DOE/METC/SP-183
Distribution Category UC-90c

MORGANTOWN ENERGY TECHNOLOGY CENTER

TOPICAL REPORT

ADVANCED-GASIFICATION PROCESSES

This overview report, prepared by Morgantown Energy Technology Center staff, describes the current status of Advanced-Gasification Processes, and includes an Appendix that provides summary descriptions of 15 categories of Advanced-Gasification Projects.

December 1980

UNITED STATES DEPARTMENT OF ENERGY
Morgantown Energy Technology Center
Morgantown, West Virginia 26505

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1.0 INTRODUCTION

Research and development programs have been conducted for many years toward the development and commercialization of coal-gasification processes. However, many unresolved problems are still involved in the establishment of a technically viable and economically competitive industry that meets today's stringent environmental standards. Analysis of current gasification technologies suggests that certain specific activities need emphasis in order to emplace these efficient environmentally acceptable technologies within a reasonable time frame.

It is apparent that the maximum impact on commercialization can be made by conducting research and development projects that involve novel gasification concepts, new process chemistries, and advanced-gasification process reactors, as well as improved technologies for the existing fixed-, fluid-, and entrained-bed configurations and catalytic-gasification concepts.

The development of technically reliable, economically feasible, and environmentally acceptable means of gas-stream processing and the handling of wastewater and other effluents are of equal if not greater importance. There also should be emphasis on evolving an understanding of gas-stream characteristics and definition of optimum gas-stream characteristics and definition of optimum gas-stream treatment and processing systems, such as novel and improved methods of acid-gas removal and improved hot-gas cleanup concepts and processes. Novel wastewater treatment processes are required for improved economics as well as to insure compliance with environmental standards.

A program for the development of advanced instrumentation and analysis is also required to develop the necessary data base for characterization of the performance of gasifiers and downstream treatment and processing units, as well as for the development of process models and process control systems.

2.0 TECHNICAL NEEDS FOR COMMERCIALIZATION OF COAL GASIFICATION

An analysis of the needs for commercial gasification reveals the following principal categories of "information gaps" that can be filled by programs already in progress or those readily initiated. The gaps are technology base needs required for successful commercialization of both currently available and advanced-gasification processes. The needs are defined further in Table 2-1, which shows the current status of the technology data base.

The need areas are classified as follows:

- Coal Preparation/Feeding/Fines Management
- Reactor Design/Performance
- Gas Cleaning/Cooling
- Acid Gas Removal/Gas Shift and Conversion Data Base on State-of-the-Art and Advanced Technologies
- Components/Materials/Instrument Development
- Health/Environmental/Safety
- General

It is anticipated that solutions to many of the problems associated with the demonstration plants, the alternative fuel plants, and the Synthetic Fuel Corporation (SFC) endeavors will not be available during the design and construction phases. However, during the operating and optimization phases of most of these projects prior to commercialization, where additional troubles will surface, the technical-support program herein described will have provided the additional data base needed to correct deficiencies and/or to advance the state of the art.

Table 2-1. Information Gaps in the Technology-Base Areas Required to Support Commercialization Of Coal Gasification

TECHNOLOGY-BASE NEEDS FOR COMMERCIALIZATION OF GASIFICATION PROCESSES	STATE-OF-THE-ART TECHNOLOGY	TECHNOLOGY-BASE DEVELOPMENT NEEDS	
		CURRENT DOE AND PRIVATE-SECTOR DEVELOPMENTS AVAILABