems' performance will be aided by a standard characterization of process generated solvents. This effort should include the following items:

- establish inter-laboratory standardization system
- develop solvent quality/hydrogen donor index
- characterize heavy portions of coal liquids
- develop accurate technique for determining molecular weight distributions
- develop standard technique for determination of oxygen content and functional group
- develop technique for identifying quinone-hydroquinone structures

Solvent quality/hydrogen donor index may be established by model compound hydrogenation (such as naphthalene). The variation in the above properties should be studied in continuous liquefaction systems as steady state is approached.

Some work in this area is underway at Texas A&M University[115] where different solvents derived from lignite are being compared. Studies in progress at GFETC[97], Exxon[91] and EPRI[102] are also investigating the use of various solvents for liquefaction. This work is an important start in coal solvent characterization and should be expanded to include other coals.

8. Low-Rank Coal Liquefaction Catalysis

The role of heterogeneous and homogeneous catalysis should be investigated for low-rank coal liquefaction. The following points should be part of the research effort:

- prepare an up-to-date paper on liquefaction catalysis
- elucidate catalyst mechanisms and apply this knowledge to catalyst development programs
- investigate the role of gas phase catalysis (for example, H_2S and sulfur vapor)

The catalytic effects of the diverse mineral matter content found in low-rank coals, and the progressive conversion of heavy organic liquids and solids are under investigation at the University of North Dakota.[105]

9. Oxidative Depolymerization of Low-Rank Coal

It is known that the polymerized structure of coal can be degraded by aqueous phase oxidation, which can be used as a pretreatment step before conversion, or as a method of producing oxygenated products. The mechanism of this reaction may be operative in other conversion processes, and therefore an understanding of it may suggest process improvements in other areas.

10. Toxicity of Coal Liquids

It is generally believed that coal conversion processes may produce and release substances that can be hazardous to human health. While exposure to carcinogenic PAH is the most severe hazard to industrial employees, acute and chronic toxicity are also important considerations. The chronic effects of low levels of materials released during coal conversion will be the principal concern of the local and general population. For these reasons, basic research is required to better understand the potential hazards of coal liquids.

5.3.9 Basic Research - Priority II Topics

11. Surface Characteristics of Low-Rank Coal and Peat Fines

Coal beneficiation processes such as froth flotation and the Otisca freon process depend upon interactions with the surfaces of coal particles. An understanding of the nature of this interaction is a key step in improving this type of coal beneficiation process.

12. Reactivity of Low-Rank Coals at 1200-1800°F in Fluidized Bed Combustion

The range of temperature between 1200 and 1800°F represents the most likely condition for operation of fluidized bed combustors. Since carbon conversion is of prime importance in FBC systems, the feedstock reactivity is an important parameter.

Hydrocarbon Research, Inc., in a program sponsored by the DOE, is evaluating the reactivity of low-rank coals in fluidized beds.[85] It is believed that the higher reactivity of these coals will make their use desirable in this process. Results from the HRI studies should be investigated and explained on the basis of a fundamental understanding of the mass transfer and chemical kinetics involved in the fluid bed combustion of low-rank coals.

13. Impacts of Drying Methods on the Rheological Properties of Low-Rank Coal-Water Mixtures

The drying of coal to increase the Btu content of coal-water mixtures may affect the fluid mechanical properties of the mixture. An understanding of the mechanism of this effect could yield benefits important to the operation of slurry pipelines and slurry injection systems for coal gasifiers.

14. Kinetics and Reaction Mechanisms of Low-Rank Coals and their Chars with H_2O, H_2, CO, and CO_2

Optimization of conditions for the gasification or liquefaction of low-rank coals requires a basic understanding of the chemical kinetics and mechanisms involved in the conversion process.

A study is currently in progress at the Bartlesville Energy Technology Center to evaluate the kinetics and mechanisms of reactions of different coals in different conversion processes.[116] Some of the processes under investigation include HYGAS, COED, H-Coal, SRC-II, and the HRI process.

This study should be continued and expanded to elucidate the mechanism of the observed reactions and their rates. Catalyst effects should also be investigated.

15. Fate of Oxygen and Nitrogen Components in Coal Conversion Systems

The quality of products from coal liquefaction, pyrolysis, and to a lesser extent coal gasification systems depends to a great extent on the fate of coal bound oxygen and nitrogen. Improvement of, and continued assurance of high product quality could be provided by a basic understanding of the fate of these coal elements during conversion.

16. Reactivity of Peat in Various Atmospheres

The development of peat as a viable feedstock for combustion and gasification processes will require an understanding of its behavior in the presence of different gas phase reactants. Reactivity is a particularly important aspect of this behavior, and as such, it should be evaluated for various peats in the presence of H_2, CO, H_2O, CO_2, O_2 and mixtures of the gases (with some N_2 present) at different temperatures.

5.3.10 Other Research Activities

During the assessment of the research, development and demonstration needs for Western low-rank coals, several important topics were identified which, because of their breadth of scope, did not fit as part of the program in the individual technology areas. These topics are presented in this section, and cover three basic areas: Regional Environmental, Market and Economic, and Regulatory and Policy.

Because of the broad nature of these areas, many different groups may be involved in the initiation, funding, management or execution of specific tasks. Topics are therefore discussed in a general way to encourage flexibility in assembling the various organizations which may be interested in addressing these needs.

5.3.10.1 Regional Environmental Studies

An aggressive program of research, development and demonstration as outlined in Section 5.3 will contribute to substantial growth in the use of Western low-rank coals. Such expansion will be accompanied by regional environmental and socioeconomic impacts which have not been assessed. Recommendations for environmental control should be made, but should also include a cost/benefit trade-off analysis between environmental, health and safety effects and capital cost, operating cost and energy consumption.

The analysis should focus on the three geographic areas of interest in low-rank coal development:

- Northern Great Plains Region
- Rocky Mountain Region
- Gulf Coast Region

5.3.10.2 Market and Economic Studies

The analysis presented in Section 4.4 is a preliminary assessment of current and potential future low-rank coal markets. Although several opportunities exist for organizing a similar, but more detailed investigation, such a study should again be oriented at the three major geographic areas of low-rank coal occurrence (Northern Great Plains, Rocky Mountain and Gulf Coast). This will allow a clearer understanding of the interrelationship of environmental, market and regulatory factors.

As a minimum, market and economic studies should cover the following areas:

- Conduct market analyses to determine the market size and penetration potential of new innovative technologies
- Determine forces which drive supply and demand market forces
- Assess the overall economic impact of existing and developing markets in low-rank coals, both inter-regional and intra-regional

5.3.10.3 Regulatory and Policy Analysis

The creation of proper and reasonable regulations and policies governing the use and development of low-rank coals is critical to the continued expansion of this energy source. This work must be guided by a complete understanding of the effects of such legislation on low-rank coal development. Two areas of impact should be studied: regulatory and financial.

1. Regulatory Constraints and Incentives For Low-Rank Coal Development

Laws governing the extraction and use of low-rank coal can be used as incentives or barriers to increased coal development. Studies falling in this category should evaluate which aspects of the industry should be stimulated and which curtailed, and the proper regulations for doing so.

2. Financial Constraints and Incentives For Low-Rank Coal Development

Financial and capital markets should be evaluated as they relate to government programs and policies. In addition, the economic impact of proposed or existing energy and environmental legislation (including effects of tax laws) should be evaluated.

APPENDIX A

PHASES OF ENERGY RD&D

PHASES OF ENERGY RD&D

1. Basic Research

Efforts to increase knowledge and quantitative understanding of natural phenomena and environment.

2. Applied Research

Systematic study directed toward the manipulation of known matter and phenomena, whether natural or created, with the objective of devising energy related processes, application, or systems, of possible (but uncertain) practical utility.

These efforts are directed toward the solution of problems in the physical, biological, behavioral, social, and engineering sciences which are not directed toward immediate applicability to specific projects. This includes the technical means of obtaining the knowledge, understanding, and solution.

3. Exploratory Development

Efforts guided by the principle that the work should lead ultimately to a particular application of project. Even so, the techniques and intrinsic intellectual value of the work may compare favorably with that of basic research activity. Exploratory development can cut across several scientific disciplines and is intended to explore possible innovation in a particular area of one or more energy technologies.

The focusing of scientific and technical effort upon a particular applied research result to explore in greater depth the parameters of the process, application or system with the objective of assessing whether further development is warranted.

4. Technology Department

Systematic use of the knowledge and understanding gained from research to achieve technical feasibility and to gauge economic and environmental potential of energy concepts, processes, materials, devices, methods, and subsystems.

Comprises development of engineering technologies, subsystems, planning and analysis studies, energy system concept formulation, comparison of alternative concepts, and development and test of laboratory-scale engineering feasibility models. This includes demonstration by experiment of alternative system concepts as well as preliminary studies encompassing system analysis, trade-offs, preliminary cost benefit studies, planning programming environmental studies.

5. Engineering Department

Systematic use of the knowledge and understanding gained from research and technology development to achieve the detailed design, construction, and test for performance, producibility, and reliability of energy system prototypes and pilot plants.

Detailed design, development and test of energy system prototypes and pilot plants judged to be technically and economically desirable as a means of achieving the principal energy goals. Engineering development may concern itself with processes, preproduction components, equipment, subsystems or systems. This capacity also includes major system test facilities directed toward specific project development and the preparation of appropriate environmental impact statements.

6. Demonstration

Verification of economic and environmental viability for commercial application, through design, construction, test and evaluation, of large-scale energy systems in operations circumstances.

Final engineering design, assembly, test and evaluation of full-scale energy systems aimed at providing directly applicable experience in an operational environment so as to demonstrate economic viability for commercial application. Demonstration projects are intended to: (a) overcome "scale-up" problems; (b) contribute to the understanding of the economics of fabrication and operation; and (c) resolve other questions such as public assistance, institutional and environment issues. Preparation of suitable environmental impact statements is included in this category.

7. Commercialization, Production, and Operation

a. Commercialization. When the predominant intents becomes bringing the system or project to commercial reality rather than demonstrating technical feasibility. When "scale-up" problems are overcome; economics of fabrication and operation are understood; public acceptance, institutional and environmental issues are resolved; and commercial interest in project exists.

b. Production. When the predominant intent becomes producing the item in quantity, bulk, or other parameters which meet specifically stated requirements.

c. Operations. When the predominant intent becomes bringing the system or project from prototype or pilot plant operational testing status, to full-scale operational condition to meet stated objectives.

APPENDIX B

ONGOING RESEARCH ON U.S. LOW-RANK COALS

The following brief project descriptions were compiled primarily from program summary documents available from DOE, the Texas Energy and Natural Resources Advisory Council, and EPRI. Some ongoing research projects on U.S. low-rank coals have undoubtedly been overlooked.

A significant amount of research is conducted on low-rank coals (primarily brown coals) in Canada, Australia, West Germany, India, and other countries. Descriptions of these projects have not been included in this Appendix.

B.1 EXTRACTION

1. The Impact of Surface Lignite Mining on Surface and Groundwater Quality

Contractor: Texas A&M University

Principal Investigators: Christopher Mathewson (Geology) and Kirk Brown (Soil and Crop Science)

Sponsor: Texas Energy Development Fund

The contractor will conduct a comprehensive investigation, including field measurements, laboratory investigations and computational procedures, to determine the impact of surface mining and groundwater quality and quantity. Based on the site specific studies and available experience and expertise, the contractor will investigate the regional influence of surface mining on groundwater quality and quantity, will identify topical and geographic areas of critical concern, and will identify mining and reclamation management alternatives available to Texas to protect groundwater quality and quantity.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-Five Years," Texas Energy Advisory Council, Report No.79-03-03 March 15, 1979.

2. Visual Resource Analysis For Texas Lignite

Contractor: Texas A&M University

Principal Investigators: Earl Hoskins (Geophysics)
Harlow Landphair (Landscape Architecture)
Violetta Burke (Political Science)
Christopher C. Mathewson (Geology)

Sponsor: Texas Energy Development Fund

The purpose of this study is to inventory and classify the landscape of the Texas lignite belt so that areas of potentially high visual impact can be readily identified. Based on the information gathered in this first phase, recommendation and techniques will be developed to help avoid major damage to the visual character of each area.

Reference same as above.

3. Oxidation of Sulfides in Lignite Mine Spoil: Influence on Return of Strip-Mined lands to Agricultural Production

Contractor: University of Texas at Austin

Principal Investigator: Lloyd Hossner, Joe Dixon, and Abu Senkayi (Soil and Crop Sciences)

Sponsors: U.S. Department of Agriculture, the Texas Agricultural Experiment Station, Industry, and the Center for Energy and Mineral Resources

More than a million acres of land may be disturbed by strip-mining operations in Texas. Much of the sulfur in overburden samples directly above lignite beds has been found to be pyritic. Studies are now being conducted to determine chemical alterations in clay minerals that are exposed to the atmosphere at varying levels of soil acidity.

Reference same as above.

4. UCG Modeling Studies

Contractor: Lawrence Livermore Laboratory

Sponsor: DOE

The Lawrence Livermore Laboratory (LLL) has developed models for two-dimensional coal recovery and product gas composition. They have also constructed a laboratory gasifier facility. Additional work includes laboratory, modeling, and field studies on UCG groundwater and air pollution, as well as subsidence.

U.S. Department of Energy Underground Coal Conversion Program Description, DOE-ET-0100, June 1979.

5. UCG Simulation

Contractor: Science Applications, Inc.

Sponsor: DOE

Science Applications, Inc. is performing analysis and interpretation of METC's laboratory UCG simulation data. Subsidence modeling is also in progress.

Reference same as above.

6. Medium-Btu Gasification of Low-Rank Coal

Designer: Lawrence Livermore Laboratory (LLL)

Sponsor: DOE

Date Initiated: 1972

LLL is studying permeability enhancement (linking) techniques and steam-oxygen gasification, having completed three tests at the HOE Creek site (near Gillette, Wyoming) on a subbituminous coal seam. Successful new diagnostics applied in one of the tests include a suite of subsidence measurements and high-frequency electromagnetic detection of the burn front.

Hill, R.W., et. al. Underground Coal Mining - An Assessment of Technology, EPRI AF-219, July 1976.

7. Reverse Combustion Studies

Contractor: The University of Washington

Sponsor: DOE

This project entails theoretical studies of reverse combustion in underground coal gasification. Findings indicate that the propagation rate of reverse combustion is sensitive to minor formation irregularities. Laboratory work on stress/mass transfer coupling in subbituminous coals has also been conducted.

U.S. Department of Energy Underground Coal Conversion Program Description, DOE-ET-0100, June 1979.

8. UCG Modeling

Contractors: LETC and University of Wyoming

Sponsor: DOE

A forward combustion model has been developed to predict gas composition and temperature profiles. A two-dimensional model forecasts shape, size, and rate of coal consumption. Other models have been developed for reverse combustion, and economic programs.

Reference same as above.

9. Substitute Natural Gas (SNG) From Coal Subprogram

Contractor: Gas Research Institute (GRI)

Sponsors: DOE and Gas Research Institute (GRI)

Five new advanced, third-generation coal gasification processes were funded in 1979 as part of the joint DOE/GRI program. In 1980, the SNG from Coal Subprogram will include the following three project areas:

Gasification Processes

1. By 1990, improve process efficiencies by up to 10 percent over existing gasification processes, or

2. By 1990, reduce capital costs compared to second-generation processes, or

3. Simplify design and operations, and increase reliability over second-generation processes.

Associated SNG Technology

1. Develop a hot gas clean-up process by 1983 which minimizes the energy lost in cleaning the raw gas stream.

2. By 1983, develop a sulfur-tolerant shift and methanation catalyst for conversion of raw gas to SNG on a pilot plant scale.

3. By 1987, develop or select materials of construction for the hostile coal gasification process environment, capable of withstanding exposure up to 10,000 hours.

In-Situ Coal Gasification

1. By 1981, demonstrate underground coal gasification, proving high coal consumption rates, well linkage by directional drilling, and 100-200 foot well spacing in deep-level (3000-5000 feet) coal seams.

2. By 1984, demonstrate underground coal gasification in a large-scale (1000 tons per day) pilot plant.

Major accomplishments planned for 1980 include:

Completion of coal gasification process evaluation reports on the five third-generation processes now being tested

Preparation of an initial process flowsheet for using novel catalysts in downstream gas processing

Completion of analysis of long-term, steam-oxygen, in-situ gasification test to determine the economic potential of this supply option.

Gas Research Institute, 1980-1984 Five-Year Research & Development Plan and 1980 Research & Development Program.

10. Block Pyrolysis Experiments

Contractor: Oak Ridge National Laboratory

Sponsor: DOE

Block pyrolysis experiments on Hanna, Hoe Creek, and Pricetown coals revealed different behavior for the bituminous versus subbituminous coals. High natural water in the coal seam was shown to markedly affect pyrolysis gas production, gas flow rate, and potential resource recovery.

U.S. Department of Energy Underground Coal Conversion Program Description, DOE-ET-0100, June 1979.

11. Steam-Char Kinetics

Contractor: Argonne National Laboratory

Sponsor: DOE

Steam-char kinetics pertaining to Wyodak (Hoe Creek), Hanna, and Pricetown coals have been completed. The reactivity of Pricetown bituminous chars is considerably lower than those of Hanna and Wyodak subbituminous chars. The mineral matter present in these Western coals is an excellent catalyst for the water/gas shift reaction.

Reference same as above.

12. Process Models for UCG

Contractor: West Virginia University

Sponsor: DOE

Investigations include coal conductivity measurements relating to the use of electromagnetic instrumentation in UCG. A one-dimensional model of the UCG process has been completed.

Reference same as above.

13. UCG Mathematical Modeling

Contractor: University of Texas

Sponsor: DOE

A mathematical model of override conditions has been developed. Studies of mechanical and ion exchange properties of Texas lignite are in progress.

Reference same as above.

14. Field Instrumentation Support

Designer: Laramie Energy Technology Center (LETC)

Sponsor: Sandia Laboratories

Diagnostic instrumentation and interpretation of field test results are included in ongoing work LETC is performing at Hanna, Wyoming, (subbituminous coal seams). Thermal data obtained in these studies have made it possible to delineate the location of the reverse combustion link(s), outward and upward progress of the gasification zones, and the utilization of coal within the experimental area.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

15. Williams Brothers Process Services, Inc.

Designer:	Williams Brothers Process Services, Inc. (A subsidiary of Resource Sciences Corporation)
Sponsor:	A Group of Companies

Studies of economics, cleanup and gas utilization for UCG, air gasification of Wyoming coal and steam/oxygen gasification of Texas lignite.

Stephens, D.R. "The Private Sector Involvement in Underground Coal Gasification," in Proceedings of the 5th Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979.

16. Atlantic Richfield Company (ARCO)

Contractor:	ARCO
Sponsor:	DOE through Lawrence Livermore Laboratory
Date Initiated:	1978

In 1978 ARCO designed, fielded and executed a successful field gasification test in a 100-foot-thick subbituminous coal seam near Reno Junction, Wyoming. The coal bed depth was about 630 feet with a 50-foot shale overburden and a hydrostatic head of 300 feet. The test included: (1) reverse combustion/forward gasification with air, (2) control of water influx, and (3) environmental monitoring.

Reference same as above.

17. Basic Resources, Inc. (A Subsidiary of Texas Utilities Company)

Contractors and Sponsors: See Below

Date Initiated: March 1975

In March 1975, Texas Utilities Company signed a license agreement with Licensintorg of the U.S.S.R. for technical documentation and assistance in UCG. A technological test was designed and executed in 1976 to prove technical feasibility near Texas Utilities' Big Brown Steam Electric Station in Freestone County, Texas. The test was classified as a success. The experiments were then moved to the Tennessee Colony site in Anderson County, Texas. A two-phase field test, including both air and oxygen/steam injection, was carried out from August 1978 to March 1979 in a multichannel, multiwell configuration. Reverse combustion was employed to link the wells.

Reference same as above.

18. Texas A&M University

Contractor: Texas A&M University

Sponsors: A Group of Companies

Date Initiated: 1977

Texas A&M University conducted a UCG test on University property in 1977. In cooperation with a consortium, a second test was recently performed near Rockdale, Texas. The lignite is 14 feet thick at a depth of 235 feet. A reverse burn link over a 50-foot distance was completed and forward gasification was conducted.

Reference same as above.

19. Steeply Dipping Beds (SDB)

Designer: Gulf Research and Development Company

Sponsor: DOE

Date Initiated: September 1977

This project entails underground coal gasification in a steeply dipping coal seam. The site, near Rawlins, Wyoming, has a subbituminous coal seam with a dip of 64 degrees and an average thickness of 20 feet.

U.S. Department of Energy Underground Coal Conversion Description, DOE-ET-0100, June 1979.

20. Low-Btu Gasification of Low-Rank Coal

Designer: Laramie Energy Technology Center (LETC)

Sponsor: DOE

Date Initiated: 1972

The LETC has been using reverse combustion as the linking technique in a series of successful field tests on a subbituminous coal seam in Hanna, Wyoming. In the second phase of this test a constant and high heating value of product gas and excellent thermal efficiency were obtained, demonstrating process feasibility.

Brandenburg, C.F. "Field Implementation of UCC Research," in Proceedings of the 5th Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979.

21. Longwall Mining

Sponsor: DOE

Longwall mining utilizes conventional room and pillar continuous mining equipment to develop panels of coal which may be a mile long, 600 feet wide, and 4 or more feet high. The room and pillar system of underground coal mining leaves undisturbed blocks of coal in a regular grid to prevent collapse of overburden strata. There are several DOE-sponsored studies in progress to determine and eliminate problems which limit productivity and to increase the economic attractiveness of longwall mining.

Otto, R.H. Three Potential Longwall Mining Methods for Thick Coal Seams in the Western United States, Bureau of Mines IC 8792, 1979.

Cassidy, S.M. (Editor), Elements of Practical Coal Mining, AIME Mudd Series, New York, 1973.

22. Evaluation of Texas Lignites Reserves by Geostatistical Methods

Contractor: Texas A&M University

Principal Investigators: H. Dennis Tolley and J.R. Alldredge (Statistics) and Christopher Mathewson (Geology)

Sponsor: Texas Energy Development Fund

The principal objective of this project is to provide a statistical methodology which will establish a basis of more efficient drilling and deposit estimation strategies. An analysis of available data allows for an evaluation of the practical strengths and shortcomings of the statistical methodology.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-Five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

23. Lignite Resources in Texas

Contractor: University of Texas at Austin

Principal Investigator: William Kaiser

Sponsors: Texas Energy Development Fund and University of Texas at Austin

The goal of this study is to document near-surface resources or those under less than 200 to 250 feet of cover. In areas where data are numerous, critical parameters such as number of seams, thickness, and lateral extent can be established. By applying mining parameters appropriate for economic recovery, reserve estimates can be made now and in the future.

An advisory committee has been established consisting of a representative from the Texas Energy Advisory Council (TEAC), two mining consultants to advise on deposit minability, and a Department of Energy representative to insure methodology and results acceptable to DOE.

Reference same as above.

B.2 TRANSPORTATION

24. Flow Properties of Methacoal Suspension of Texas Lignites

Contractor: Texas A&M University

Principal Investigator: Ron Darby (Chemical Engineering)

Sponsors: DOE, The Texas Engineering Experiment Station, and the Center for Energy and Mineral Resources

The non-Newtonian viscous rheological properties of Methacoal suspensions of lignite are being determined as a function of particle size and size distribution, concentration, and lignite moisture content. The most practical system for transporting large volumes of coal is by means of slurry pipelines. There is evidence that the optimum flow properties are achieved when a considerable amount of relatively fine particles is included in a slurry of larger particles.

Suspensions of dried coal or lignite in methanol (called Methacoal) are being studied as a substitute for water slurries. A pipe flow system is being constructed which will be used to measure the pressure drop characteristics of these suspensions as a function of flow rate and pipe size, in both laminar and turbulent flow. The rheological data and pipe flow data will be correlated to enable scale-up and prediction of the behavior of larger pipelines.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-Five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

25. Comparative Assessment of Water Use and Environmental Implications of Coal Slurry Pipelines - USGS Coal Slurry Model

Principal Investigators: R.N. Palmer, I.C. James, and R.M. Hirsch

Sponsor: U.S. Geological Survey

This coal slurry model is being applied to assess the head loss and energy requirements associated with the pumping of slurry. Hydraulic principles as well as recent pipeline experience have been integrated into this model. In one study performed it was assumed that the coal would be crushed to the same particle size distribution as that used by the Black Mesa system in Arizona, a lignite coal. This is the only slurry system operating in the U.S. The results of this study indicate that the minimum total cost occurs at 52 percent solids in slurry by weight, quite close to the 50 percent coal ratio for which most large coal slurry pipelines have been designed.

Palmer, R.N., I.C. James, and R.M. Hirsch. Comparative Assessment of Water Use and Environmental Implications of Coal Slurry Pipelines, U.S. Geological Survey, Open File Report 77-698, August 1977.

B.3 PREPARATION, HANDLING, AND STORAGE

26. Moisture Reduction Techniques

Contractor: GFETC

Sponsor: DOE

In a test conducted by the GFETC, 400 tons of Rosebud subbituminous coal and Gayscoyne lignite were dried in a commercial scale dryer, oil sprayed, cooled and shipped by rail approximately 800 miles. After stockpiling the coal, it was concluded that storage and handling requirements do not appear to differ significantly from those required for as-mined coal (although greater compaction has been needed). Furthermore, although more than 4 inches of precipitation had fallen on the pile during the two year test period there was no indication of moisture penetration.

(Anonymous), "How to Get Water Out of Lignite, Wood, and Peat," Chemical Engineering, March 27, 1978.

27. Ion Exchange

Contractors: GFETC and University of North Dakota

Sponsor: DOE

Bench scale experiments and process design studies have been conducted at the University of North Dakota and the Grand Forks Energy Technology Center. A preliminary economic analysis of a system based on sulfuric acid (H^+ cation exchange with sodium) has disclosed a cost (excluding profit) of $1.30 per ton of lignite for a 1.58 million ton per year facility (1979 dollars). The process design was based on a Beulah lignite feed containing 8.5 percent Na_2O in the ash, and calls for a reduction to 1.35 percent in the final product (coals having less than 4 percent Na_2O in the ash are not severely fouling coals). It may also be expected that reductions in other minerals will occur during the process, notably sulfur and total ash content.

Chemical cleaning processes might also be applied to low-rank coals to remove the trace quantities of uranium and other potentially hazardous wastes that otherwise might be released to the atmosphere or leached from a disposal site. However, until some substantial cost is assigned to the release of these materials to the environment, or cleanup is mandated, no economic driving force will support the development of such processes.

Baria, D.N., W.R. Kube, and L.E. Paulson. "Conceptual Design of a Commercial Plant for Sodium Removal from Lignite," January 1980.

28. Float/Sink Tests

Contractor: GFETC

Sponsor: DOE

Studies were performed on Northern Great Plains lignite to determine the feasibility of ash, sodium, and sulfur removal by washing and float/sink methods. It was demonstrated that 15 percent of the ash and 30 percent of the sulfur (in the pyritic form) could be removed. Because most of the sodium is bound in the coal matrix, it was not reduced significantly. A Texas lignite and New Mexico subbituminous coal were included in similar investigations.

Paulson, L.E., W. Beckering, and W.W. Fowkes. "Separation and Identification of Minerals from Northern Great Plains Province Lignite," Fuel, Vol. 51, July 1972, pp. 224-227.

29. Pelletizing at Pittsburgh Mining Technology Center

Designer: Pittsburgh Mining Technology Center

Sponsor: DOE

This ongoing experimental effort has produced pellets from a North Dakota lignite. The mechanical properties of the lignite pellets are enhanced when the moisture content is maintained at maximum possible levels. It was also learned that in addition to pelletizing, lignite can be agglomerated by briquetting and by extrusion.

The second phase of the study, currently underway, is confirming the laboratory results on successively larger scale pelletizing equipment. Based on pilot work, a 4000 TPD lignite pellet plant will be designed.

Goksel, M.A., and L. Valentyik. Production and Evaluation of Lignite Pellets, presented at the Institute of Briquetting and Agglomeration 16th Biennial Conference at San Diego, California, August 6-8, 1979.

Grant, A.J., and R.E. McKeever. Pelletizing and Drying of Lignite, presented at "Coal Technology '78," Houston, Texas, October 1978.

30. Firing of Iron-Ore Pelletizing Furnace with Low-Btu Producer Gas

Contractor:	Department of Interior, Bureau of Mines
Sponsor:	DOE
Period of Contract:	5/5/77 - 3/1/81

The program consists of six tests of about 120 hr each (5 days around-the-clock) with an extra 120 hr provided in the first test for gasifier shakedown. Actual pelletmaking is being tried with gas generated by gasifying a bituminous coal from Eastern Kentucky, subbituminous coals from Colorado/Wyoming and Montana, and a lignite from North Dakota. Approximately 100 to 150 t of raw coal are processed in each test. Pellets are made from commercial magnetic taconite concentrates and will be processed at rates of about 0.5 t/hr in a 34-in.-diameter by 34-ft-long rotary kiln. The test program is based on the assumption that the Wellman-Galusha producer will gasify bituminous, subbituminous, and lignite coals under reasonably stable conditions and produce gases typical of atmospheric producers for these fuels; however, this producer was designed originally for tarfree coke and anthracite and it is expected that some modifications will have to be made for it to operate successfully with this wide range of fuels.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

31. Determination of Self-Heating Properties of Western Coal

Contractor:	National Bureau of Standards
Sponsor:	DOE
Period of Contract:	6/30/76 - present

The major objective of this study is to develop an understanding for both chemical and physical parameters influencing the spontaneous combustion of coal. New and existing experimental techniques will be applied to the detection and measurement of spontaneous combustion at its early stages so as to derive a measure of the relative susceptibility of low-rank Western coal to thermal ignition.

Testing has begun to determine the effect of moisture, particle size, sample size, and geometry on the spontaneous ignition process in Western low-rank coals. Current work includes the completion of electronics for the adiabatic furnace and measurements of spontaneous heating of 20 coal samples. Resultant ignition energetics will be correlated with ultimate and proximate sample analyses.

Reference same as above.

32. Know Your Material - How to Predict and Use the Properties of Bulk Solids

Principal Investigator: J.R. Johnson

Sponsor: National Coal Board

Journal: Chemical Engineering Deskbook Issue, Vol. 85. No. 24, October 1978

This article on the flow properties of bulk solids includes a discussion of the behaviour of coal reclaimed from a frozen stockpile, the problems caused by partial melting and subsequent re-freezing of ice during coal handling, and the behaviour of coal with various additives.

Abstracts A: Technical Coal Press, National Coal Board, Technical Intelligence Branch House, Harrow, January 1979.

B.4 CONVENTIONAL COMBUSTION

33. Laminar-Flame Combustion/Ash-Fouling Studies of Low-Rank Western Coals

Contractor: Midwest Research Institute

Sponsor: DOE

Period of Contract: 9/1/77 - continuing

This program will provide the first detailed documentation of the combustion and ash-formation processes in low-rank Western coal flames. The aims of the program are to verify that the low-rank coals can be burned in the laminar-flame test system, collect samples of particulates from these flames at various distances above the burner, measure the temperature profile during sampling, and provide representative particulate samples to GFETC for analysis.

The first tests at the Midwestern Research Institute (MRI) were conducted with pulverized lignite from North Dakota. The ash particles from the lignite showed significant visible differences in the pockmarked appearance compared to the smooth, spherical ash shapes obtained from Eastern coals. Further testing is in progress using a subbituminous coal from Montana.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

34. Continuous Nuclear Analysis of Coal (CONAC)

Sponsor: EPRI

CONAC is a method which blends the principles of nuclear physics with the practicalities of coal technology. This new apparatus for coal analysis will be available in prototype form for full-scale utility tests by late 1980. CONAC is expected to play a major role in the efficient use of coal resources, while meeting increasing environmental constraints.

"Reading the Composition of Coal," EPRI Journal, July/August 1980, pp. 6-11.

35. Fuel and Combustion Additives for Boilers

Contractors: Battelle, Columbus Laboratories

Sponsor: EPRI

The objective of this project is to provide utilities with a guide to enable them to decide whether a specific fuel-related problem might be alleviated by use of an additive. The study will: (1) assemble existing knowledge of the more important chemical and physical effects of substances used in fuel and combustion additives (magnesium, calcium, ammonium, iron copper, and managanese); and (2) relate predicted and observed additive effects on combustion, deposition, corrosion, and emissions to their chemical composition, physical form, and method of application.

EPRI, Research and Development Projects, November 1, 1979.

36. Use of Additives to Improve the Slagging, Fouling, and Corrosive Characteristics of Fossil Fuels

Contractor: Battelle, Columbus Laboratories

Sponsor: EPRI

The objective of this project is to perform laboratory and field testing to quantitatively evaluate and demonstrate the effectiveness of additives in combatting slagging, fouling, and fireside corrosion associated with utility boilers firing fossil fuels. Two studies planned are: (1) to provide the theoretical and operational evidence for the selection of magnesium and maganese-containing additives to reduce high-temperature fouling and corrosion in oil-fired boilers; and (2) to develop improved techniques of boiler cleaning by using additives in combination with modified on-load cleaning procedures.

Reference same as above.

37. Control of Ash Fouling

Contractor: GFETC

Sponsor: DOE

Period of Contract: 1976 - continuing

This project is developing methods for control of ash fouling on boiler heat transfer surfaces from combustion of lignite and Western subbituminous coals. Reduced boiler efficiency and availability resulting from ash fouling has been the greatest single problem facing utilities burning low-rank Western coals, particularly those containing appreciable sodium in the ash. This project evaluates the effects of coal characteristics and boiler operating conditions on the severity of fouling.

The tests to evaluate the effects of coal cleaning were performed on samples of New Mexico subbituminous coal and Texas lignite. Basic research employing mineral separation, X-ray diffraction, and microscopic examination was performed to characterize minerals and their spacial distribution in selected samples of North Dakota lignite and Montana and Wyoming subbituminous coals.

Pilot plant tests are being performed to evaluate a blending program using coals from four sources - three in New Mexico and one in Utah. Other tests include high-sodium subbituminous coals and cleaned versus raw Alabama lignite.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

38. Design of Improved Alloys for Coal-Fired Boiler Superheater and Reheater Tubes

Contractors: Foster Wheeler Energy Corporation and International Nickel Company

Sponsor: EPRI

This project is designed to develop alloys and coatings with superior resistance to fireside corrosion and steamside exfoliation of scale for reheater and superheater tubing in coal-fired boilers. Exfoliation of scale in reheaters and superheaters, leading to erosion in high-pressure turbines, has been identified as a major maintenance problem. Fireside corrosion resulting from the formation of molten slag deposits is the major factor in limiting steam temperatures to 100°F, it is also a problem in the superheater and reheater when corrosive coals are used. The project is now focusing on a chromate conversion coating to reduce steamside exfoliation.

EPRI, Research and Development Projects, November 1, 1979.

39. Comparative Analysis of Alternative Direct Coal-Fired Utility Systems

Contractors: See Below

Sponsor: EPRI

This project provides for engineering and economic evaluations of developing technologies, such as advanced coal preparation, stack gas scrubbing, and fluidized bed combustion, in order to plan for the integration of these technologies into utility systems. Results will also aid in planning R&D efforts to assure that these technologies are operable in utility systems. Evaluation studies include: (1) Evaluation of a Gulf Coast Lignite AFBC Power Plant, by Burns and Roe; (2) Evaluation of Combined Coal Cleaning FGD Systems for SO_2 Control, by Bechtel/Dravo; (3) Economic Evaluation of Wellman Lord, Chiyoda, and Concurrent Scrubbing Processes, by Stearns-Roger; (4) Preliminary Feasibility Study of Coal Water Slurry Systems for Oil Design Power plants, by Combustion Processes, Inc; (5) Increased NO_x Control Requirements for Utilities, Resulting from the 1977 Clean Air Act Amendments by Flow Resources; (6) Economic Evaluation of Atomics International Open-Loop Aqueous Carbonate Process, by TVA; (7) Impact of Solid Waste Resource Recovery Design on Refuse Fuel Quality, by Cal Recovery Systems; (8) Study of Future Environmental Regulations, by Radian; (9) Economic and Design Factors for FGD Technology, by Bechtel; and (10) Compendium of Precipitator Plate Rapping and Reentrainment Studies, by Joy Manufacturing.

Reference same as above.

40. Engineering Assessment of an Advanced Pulverized Coal Power Plant

Contractors: General Electric Company and Westinghouse Electric Corporation

Sponsor: EPRI

The project objective is to quantify performance improvements and associated costs for advanced pulverized coal technology. Relationships among steam and water conditions, costs, part-load performance, reliability, and operability will be determined. Hardware development required to accomplish a low heat rate design will be defined. Anticipated environmental constraints will be factored into the systems study to assure the consideration of all relevant trade-offs.

Reference same as above.

41. Combustion Processes in a Pulverized Coal Combustor

Contractor: Brigham Young University

Sponsor: EPRI

The objectives of this project are: (1) to conduct an experimental investigation of pulverized coal combustion processes to determine optimum operating conditions; (2) to obtain detailed maps of gas and particle profile data of composition inside the combustor for a family of coal types; and (3) to develop a generalized, two-dimensional model for predicting pulverized coal combustion performance, comparing the results with laboratory profile measurements and applying the code to a series of industrial combustors.

Reference same as above.

42. Influence of Mineral Matter of Coal on Fireside Slagging and Fouling of Utility Boilers

Contractors: Battelle, Columbus Laboratories

Sponsor: EPRI

Ash buildup on boiler walls and tubes can interfere with boiler capacity. The objective of this research project is to determine which minerals in coal are the cause of ash deposition in boilers. The work will consist of laboratory analysis of five coals to identify types and amounts of minerals present in each coal and tests of five similar boilers to establish the severity of ash deposit problems with one type of coal burned in each boiler.

Reference same as above.

43. Advanced Staged Combustion Configurations for Pulverized Coal

Contractor: University of Arizona

Principal Investigator: J. Wendt (Chemical Engineering)

Sponsor: DOE

This study will entail the development of the advanced staging concept for pulverized coal combustion. Mathematical models will be constructed to describe quantitatively the fate of coal nitrogen under fuel rich and stage combustion conditions. Also included in an assessment of whether modified or staged combustion may have an adverse influence on primary sulfate emissions.

University Contracts Summary Book, Fossil Energy, U.S. Department of Energy, December 1979.

B.5 ENVIRONMENTAL CONTROL TECHNOLOGY FOR CONVENTIONAL COMBUSTION

44. Current Developments in Control Technology

Principal Investigators: K.E. Yeager and C.R. McGowin

Sponsor: EPRI

Emerging air, water and solid waste control requirements at both the national and local level are rapidly becoming the dominant specification in the design and operation of new coal-fired plants. The capital cost for a typical new coal-fired unit beginning design and engineering in 1979, is for example, about $800/kW. About 40 percent of this investment is directed to environmental control requirements. Potentially more stringent requirements planned within the next 5 years are expected to increase this cost to $1000 to $1,400/kW, of which 50-60 percent will be for environmental control. The technology to meet these requirements is expected to increase busbar energy costs to at least 5-7 cents/kWh.

Comparative cost analyses are performed in this study for Illinois bituminous versus Wyoming subbituminous coal-fired plants.

McGowin, C.R. and K.E. Yeager. Current Developments in Control Technology, Electric Power Research Institute, for presentation at the Conference on Clean Coal Utilization, MIT, Cambridge, Massachusetts, June 14, 1979.

45. Laboratory Evaluation of Dry Alkalis for Removing SO_2 from Boiler Flue Gases

Contractor: KVB Engineering, Inc.

Sponsor: EPRI

This project is a bench-scale study of dry SO_2 scrubbing processes utilizing alkali compounds. The primary objectives are to investigate the technical feasibility, define the range of operating parameters, and provide a basis for preparing process and equipment specifications. The effect of sorbent type, resident time, temperature, particle size, stoichiometric ratio on SO_2 removal efficiency and sorbent utilization will be evaluated. Testing for Phase I and II is completed.

EPRI, Research and Development Projects, November 1, 1979.

46. Integrated Environmental Control

Contractors: Public Service Company of Colorado and EPRI

Sponsor: EPRI

EPRI has initiated a project to construct a 2.5-MW pilot facility to assess the integration of air, water, and solid-waste technologies for pulverized-coal-fired power plants. The test facility is being built at the Arapahoe Station of Public Service Co. of Colorado. Using their experience in precipitators and scrubbers, compliance with State and Federal standards requires a series of applications with control devices which have a compound negative effect on unit availability, heat rate, rate of load exchange, and other plant operations. The control equipment is considered an integral part of the power generation system, thereby reducing these adverse effects and lowering costs.

Balzhiser, R.E. R&D Status Report: Fossil Fuel and Advances Systems Division, EPRI Journal, May 1979, pp. 43-46.

47. Sulfur Dioxide Control For Combustion of Low-Rank Coals

Contractor: GFETC

Sponsor: DOE

Period of Contract: 10/1/76 - continuing

This project is designed to investigate alternative methods for control of SO_x/NO_x emissions from the combustion of low-rank coals. Although most low-rank coals are low in sulfur content, few can be used without sulfur oxide emission control under the present Federal New Source Performance Standards (NSPS). Pending revision in the NSPS will require sulfur control for all low-rank coals. The studies on SO_x control at GFETC are concerned with: wet scrubbing using alkaline ash as a reagent; dry absorbents for removal of SO_x; studies on the sulfur forms and the physical dispersion of the sulfur in low-rank coals; and physical and chemical properties of sludge.

The pilot plant scrubber is being used to survey SO_2 removal efficiencies and scaling rates for a wide variety of low-rank coals fly ashes. Materials under investigation are spent-bed substances produced by FBC of low-rank coals, raw and chemically treated scrubber sludge, and spent dry-sorbent materials.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

48. Evaluation of Fine Particulate/Trace Element Fractional Efficiency of Electrostatic Precipitators (ESP)

Contractors: Meteorology Research, Inc. and LFE Environmental Analysis Laboratories

Sponsor: EPRI

This project is designed to produce the first complete characterization of ESP fractional efficiency and trace element enrichment factors over the 0.02-20 micron size range. The economic and maintenance aspects of each unit will also be evaluated. The ESPs selected are state-of-the-art high-SCA installations. The first phases will be performed on a hot and cold side ESP handling low sulfur Western coal fly ash. The establishment of particulate emission standards based on particle size and composition rather than total mass is becoming more imminent as recognition of the fact that submicron particles are those that constitute the major impact to health.

EPRI, Research and Development Projects, November 1, 1979.

49. Advanced Particulate Control and Test Facility

Contractors: Air Pollution Systems, Kaiser Engineers, Joy Mfg. Company, Apitron, Inc., and Public Service of Colorado

Sponsor: EPRI

This 21 month project has established a testing facility at the Public Service of Colorado comprising one 35,000 cu ft/min and two 10,000 cu ft/min slipstreams and permanent pilot plants for testing advanced electrostatic precipitator (ESP) and fabric filter designs and concepts. EPRI's aim is to substantially reduce the size and cost of precipitator and fabric filtration technology and to increase reliability. Temperature range is ambient to 750°F. A laboratory/support/control building has been completed in which data is acquired and reduced in real time. Testing has begun on the High Intensity Ionizer and the Apitron and Ducon filters.

EPRI, Research and Development Projects, February 7, 1980.

50. Removal of Fly Ash From Stack Gases by Electrostatic Precipitation

Contractor: GFETC

Sponsor: DOE

Period of contract: 10/1/76 - present

This project was established to develop a reliable basis for designing and sizing electrostatic precipitators (ESPs) for high-resistivity Western coals, based on data that can be obtained from laboratory procedures performed on relatively small samples of coal. New methods of fly ash conditioning will also be investigated to improve ESP efficiency. A future objective is to measure, characterize, and develop control measures for fine particulate generated during the combustion of lignites and subbituminous coals. These coals contain atomically dispersed alkali cations that can react with the coal sulfur during combustion to form very fine sulfate particulate in the fly ash.

Pilot ESP performance data and in situ resistivities are being obtained for a variety of coals. Testing is being performed with blends of New Mexico and Utah subbituminous coals, raw and cleaned Colorado subbituminous coal, and selected samples giving high-, moderate-, and low--temperature ESP operation.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

51. Evaluation of a Fabric Filter on a Pulverized Coal (PC) Fired Boiler

Contractor: Nebraska Public Power District

Sponsor: EPRI

The objective is to perform a complete particulate and engineering evaluation of the fabric filter (baghouse) on the 40 MW Kramer Unit P-C boiler of the Nebraska Public Power District. The unit burns a subbituminous coal from Wyoming and Colorado. This baghouse is well suited to evaluation since it represents a state-of-the-art conservative design with low air-to-cloth ratio. Important results will include overall and fractional collection efficiency as a function of air-to-cloth ratio, trace element fractional efficiency, stack opacity, and an engineering-economic analysis of the installation.

EPRI, Research and Development Projects, November 1, 1979.

52. Fabric Filter Pilot Development and Optimization

Contractor: Kaiser Engineers

Sponsor: EPRI

The objective is to define the optimum major design and operating criteria for fabric filters (baghouses) and to identify any possible improvements. The project involves the design, fabrication, and installation of a flexible, state-of-the-art, full-scale fabric filter test module at the Advanced Particulate Test Facility. Experiments will be performed to determine optimum cost-effective conditions for fine particulate and trace element control and the elimination of visible plumes for coal-fired utility boilers.

Reference same as above.

53. Reliability Assessment of Particulate Control Systems

Contractor: Burns & Roe, Inc.

Sponsor: EPRI

The purpose of this project is to identify the causes of reduced reliability of particulate control systems and to propose cost effective solutions. Evaluation will be made of several state-of-the-art systems that are representative of both Western and Eastern coal applications. Information will be compiled into a detailed data base documenting the major factors influencing reliability, with emphasis on separating cause and effect.

Reference same as above.

54. Economics of Dry Flue gas Desulfurization (FGD) - Particulate Removal Systems

Contractor: Bechtel

Sponsor: EPRI

The objectives of this project are to develop conceptual design and capital and operating cost estimates for dry FGD systems and to provide guidelines on the application of these systems for combined SO_2 and particulate emission control. Major emphasis is placed on dry SO_2 removal processes suitable for low sulfur Western coal application. Processes involving dry alkali injection of nahcolite and trona as well as spray dryer using sodium and calcium compounds will be considered. Disposal costs for waste sodium compounds will also be developed.

Reference same as above.

55. Dry SO_2 Control Demonstration

Contractor: See below

Sponsor: See below

This project is a cooperative effort by EPRI and the Public Service Company of Colorado (PSCC) to demonstrate a prototype of the dry SO_2 scrubbing process, first researched under RP982-8. The technique of injecting nahcolite or trona in the flue gas duct and collecting the spent material in a baghouse will be tested under typical operating conditions, and the process will be evaluated for its operability and reliability. The existing 22-MW baghouse at the Cameo Station of PSCC will serve as the demonstration site, and the Multi-Mineral Corporation is expected to supply the nahcolite. Stearns-Roger and KVB are also contractors.

Reference same as above.

56. Utilization of Lignite of Subbituminous Ash

Contractor: University of North Dakota

Principal Investigator: Oscar E. Manz

Sponsor: National Ash Association

"Basic" ash is defined as that ash in which the sum of the CaO and MgO is greater than Fe_2O_3, a characteristics of most Western coals. ASTM acceptance of basic fly ashes for use in portland cement concrete has been a major objective of this organization's research. Work is being directed towards the substitution of cement with basic coal fly ash. The use of fly ash for mineral filler and its dependence on particle size has been under investigation. Application of fly ash and clay mixtures in the production of extruded bricks has also received attention.

Manz, O.E. Utilization of Lignite and Subbituminous Ash

57. Analysis of Metals and Their Chemical States Produced by the Combustion of Texas Lignite

Contractor: Texas A&M University

Principal Investigator: James Carver (Chemistry)

Sponsor: Texas Energy Development Fund

Nuclear pore filters will be used in the stacks of lignite-burning facilities in Texas for collection of the samples. Initially identification of metals present will be made by X-ray fluorescence and atomic absorption. By knowing the identify and concentration of each metal containing species produced in lignite combustion, appropriate measures can be taken to reduce environmental hazards.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

58. Heavy Trace Element Analysis of Coal and Lignite

Contractor: Texas A&M University

Principal Investigator: Rand Watson (Chemistry and Cyclotron Institute)

Sponsor: Texas Energy Development Fund

Trace elements have been identified as an important issue requiring more data to assess the extent to which these elements enter the biosphere. The objective of this project is to utilize modern techniques of X-ray fluorescence analysis to perform detailed and wide-ranging investigations of the heavy trace element composition of Texas coal and lignite. The results of this study will be used to construct a detailed catalogue which will provide a basis for classifying and identifying coal and lignite from various locations around the state.

Reference same as above.

59. Evaluation of Alternative Low-NO_x Furnace Designs

Contractor: KVB, Inc.

Sponsor: EPRI

The objectives of this project are: (1) to verify and characterize the low-NO_x behavior of roof-fired furnace systems and (2) to examine the engineering, economic, and operating implications of applying this technology to large, modern pulverized coal boilers. KVB, Inc. is the contractor, and Wisconsin Electric Power Co. will provide the field test site.

EPRI, Research and Development Projects, November 1, 1979.

60. Low-NO_x Emission Coal Combustor Development

Contractor: Babcock and Wilcox Company

Sponsors: EPRI and Babcock and Wilcox Company

The objective is to define the technical potential for increased NO_x control on coal-fired steam generators, using advanced combustion process modification technology while maintaining acceptable boiler operation and reliability. Work will include: (1) a review of all current research; (2) a series of experiments to evaluate the chemical aspects of fuel nitrogen conversion and control; and (3) the design, testing, and development of a low-NO_x combustion process.

Reference same as above.

61. Laboratory Testing - RESOX

Contractor: Foster Wheeler Energy Corporation

Sponsors: EPRI and Foster Wheeler Energy Corporation

The project objective is to broaden RESOX application to U.S. coals, including bituminous types, and various feed gas compositions through laboratory tests. These tests supplment RESOX tests being done in Lunen, West Germany, on German anthracite coals, as part of another EPRI report. RESOX produces elemental sulfur from sulfur dioxide rich gas streams without using a reducing gas.

Reference same as above.

62. A Laboratory Method to Simulate Utility Boiler Fly Ash

Contractor: The Energy and Environmental Research Corporation

Sponsor: EPRI

The objective of this project is to develop a laboratory method of generating fly ash with the same characteristics as fly ash produced in full-scale, pulverized coal-fired utility boilers; knowing the properties of the fly ash which would be produced by a power plant will lead to improved designs of electrostatic precipitators. A laboratory-scale combustor, firing approximately 5 lbs. of coal per hour, is being constructed to simulate the conditions that affect the fly ash mass loading, mean particle size and distribution, SO_3 concentration, and resistivity.

Reference same as above.

B.6 FLUIDIZED BED COMBUSTION

63. Atmospheric Fluidized Bed Combustion of Low-Rank Coals

Contractor: GFETC

Sponsor: DOE

The GFETC is operating a 2.25 ft^2 atmospheric fluidized bed combustor (AFBC), with a fuel feed rate of 180 lb/hr of lignite. The combustor system has been designed to operate over a wide range of conditions. The data generated from tests on this unit show excellent correlation with data obtained from the earlier, smaller combustor (0.2 ft^2).

Goblirsch, G.M., and E.A. Sondreal. "Low-Rank Coal Atmospheric Fluidized-Bed Combustion Technology," presented at the 1979 Lignite Symposium, May 30-31, 1979, Grand Forks, North Dakota.

64. Atmospheric Fluidized-Bed Bench-Scale Studies

Contractor: MERC

Sponsor: DOE

The Morgantown Energy Technology Center operates two 1.8 ft^2 AFBC's in the their pilot plant. The nominal coal feed rate to the combustor is about 110 lbs/hr. The unit has in-bed and freeboard cooling tubes to control bed and flue gas temperatures. The Morgantown Center has the most AFBC performance data on Texas lignites and coal refuse.

Reference same as above.

65. Industrial Application FBC

Contractor: FluiDyne Engineering Corporation

Sponsor: DOE, FluiDyne

FluiDyne Engineering Corporation of Minneapolis has conducted tests on North Dakota lignite for a private company. They have used an 18-inch square combustor and a 40 x 64-inch combustor (17.8 ft^2). The average feed rate is about 800 lbs/hr, but there are variations with operational conditions. Unlike the others, this is an air-cooled unit, and is therefore well-suited for testing industrial process air requirements. An important feature of the FluiDyne system is its distributor plate, which has been subjected to more than 150 startup-shutdown cycles with no evidence of thermal deformation.

Reference same as above.

66. Lignite FBC

Contractor: Combustion Power Corporation

Sponsor: GFETC/DOE

The Combustion Power Company, Inc. of Menlo Park, California, is performing tests using a combustor which has a bed surface area of 7.1 ft^2. A Beulah, North Dakota, lignite is fed at a rate of 500 lbs/hr. Vertical cooling tubes have been installed in the combustor for the lignite test program.

Reference same as above.

67. Preliminary Evaluation of Fluidized Bed Combustion Concepts and Design Criteria

Contractors: Combustion Engineering, Foster Wheeler, Radian Corporation, and Westinghouse Corporation

Sponsor: EPRI

This project provides for experimental and engineering studies on specific FBC concepts and design criteria. The purpose is to supplement and expedite major FBC projects. Areas anticipated for study are: improved sorbent utilization, gas-solid cleanup, and materials evaluation. Westinghouse Electric Corporation is studying sorbent requirements for a Gulf Coast lignite AFBC power plant. Combustion Engineering and Foster Wheeler are analyzing the results developed under an earlier contract. Radian Corporation is developing advanced concepts for AFBC gas sampling and analysis.

EPRI, Research and Development Projects, November 1, 1979.

68. Analysis of Sulfur Removal by Natural Sorbents in Texas Lignite Ash During Fluidized Bed Combustion

Contractor: University of Texas at Austin

Principal Investigator: T.F. Edgar

Sponsors: Texas Energy Development Fund and the University of Texas at Austin

Little is known about the amount of sulfur oxides produced during combustion of Texas lignite over a wide range of operating temperatures and coal compositions. A better determination of the SO_2 emissions is required to quantify the costs of SO_2 control and the materials requirement (mainly dolomite) for FBC. The goal of this project is to provide combustion data under carefully controlled experimental conditions so that such data can be analyzed for trends and the effects of coal composition and bed operating variables.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-Five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

69. Pressurized Fluidized Bed Combustion Systems Analysis

Contractor: Burns & Roe

Sponsor: EPRI

The purpose of this project is to perform an engineering and economic evaluation of three combined cycle FBC power plants, identifying potential market penetration and development needs. The three concepts will be chosen: from a reference combined cycle FBC, i.e., one of several commercially developed systems; according to the criteria of minimal technological risk, for which the results from projects in materials selection and hot gas cleanup will be used; and from parametric studies evaluating the efficiency and technical feasibility of several advanced, combined cycle, fluidized bed combustors.

EPRI, Research and Development Projects, November 1, 1979.

70. Environmental R&D Needs for Advanced Energy Conversion Technologies

Principal Investigators: W.C. Cain (EPA), C.E. Jahnig, and H. Shaw (Exxon Research and Engineering Company)

Sponsors: U.S. Environmental Protection Agency (EPA) and Exxon Research and Engineering Company

Environmental aspects of advanced energy systems have been analyzed to identify R&D needs so that the necessary work can be planned and accomplished in a time frame consistent with their commercialization.

One of the major conclusions from the study is that advanced steam cycles using pressurized fluid bed combustion (PFBC) as the heat source offer significant economic advantages over all other cycles when particulate removal requirements for turbine protection are relaxed. If very stringent environmental standards are promulgated, then coal-derived low heating value gas (LHVG) fueled combined cycle plants using gas turbines or fuel cells may share the utility market with PFBC steam plants.

Cain, W.C., C.E. Jahnig, and H. Shaw. Environmental R&D Needs for Advanced Energy Conversion Technologies, U.S. Environmental Protection Agency and Exxon Research and Engineering Company, August 1979.

B.7 GASIFICATION

71. Advanced Fluidized-Bed Gasification System

Contractor: Westinghouse Electric Corporation

Sponsors: DOE and Industry

Period of Contract: 8/9/72 - present

The objective is to develop and demonstrate the feasibility of the advanced fluidized-bed gasification process for production of low- and intermediate-Btu gases for a variety of applications including fuel for a combined-cycle or fuel-cell power generation plant, industrial fuel gas, and feedstock for chemical synthesis or SNG production.

Three series of successful tests were conducted with the PDU, concentrating on gasifier reactor design and operation. The second series of tests were conducted with air, steam, and a number of coals fed directly to the gasifier without pretreatment. The coals were Wyoming subbituminous, Indiana, and Pittsburgh. The first two tests resulted in the production of low-Btu gas.

The single-stage, oxygen-blown gasifier and the single-stage, air-blown gasifier evaluation continue using a number of feedstocks. Tasks are being initiated to study heat recovery, desulfurization, controls, particulate collection and recycling, and related systems-oriented issues.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Energy, December 1979.

72. Economic Evaluation of Integrated Retrofit of Boilers and Combined Cycles with Gasifier

Contractor: Contract under negotiation

Sponsor: EPRI

The objective of this project is to develop cost estimates to assess the economic benefit of the integrated retrofit of natural gas fired boilers and oil-fired combined-cycle units, with medium-Btu coal gasification systems. The impact of the choice of O_2-blown gasification technology on the cost of the heat-integrated retrofit option will also be determined.

EPRI, Research and Development Projects, November 1, 1979.

73. Development of a Reliability Prediction Methodology for a Gasification Combined Cycle (GCC) Plant

Contractor: ARINC Research Corporation

Sponsor: EPRI

This project will base its development of a methodology for predicting GCC plant reliability on an analysis of the Texaco-based system. A critical parts list, a failure modes and effects analysis (FMEA), and other methods will be used to evaluate new elements, failure modes and system reliability. Recommendations will be made for methods of improving reliability.

Reference same as above.

74. Exploratory Gasification System Support Studies

Contractor: Contract under negotiation

Sponsor: EPRI

The objective of these exploratory studies is to extend the range of feed coals that can be economically processed and to enhance system performance. Engineering and experimental studies will be designed to aid in the understanding of coal behavior in gasifiers; to improve gasifier performance, particularly for low-rank coals; and to develop components that would improve the performance of gasification-based power systems.

Reference same as above.

75. Purification of the Products of Lignite Gasification

Contractor: Texas A&M University

Principal Investigator: Charles Holland (Chemical Engineering)

Sponsor: Texas Engineering Experiment Station, Industry, and the Center for Energy and Mineral Resources

The fundamental involved in two separation processes for the purification of the gasification products are being investigated. The first process, called COSORB, separated carbon monoxide from carbon dioxide, hydrogen, and hydrogen sulfide at ordinary temperatures and pressures. The second process, called MEA (monoethanolamine) solvent extraction, permits the separation of carbon dioxide from hydrogen and hydrogen sulfide.

76. Low-Btu Gas to Power Turbines and Diesel Engines

Contractor:	Texas A&M University
Principal Investigators:	G. Hopkins, M. Boyce, T. Lalk (Mechanical Engineering) and W. Heffington (Engineering Design Graphics)
Sponsors:	Texas Engineering Experiment Station and the Center for Energy and Mineral Resources

It is not economical to pipe gasified lignite because of the low energy content per unit volume. Therefore, this gas should be used at or near the generation site.

The first phase of this project will be directed at determining basic combustion and corrosive characteristics of the gas by burning actual or synthetic gas (with the same composition) in a special combustion facility constructed for this purpose.

If it is concluded from the test results that it is feasible (technologically, economically and environmentally) to use gas turbines and diesel engines for power production from low-Btu gas, additional research efforts aimed at solving these problems will be identified.

Reference same as above.

77. Mechanistic Coal Hydrogenation Studies with Radioactive Tracer

Contractor:	Texas A&M University
Principal Investigator:	Yi-Noo Tang (Chemistry)
Sponsor:	Texas Energy Development Fund

Employing radio-gas chromatographic techniques, the role of hydrogen in the hydrogasification of coal will be investigated. Mechanistic studies of catalyzed coal hydrogasification will also be performed to reveal whether the carbon atom in the catalyst has been exchanged during the reaction.

Reference same as above.

78. The High Temperature Winkler (HTW) Process

Contractor: Rheinische Braunkohlenwerke AG (Rheinbraun)

Sponsor: Federal Minister for Research and Technology

The purpose of this study is to operate a fluidized bed at higher pressures and temperatures than have been considered for comparable types of coal in a Winkler-type gasifier.

The use of low-rank coals in the HTW system may require special attention due to possibly lower ash fusion temperatures. Although this is also a consideration for other coals, low-rank coals may require especially high additions of refractory agents such as limestone. Additional problems with low-rank coals due to higher temperature and pressure operations are not anticipated.

Franke, F.H., E. Pattas, and W. Adlhoch. First Experimental Results on Operation of the High Temperature Winkler Process in a Semi Technical Plant, presented at the Tenth Biennial Lignite Symposium, Grand Forks, North Dakota, May 30-31, 1979.

79. Economics of Current and Advanced Gasification Processes

Contractor: Fluor Engineers and Constructors, Inc.

Sponsor: EPRI

This project with Fluor Engineers and Constructors, Inc., provides for preliminary engineering and economic evaluations of a variety of coal gasification processes (Report No. EPRI 239-1, January 1975) and of the use of these processes for production of low- or intermediate-Btu fuel gas (Reports No. AF244, July 1976 and No. AF782, May 1978) and for integrated gasification-combined cycle (GCC) power generation (Reports No. AF642, January 1978; No. AF753, April 1978; and No. AF930, October 1978). A study has been completed of the effect of stringent sulfur removal requirements on the cost of a Texaco based GCC plant (Report No. AF916, October 1978). Ongoing economic studies include: evaluations of molten carbonate fuel cell CC systems, using a Texaco or BGC/Lurgi gasifier; comparisons of Texaco and Lurgi based STEAG CC systems with a Texaco based GCC, which contains a conventional 1980°F gas turbine; cost estimates for methanol coproduction in a Texaco based GCC plant; and updating all previous economic studies to mid-1978 dollars.

EPRI, Research and Development Projects, November 1, 1979.

80. Fast Fluid Bed Process

Contractor: Hydrocarbon Research Inc.

Sponsor: DOE

In this process, -20 mesh coal is fed into the lower section of the gasifier. The incoming coal is mixed with char feed from a comparison slow-bed gasifier at a rate of ten parts char to one part feed coal.

An operating temperature of 1700°F has been applied for an Eastern bituminous coal feed. These temperatures will be increased with a variety of coals. The higher reactivity fo low-rank coals makes their use desirable in this process. The low ash fusion point of low-rank coals may limit the reaction temperature when these coals are gasified.

Fossil Energy Program Summary Document, U.S. Department of Energy, Document No. DOE/ET-0087, March 1979.

81. Coal Gasification Systems Analysis

Contractors: See Below

Sponsor: EPRI

This project provides for engineering and economic assessments of various gasification concepts and of the performance of novel power cycles integrated with gasification systems. A preliminary engineering design and cost estimate for the construction of a 100-MW Texaco-based gasification-combined-cycle power plant at Southern California Edison Company's cool water site was performed by the Ralph M. Parsons Company; Final Report No. AF880, August 1978. The performance potential of novel power cycles, e.g., nonsteam bottomed cycles, integrated with gasification plants has been evaluated by United Technologies, Westinghouse Electric Corporation, and General Electric Company. Results are given in Final Report No. AF992, February 1979, and Final Report No. AF1160, April 1979. The effects of the system configuration on the performance of gasification-combined-cyle power plants are now being determined.

Reference same as above.

82. Coal Gasification: Duluth Campus Heating Plant

Contractor: University of Minnesota

Principal Investigator: Warren Soderberg

Sponsor: DOE

This project entails an investigation of a state-of-the-art gasification system with the heating plant on the University campus. Using Wyoming coal, full- and partial-load performance tests are conducted on the gasifier and boiler operation. Short duration tests are performed on alternate subbituminous coals and lignite.

University Contracts Summary Book, Fossil Energy, U.S. Department of Energy, December 1979.

83. HYGAS

Contractors: Institute of Gas Technology and Procon, Inc.

Sponsor: DOE

The HYGAS process was developed by the Institute of Gas Technology in the late 1960's under American Gas Association and Office of Coal Research sponsorship. A pilot plant operation of a 75 TPD system began in 1974 and is presently in operation. The HYGAS process is one of three selected for the design of a high BTU gas demonstration plant sponsored by DOE.

A conceptual design for a commercial scale demonstration is now being completed by Procon, Inc. for construction consideration. The HYGAS process has the advantage of having been tested with a variety of coals, from lignite to subbituminous to bituminous coals. The use of low-rank coals may prove to be advantageous in the HYGAS process. Their higher reactivity may reduce the amount of carbon lost in the ash withdrawal stream. However, the tendency for dried low-rank coals to reabsorb moisture may limit solids content in slurry line.

Hartman, H.F., et al. Low-Btu Coal Gasification Processes, Volume 2, Selected Process Descriptions, ORNL/ENG/TM-13V2, November 1978.

84. Slagging Fixed-Bed Gasification

Contractor: Grand Forks Energy Technology center

Sponsor: DOE

Period of Contract: 10/1/76 - present

The major objectives of this project are to test a selection of both low-rank Western coals and agglomerating Eastern bituminous coals to determine differences in operating characteristics, product yield, and effluent analysis; to develop a detailed environmental assessment of the slagging fixed-bed gasification process, including characterization of both gaseous and liquid effluents; to test scaleable process simulations for treatment of tar-water effluents; to determine operating limitations on moisture and particle size for the coal feed; and to provide a source of coal-specific gasifier products and wastes for experiments on use or disposal.

The GFETC slagging fixed-bed gasifier is the only operable unit of its type in the United States. Recent objectives have been based on the existing short-duration test capability on nonagglomerating low-rank coals. Four different coals have been tested. Successful runs were achieved on two lignites, including one test of 25-hr duration. Limited success was achieved on a subbituminous coal. Slagging operation was established on a high-moisture content (40+ percent) lignite, but could not be maintained because of the excessive heat loss required to evaporate the moisture.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

85. Evaluation of Environmental Controls for Coal Conversion Processes

Contractor: Oak Ridge National Laboratory

Sponsor: DOE

Period of Contract: 7/1/77 - continuing

Work in this program was limited to low-Btu coal gasification processes. Technical evaluations and cost estimates for 25 selected environmental control processes were made, and economic evaluations of eight conceptual low-Btu gasification plants were performed. The eight conceptual plants were selected on the basis of the following parameters: four coals from significant coal regions of the United States - West Virgina (hvA bituminous), Illinois (hvC bituminous), Wyoming (subbituminous), and Texas (lignite); four representative gasifiers - Wellman-Galusha, Lurgi (dry-ash bottom), U-Gas, and Babcock & Wilcox; four nominal plant capacities: 200, 2000, 5000, and 10,000 t/day; and four possible plant locations: Chicago, Houston, Pittsburgh, and Salt Lake City.

A similar evaluation of the application of potential environmental control processes for coal liquefaction plants is proposed. Such an evaluation should yield the costs/benefits of providing the necessary environmental control processes to produce clean liquids from coal in an environmentally acceptable manner.

Reference same as above.

86. U-Gas (Ash Agglomerating Gasifier)

Contractor: Institute of Gas Technology

Sponsors: American Gas Association and the Office of Coal Research

The U-Gas gasifier is not commercially available, however a demonstration-plant program is underway to establish the technical and economic feasibility of the process. Some uncertainty still exists concerning the viability of the full scale unit, since complete sets of pilot plant data are not yet available.

Highly reactive low-rank coals may be more desirable than others, because of the tendency to produce unreacted carbon. Because low-rank coals do not display caking characteristics, pretreatment will not be required. While the high moisture of these coals may affect the flow of crushed coal in freezing weather, it will not be detrimental to gasifier operation.

Patel, J.G. and D. Leppin. The U-Gas Process, presented at the Sixth Annual International Conference on Coal Gasification, Liquefaction and Conversion to Electricity at the University of Pittsburgh, July 31-August 2, 1979.

87. Wellman-Galusha Gasifier

Contractor: DOE Morgantown Energy Technology Center (METC)

Sponsor: DOE

The METC is performing a pilot plant test program with a Wellman-Galusha gasifier. The Wellman-Galusha coal gasification process was first used commercially in Germany in 1941 and is currently licensed by the McDowell-Wellman Engineering Company of Cleveland, Ohio.

A tar combustor and novel wastewater evaporator are being added during 1980. This gasifier has a high fuel inventory due to the fixed bed design providing for greater safety and a high turndown ratio.

Low-rank coals have some characteristics which may affect their performance in the Wellman-Galusha gasifier. The high moisture level in some low-rank coals could cause problems in handling crushed coal, reducing the temperature of the gasifier effluent. Temperature control and additional steam injection may be required for those coals having ashes with lowering softening points.

Solid Fuels for U.S. Industry, Volume II, Coal Resource, Transportation Technology by Cameron Engineers, February 1979.

88. Entrained Flow, Atmospheric Pressure Gasifier

Contractor: Combustion Engineering, Inc.

Sponsor: Office of Coal Research

Combustion Engineering, Inc. proposes an entrained flow, atmospheric pressure gasifier to produce low-Btu gas for electric power generation. Conceptual design studies were initiated in 1972 to develop a gasifier, the design of which was funded in 1974 by the Office of Coal Research to be part of a 120 TPD pilot plant. The pilot plant was completed in December 1977, and is now in operation.

The higher reactivity of low-rank coals may be an important factor in attaining high single pass carbon conversions, limiting the amount of char recycle required. Because pulverized coal is the required form of coal feed, the fines produced in operation with low-rank coals do not present a problem.

Hartman, H.F., et al. Low-Btu Coal Gasification Processes, Volume 2, Selected Process Descriptions, ORNL/ENG/TM-13V2, November 1978.

89. Dilute-Phase Hydrogasification Process

Contractor: Pittsburgh Energy Technology Center

Sponsor: DOE

Period of Contract: 1968 - present

Primary experimental efforts were made in parametric tests using lignite and subbituminous coal to determine optimum test conditions and provide a design data base for process analysis. Operation with both lignite and subbituminous coal at 500 psig resulted in an 18 percent decrease in carbon conversion when compared to 1000 psig tests. In experiments where hydrogen/coal ratio was varied at constant coal-feed rate, both conversion and methane yield varied directly with hydrogen/coal ratio for both test coals. The variation of carbon conversion with hydrogen/coal ratio was nearly the same for lignite and subbituminous coal; however, methane yield showed a greater variation with hydrogen/coal ratio for lignite than for subbituminous coal. Data were obtained in a contracted study on the gasification rates for chars from lignite and Illinois No. 6 coal in stream, steam/hydrogen, and steam/hydrogen/carbon dioxide/carbon monoxide gas mixtures. At nearly all test conditions, lignite char gasified at a faster rate than Illinois No. 6 char.

Studies continue with operation of the 10 to 50 lb/hr hydrogasifier to obtain reactor design data using both caking (Illinois No. 6 coal) and noncaking (North Dakota lignite) feedstock.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

90. Exxon Catalytic Gasification

Contractor: Exxon Research and Engineering Company

Sponsor: DOE

Since 1968, the Exxon Research and Engineering Company has been developing the Catalytic Coal Gasification process to substitute natural gas. The process is still in a developmental state. Technically and economically, adequate catalyst recovery must still be achieved. The chemical composition of low-rank coal ash may have a different effect on catalyst activity or recovery than that associated with higher rank coals. Higher ash contents present in some low-rank coals may increase the difficulty of catalyst recovery because of the higher volume of inert material requiring processing.

Gallagher, J.E. and C.A. Euker, Jr. Catalytic Coal Gasification for SNG Manufacture presented at the Sixth Annual International Conference on Coal Gasification, Liquefaction and Conversion to Electricity, at the University of Pittsburgh, July 31-August 2, 1979.

B.8 LIQUEFACTION

91. Exxon Donor Solvent Coal Liquefaction Process

Contractor: Exxon Research and Engineering Company

Sponsors: DOE, The Carter Oil Company, Electric Power Research Institute, Japan Coal Liquefaction Development Company, Phillips Petroleum Company, Atlantic Richfield Company, Ruhrkohle, A.G.

Period of Contract: 1/1/76 - 12/31/82

The Exxon Donor Solvent (EDS) coal liquefaction process produces distillate fuels from a wide range of coals. Successful process development represents a major contribution to the emerging coal liquefaction technology and is based on laboratory and engineering R&D efforts integrated with the operation of a 250 t/d coal liquefaction pilot plant.

Efforts verified that the EDS process can be applied to a wide variety of coal types including bituminous, subbituminous, and lignites. The younger subbituminous coals and lignites were found to be more difficult to process. The bituminous coals give total liquid yields (from liquefaction and Flexicoking) in the 43 to 45 percent range, the subbituminous coal about 40 percent, and the lignites 33 to 36 percent. Yields have potential for being increased using process improvements under investigation. The difficulty of processing younger coals is reflected in the viscosities of coal liquefaction bottoms derived from the various coals. The viscosities of the bottoms from the younger coals were found to be higher than from bituminous coals. Generally, these higher viscosities can be reduced with somewhat longer liquefaction reactor residence times under typical EDS conditions. The high calcium content of the younger coals has led to the formation and deposition of calcium carbonate in the liquefaction reactor in the form of wall scale and oolites, which were first observed in German operations. Methods for effective control of these deposits in the liquefaction system were investigated. One method of control is to use solids withdrawal from the liquefaction reactor coupled with strainers upstream of critical equipment. In addition, reactor cleaning by chemical means during normal reactor turnarounds would be used to ensure the required onstream time. This concept for calcium carbonate control is to be demonstrated in the 250 t/d pilot plant during operations on a subbituminous coal. Another method of calcium carbonate control is pretreatment of coal with SO_2 to render the calcium innocuous as calcium sulfate. The mechanical method of controlled scaling is the preferred method because of its simplicity and more favorable economics, but SO_2 treatment is a viable alternative if needed.

Functional plans providing a means with which to gauge project accomplishments and stewardship have been formulated, and include a Wyoming coal study design, to be completed by FY 1980.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

92. H-Coal

Owner/Designer:	Ashland Oil Co. & Hydrocarbon Research Inc.
Construction:	Badger Plants
Sponsors:	DOE, EPRI, Ashland Oil Inc., Standard Oil of Indiana, Conoco Development Co., Commonwealth of Kentucky
Years Operation:	H-Coal Project began in 1965; pilot plant construction began in 1977

The H-Oil Process was originally developed by Hydrocarbon Research Inc. (HRI) to convert heavy oil residues to lighter fractions. H-Coal, an extension of the H-Oil Technology, is a catalytic hydroliquefaction process which converts coal to either a boiler fuel or a refinery syncrude.

The DOE H-Coal pilot plant is scheduled for start up in 1980. Although the reaction temperature is similar, the reaction pressure is notably higher for subbituminous versus bituminous coal. Yields of CO_2 and H_2O are also higher for the low-rank coal, due to the higher initial moisture content of the feedstock.

International Coal Technology Summary Document, prepared by the U.S. Department of Energy with the assistance of TRW Energy System Planning Division, December 1978.

93. The Relation of Coal Characteristics to Liquefaction Behavior

Contractor:	Pennsylvania State University
Principal Investigator:	P.H. Given
Sponsor:	DOE

The objective of this study is to predict differences in yields, compositions, and other properties of liquefaction products from laboratory characterization of coal feedstocks. One of the seven phases is to evaluate those properties of low-rank coals which determine their behavior in liquefaction. The mechanisms of hydrogen transfer from a donor solvent to coal will be defined in order to provide scientific bases for the empirical correlations.

University Contracts Summary Book, Fossil Energy, U.S. Department of Energy, December 1979.

94. Coal Liquefaction Research

Contractor: University of California, Berkeley

Principal Investigator: H. Heineman (Materials and Molecular Research)

Sponsor: DOE

This project involves an investigation of methods which would simplify the upgrading of coal liquids, by eliminating complex equipment and reducing hydrogen consumption. The hydrogen transfer between solvent and coal will be studied. The sources of incompatibility between coal liquefaction products and petroleum fractions will be evaluated, so that better blending of these products can take place.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979,

95. Effect of Solvent Characteristics on Wyodak Coal Liquefaction

Contractor: University of Wyoming

Principal Investigators: H. Silver and R. Hurtubise (Chemical Engineering)

Sponsor: DOE

The purpose of this study is to investigate the effect of solvent characteristics on coal conversion, asphaltene formation, and nitrogen removal in hydrogenation of Wyodak coal (A Wyoming subbituminous coal). The liquid products obtained from Wyodak coal hydrogenation will be chemically characterized.

University Contracts Summary Book, Fossil Energy, U.S. Department of Energy, December 1979.

96. Mechanisms and Kinetics of Coal Hydrogenation

Contractor: Colorado School of Mines

Principal Investigators: J.H. Gary and R.L. Bain (Chemical Engineering)

Sponsor: DOE

This study will include an investigation of mild hydrogenation processes for producing a low sulfur, low nitrogen boiler fuel from coal. The second phase of this project entails evaluation of the kinetics and mechanisms of coal liquefaction in a pure donor solvent and a coal-derived solvent using batch stirred reactors.

Reference same as above.

97. Application of Liquefaction Processes to Low-Rank Coals

Contractor: Grand Forks Energy Technology Center

Sponsor: DOE

Period of Contract: 10/1/76 - continuing

Liquefaction research is being performed to obtain basic scientific and engineering data on the liquefaction behavior of Western and Gulf Coast low-rank coals and to establish a data base necessary to apply major developing processes to these distinctly different coals. Work is being carried out both in-house and through satellite contracts with the University of North Dakota (UND). The project retains some emphasis on the previous CO-Steam work; however, increased emphasis will be placed on maximization of distillate product yield through operations at increased reactor temperatures and reduced residence times.

A hydrogenated lignite-derived recycle solvent will be prepared and tested in the continuous process unit operating as a CSTR. At least one extended run employing "batchwise" recycle of product slurry to line-out will be performed in the CSTR mode. The CSTR will then be replaced by a tubular reactor with near-plug flow. Followup work with the tubular reactor will involve systematic investigation of reducing the gas-to-coal ratio, residence time distributions, and temperature. Pressure reduction and moisture effects will be studied by partially dewatering the lignite under conditions that avoid deactivation. "Batchwise" product slurry recycle to steady-state will be investigated at near-optimum conditions. The effect of residence time distribution and level of turbulence will be studied, employing continuous recycle of part of the product slurry stream around the reactor. Studies will be initiated on use of the new field-desorption source for the mass spectrometer to characterize heavy products having high molecular weights. New analytical procedures will be studied for determination of organic functional groups and the basic carbon framework of liquefaction products. Gel permeation chromatography will be further examined as a technique to determine steady-state solvent characteristics for recycle runs.

Fossil Energy Program Report, U.S. Department of Energy, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

98. The SRC Process (Solvent Refined Coal)

Contractor:	Pittsburgh and Midway Coal Co.
Sponsor:	Office of Coal Research
Years Operation:	SRC began in the 1920's in Germany U.S. work began in 1966 and continues today

The primary purpose of the SRC-I process is to produce a low-sulfur, low-ash solid fuel. The SRC-II process was developed as an extension of the first, to operate at higher reactor temperatures, with slurry recycle, thus promoting greater hydrogen addition to the feedstock and producing a substantial yield of liquid, rather than solid product.

Two pilot plants are currently in operation, one a 50 TPD unit at Ft. Lewis, Washington, and the other 6 TPD plant at Wilsonville, Alabama. The Ft. Lewis work has generated data which will provide the design basis for planned demonstration plants for solid and/or liquid products. The Wilsonville pilot plant has provided supplemental screening of various coals and produced improvements in solid-liquid separation techniques. Supporting research at various facilities rounds out the SRC development effort.

Pilot plant problems with lignite operation concerned solvent balance and accumulation of solids in the dissolver. The effectiveness of the solvent as measured by lignite conversion was reduced if light oil ($<400^{o}F$) was recycled.

Fossil Energy Research Program of the Energy Research and Development Administration, FY 1978, ERDA 77-33, April 1977.

99. Liquefaction Applications Using Synthesis Gas

Designer:	Pittsburgh Energy Research Center, Grand Forks Energy Technology Center
Sponsor:	U.S. Bureau of Mines

The CO-Steam concept was initially studied at the Pittsburgh Energy Research Center under the U.S. Bureau of Mines and developed further by the Grand Forks Energy Technology Center specifically for coals of high moisture contents and high reactivities; i.e., low-rank coals. Due to the high reactivity of these coals, with carbon monoxide, synthesis gas is indicated to be the preferred reducing gas in place of hydrogen.

Recent emphasis has moved towards distillate products as a means of avoiding problems of ash-solids separation. The optimization of distillate yield will present a balance bewtween the depolymerization of heavy ends and the coincident formation of gaseous products. Research will continue on improving the breakdown of high molecular weight lignite structures with recycle and high temperature techniques.

Fossil Energy Research and Development Program of the United States Department of Energy, FY 1979, DOE/ET-0013 (78), March 1978, 476 pp.

100. Disposable Catalyst Hydrogenation

Designer: Pittsburgh Energy Technology Center

Sponsor: DOE

This disposable catalyst hydrogenation process is part of the DOE's Third Generation Processes Program. The process employs inexpensive single pass catalysts, avoiding costly catalyst recovery and regeneration steps. A sulfur-free fuel oil is produced. The major emphasis in the ongoing research is catalyst selection. During 1980 promising leads are being further pursued in the laboratory and larger scale testing will be intensified.

The effects of low-rank coals in the disposable catalyst hydrogenation process are expected to be similar to those in other liquefaction systems. When the catalyst selection is made, compatibility with the mineral matter present in low-rank coals must be guaranteed.

Fossil Energy Program Summary Document, U.S. Department of Energy, Document No. DOE/ET-0087, March 1979.

101. Direct Liquefaction of Wyoming Subbituminous Coal

Contractor: Contract under negotiation

Sponsor: EPRI

Using Wyoming subbituminous coals in coal liquefaction processes has resulted in unpredictable and nonreproducible coal conversions, product distributions, and hydrogen consumptions. The objective of this project is to characterize the properties of Wyoming subbituminous coal and to correlate the composition and properties of the coal with its behavior during liquefaction. From this research, operating strategies for reliable liquefaction of varieties of this coal will be developed.

EPRI, Research and Development Projects, November 1, 1979.

102. Process Engineering Evaluation of Major Coal Liquefaction Processes

Contractor: Stone & Webster Engineering Corporation

Sponsor: EPRI

The objective of this project is to evaluate the leading coal liquefaction processes on a consistent economic basis. Opportunities for improvements in process design and economics will be identified, and the effects of various financing methods on product costs will be assessed. As well as evaluating the EDS, H-Coal, and SRC-II liquefaction processes, parallel economic studies will be made on methanol production.

Reference same as above.

103. The Chemical Characterization of Texas Lignites

Contractor: Texas A&M University

Principal Investigators: Ronald MacFarlane and Ralph Zingaro (Chemistry)

Sponsor: Texas Energy Development Fund

Lignite is primarily used as a fuel, however it is also a potential feedstock for the chemical industry. For this reason, a study is being performed to learn more about the chemistry of lignite. Using liquid sulfur dioxide, hydrogenated coal oils (Synthoil) are extracted at low temperatures. Dimethyl sulfoxide (DMSO) is also used as a solvent for raw lignite. The soluble material is being separated into various fractions which will be subjected to careful chemical characterization.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

104. Underground Liquefaction of Lignite

Contractor: Texas A&M University

Principal Investigator: R.G. Anthony (Chemical Engineering)

Sponsors: Dow Chemical USA, the Texas Engineering Experiment Station, and the Center for Energy and Mineral Resources

The objective of this project is to determine the feasibility of mining lignite by physical and chemical methods. The basic idea is to chemically comminute the lignite in place and then slurry the lignite particles to the surface. The major advantage of underground liquefaction is that a high Btu oil-slurry would be produced which can be economically stored or transported considerable distances.

The lignite would be comminuted by one of two methods. The first is comminution by a solution of caustic. The second is the injection of a hot-hydrogen-donor solvent and hydrogen into the lignite formation to simultaneously comminute and liquefy the lignite.

An apparatus is being constructed which can be used to more closely stimulate in situ solutions mining. Lignite will be packed in a tube and hot solvent and hydrogen will be passed over the lignite. The tube will be operated adiabatically. This apparatus is currently being tested for leaks. Reaction conditions used in the autoclaves which have yielded successful results will be examined in this system.

Reference same as above.

105. Application of Liquefaction Processes to Low-Rank Coals

Contractor: University of North Dakota

Sponsor: DOE

Period of Contract: 6/1/78 - present

The catalytic effect of the diverse mineral content found in Western and Gulf Coast lignites and subbituminous coals, and the progressive conversion of heavy organic liquids and solids in successive passes through a reactor are being investigated. The mineral matter of these coals is believed to catalyze liquefaction reactions. These properties have important effects on coal reactivity, including autocatalytic activity, hydrogen or Syngas requirements, product yields and quality, processability, and catalyst life; however, these effects are sufficiently well defined to predict their impacts on process design in applying liquefaction technology to these distinctive coals. Therefore, research directed specifically at the low-rank Western and Gulf Coast coals is required.

Experiments are being conducted to establish rates and product distribution from several liquefaction solvents. Two solvents are being chosen for subsequent tests aimed at determining the catalytic effects of diverse mineral matter in 11 different low-rank coals.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

106. Zinc-Halide Hydrocracking Process for Distillate Fuels from Coal

Contractor:	Conoco Coal Development Company
Sponsors:	DOE and Conoco Coal/Shell Development Company

The objective is the further development of the zinc-halide process to produce clean gaseous and liquid fuels from coal, with particular emphasis on gasoline. The work is to include continuous bench-scale and process development unit investigation of zinc halide as a catalyst for the hydrogenation and hydrocracking of coals and coal extracts, and development of an economical regeneration process for the efficient recovery of zinc halide from the spent melt.

The liquefaction of Colstrip subbituminous coal with molten zinc-chloride catalyst was successfully extended in one stage to 440°C without significant increase in heavy products. Using two stages, it was shown that a 496°C second stage at 2500 psig was operable and could convert 70 percent of the organics remaining from a first stage with 74 percent coal conversion (MAF). Colstrip coal contains approximately 35 percent petrographic inerts, and thus yields about 20 percent lower conversion to liquid than bituminous coals at the same conditions.

Batch liquefaction tests have shown that yields from conversion of subbituminous coal with zinc chloride can be reduced if the coal is crushed and dried in hot gases containing as much as 6 percent oxygen. An economic study is underway to compare direct feeding of SRC to zinc-chloride hydrocracking.

Reference same as above.

B.9 PYROLYSIS

107. Pyrolysis of Hot Solids from a Fluidized Bed Combustor

Contractor: Massachusetts Institute of Technology

Principal Investigator: J. Longwell (Chemical Engineering)

Sponsor: DOE

The purpose of this project is to determine the operating characteristics and assess the economic feasibility of directly producing gaseous and liquid fuels, by means of coal pyrolysis. Two different coals will be evaluated in the study, one with a high sulfur content, the other with low sulfur content. Global kinetic models and correlations will be developed for the yields of the pyrolysis products.

University Contracts Summary Book, Fossil Energy, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

108. Process to Produce a Metallurgical Formed Coke

Operators: Food and Machinery Company (FMC) and the United States Steel Corporation

A Wyoming subbituminous coal is the feedstock for this process to produce a metallurgical formed coke. The first step involves the production of a low-temperature char.

Lowry, H.H., (Editor). Chemistry of Coal Utilization - Supplementary Volume, John Wiley & Sons, Inc., New York, 1963.

109. COED (Char-Oil-Energy Development)

Designer: FMC Corporation (Food and Machinery Corporation)

Sponsor: Office of Coal Research (OCR)

Date Initiated: 1962

Project COED is a process for converting coal to char, oil, and gas by reacting the coal in a multi-stage, fluidized bed system. Over 20,000 tons of coal have been processed in the pilot plant, including high-volatile bituminous coals from Colorado, Utah, Illinois, and Kentucky; subbituminous coals from Wyoming; and lignite from North Dakota. Reliable operation of the four fluidized beds with the transfer of solids and gases between them was demonstrated over a variety of processing conditions. The 36 TPD pilot plant has been operated since August 1979.

Considine, D.M., (Editor). Energy Technology Handbook, McGraw-Hill Co., New York, 1977.

Evaluation of Coal Conversion Processes to Provide Clean Fuels, Part II, University of Michigan, PB-234-203, Electric Power Research Institute, February 1974.

110. The Toscoal Process

Designer: The Oil Shale Corporation (Toscoal)

The Toscoal process is an offspring of the Tosco II oil-shale retorting process devloped by The Oil Shale Corporation. The Toscoal process objective is to upgrade the low heating value of coal, especially low-sulfur western coal, through pyrolysis.

Tests have been conducted on a Wyoming subbituminous coal in the Toscoal 25 TPD pilot plant. The chars produced from subbituminous coals in the temperature range of 800° to 1000°F are relatively reactive and require care in storage and transportation to avoid spontaneous ignition.

Considine, D.M., (Editor). Energy Technology Handbook, McGraw-Hill Co., New York, 1977.

Fowkes, W.W., C.M. Frost, J.J. Hoeppner, W. Beckering, P.G. Freeman, and R.W. Youngs. An Examination of Low-Temperature Tar from a North Dakota Lignite, U.S. Bureau of Mines, RI 5813, 1961, 27 pp.

111. Garrett Flash Pyrolysis

Designer: Garrett Research and Development Co. (a subsidiary of Occidental Petroleum Corporation)

Date Initiated: 1969

This process, developed to produce liquids and gases, is based on the concept of partial gasification in which direct yields of methane and other hydrocarbons are obtained by rapid pyrolysis of coal. The objectives of the rapid heating is to minimize the production of gas. A Western subbituminous coal has been used as the feed to this process, and product yield data are available.

Evaluation of Coal Conversion Processes to Provide Clean Fuels, Part II, University of Michigan, PB-234-203, Electric Power Research Institute, February 1974.

Smith, Howard I., and G.J. Werner. Coal Conversion Technology, Noyes Data Corporation, Park Ridge, N.J., 1976.

112. Fluidized Bed Pyrolysis of Lignite to Produce Liquids, Gas and Char

Contractor: University of Houston

Principal Investigator: Amir Attar

Sponsors: Texas Energy Development Fund and the University of Houston

This project will investigate a pyrolysis process which takes advantage of the high volatility and other special properties of Texas lignite to produce clean gaseous fuel, clean liquid fuel, and clean burning char from the lignite. The objectives of this study are to scale-up the experimental system and to produce additional data which are needed for a detailed economic evaluation of the process. On the basis of this evaluation, decisions of the feasibility of lignite pyrolysis in this or other similar processes can be made.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

113. Australia

Operator: CSIRO

The Australian company CSIRO is scheduled to begin pilot plant operations in 1980 for a flash pyrolysis process using no hydrogen or catalyst. Laboratory test units are presently being conducted on fluidized and entrained bed reactors operating at 0.5 TPD. The primary product from the plants will be char. The full scale plant is slated for 1985 start-up.

Considine, D.M., (Editor). Energy Technology Handbook, McGraw-Hill Co., New York, 1977.

114. Basic Studies of Coal Pyrolysis and Hydrogasification

Contractor: Massachusetts Institute of Technology

Principal Investigator: J.B. Howard (Chemical Engineering)

Sponsors: National Science Foundation (NSF) and DOE

The objective of this study is to perform small-scale experiments on the pyrolysis and hydrogasification of coal in both captive-batch and entrained flow reactors. These tests will allow for the analysis of parameters affecting the yield of light hydrocarbon gases, oil, liquid, tar, and char. A Pittsburgh bituminous coal and a dried Montana lignite will be investigated.

University Contracts Summary Book, Fossil Energy, U.S. Department of Energy, December 1979.

B.10 BASIC RESEARCH

115. Novel Approaches to a Study of the Fundamental Organic Chemistry of Coal

Contractor:	Texas A&M University
Principal Investigators:	C.S. Giam and Tom Goodwin (Chemistry)
Sponsors:	DOE and the Center for Energy and Mineral Resources

The study is in the initial stages utilizing novel organochemical reagents and reactions to probe the basic structural and chemical features of Texas lignite. These procedures attempt to capitalize upon supposed similarities in the structures of lignin (a wood polymer) and lignite. The latest methods of product isolation (including high pressure liquid chromatography) and structure proof (e.g., Fourier transform ^{13}C nuclear magnetic resonance spectroscopy and high resolution gas chromatography/mass spectrometry) will be employed to deduce the identity of degradation fragments.

White, David B. "Texas Lignite Technology Development Priorities Over the Next Twenty-five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

116. Thermodynamics Studies on Coal Conversion Processes

Contractor:	Bartlesville Energy Technology Center
Sponsor:	DOE
Period of Contract:	1/75 - continuing

Heat capacities were measured by means of differential scanning calorimetry for six chars - a Hygas process char; a COED process char; and four chars obtained from GFETC, two derived from lignite gasification and two from gasification of bituminouss coal. Heat capacities also were measured for a syncrude derived from Western Kentucky coal and its distillation fractions, for distillation fractions from syncrude derived from West Virginia and Utah coals, and for distillates derived from the H-Coal and Conoco Development Company (CDC) processes. Heats of combustion were measured for sets of distillation fractions derived from the H-Coal and CDC processes.

Heat capacities, heats of combustion, and hydrogen solubility will be measured for selected fractions derived from the SRC II process and the HRI process.

Fossil Energy Program Report, U.S. Department of Energy, Assistant Secretary for Fossil Energy, December 1979.

117. Continuous Real Time Assay of Coal

Contractors: Science Applications, Inc. and McNally-Pittsburgh, Inc.

Sponsor: EPRI

The overall objective is the development of an instrument to continuously analyze coal in the dry state, with minimized time delay, providing information on composition including Btu content, sulfur, and ash. It would be suitable for field utility use, e.g., in slurry pipelines, coal bunkers and dry feed systems, and would allow significant operating cost savings through improved coal quality control. This project is directed toward: (1) determining what practical level of resolution and accuracy for coal composition in the dry state can be achieved; (2) adapting neutron activation techniques for monitoring mass, thickness or elemental composition to coal assay; and (3) defining the costs of achieving compatibility between the detector instrumentation and coal handling hardware.

EPRI, Research and Development Projects, November 1, 1979.

118. Analysis and Speciation of Selonium, Uranium, and Arsenic in Texas Lignite

Contractor: Texas A&M University

Principal Investigators: Ralph Zingaro and Kurt Irgolic (Chemistry)

Sponsor: Texas Energy Development Fund

In order to develop a chemical method for the isolation of arsenic or selenium-containing species, two techniques are utilized. One involves floatation of a powdered sample in a series of liquids of different densities. This affords a separation based on a series of components of different densities. Each fraction is then analyzed. The other approach utilizes selective solubility. Thus, extraction of lignite by dimethyl sulfoxide dissolves components which are four times as rich in arsenic as the raw lignite. Extraction by liquid sulfur dioxide, on the other hand, extracts components which are virtually arsenic-free.

It is believed that the most highly developed gas-chromatograph-D.C. helium arc or neon-plasma emission spectrometer is being used for this study. This spectrometer has been used with great success for arsenic, and is being developed at present for use with selenium.

White, David B. "Texas Lignite Technology Developmental Priorities Over the Next Twenty-five Years," Texas Energy Advisory Countil, Report No. 79-03-03, March 15, 1979.

119. Current Research on the Inorganic Constituents in North Dakota Lignites and Some Effects on Utilization

Contractor: GFETC

Principal Investigators: D.K. Rindt, F.R. Karner, W. Beckering, and H.H. Schobert

Sponsor: DOE

With the resurgence of interest in coal utilization and conversion processes in recent years has come an increased appreciation for the need to understand both the mineralogical characteristics and the chemical behavior of the inorganic constituents of coal. The recent coal literature contains numerous discussions of the importance of knowing the character, distribution, and behavior of the inorganic species; these discussions span the whole spectrum of coal technology -- preparation and storage, combustion, liquefaction, gasification, and environmental studies.

This paper discusses results of laboratory studies on the characterization of inorganic constituents in low-rank coals and elucidation of the role of these constituents in combustion and conversion processes.

Rindt, D.K., F.R. Karner, W. Beckering, and H.H. Schobert. Current Research on the Inorganic Constituents in North Dakota Lignites and Some Effects on Utilization, Grand Forks Energy Technology Center, for presentation at the American Chemical Society Symposium, March 1980, Houston.

B.11 MARKET/ECONOMIC STUDIES

120. Environmental Assessment and Research Plan for Texas Lignite Development

Contractor:	Radian Corporation
Principal Investigator:	Lee Wilson
Sponsors:	Texas Energy Development Fund, Radian Corporation, DOE, and EPA

The purpose of this project is to provide the information needed in order to assess the need for lignite technology development in Texas and in order to understand and plan for the state's anticipated conversion to lignite as a major fuel source. The project included an analysis of technology options, projections of future production levels, quantification of anticipated energy demands by electric utilities and industry, identification of constraints with regard to energy development siting, description of anticipated regional environmental and socioeconomic impacts, and analysis of public policy issues related to energy development.

White, David, B. "Texas Lignite Technology Development Priorities Over the Next Twenty-five Years," Texas Energy Advisory Council, Report No. 79-03-03, March 15, 1979.

121. Economics of Energy Alternatives, Industry and Electric Power Applications For Use of Coal and Lignite

Contractor:	University of Houston
Principal Investigator:	Russell Thompson
Sponsors:	Texas Energy Development Fund and the University of Houston

The primary objective of this study is to develop a set of cost estimates for using coal and lignite as the primary energy source for electric power generation and heavy industry in Texas. Cost estimates from various sources will be converted to a consistent, comparable basis for a number of representative fuel-using systems, including: (1) those using solid fuels directly; and (2) production of gaseous and liquid fuels from coal and lignite. Cost estimates developed in this study may be used either as stand-alone engineering costs or as inputs for estimating economic costs.

Reference same as above.

122. Economic Feasibility For the Conversion of Texas Lignite to Petrochemical Feedstocks

Contractor: University of Houston

Principal Investigators: J.T. Richardson and J.R. Crump

Sponsors: Texas Energy Development Fund and the University of Houston

This project examines the economics of the process and its application to Texas lignite and petrochemical markets. In particular, the focus will be upon (1) technology availability and initial commercialization time tables, (2) process economics, (3) comparisons with competing liquefaction and existing Fischer-Tropsch routes, (4) potential market size and location, and (5) significance to the Texas economy.

Reference same as above.

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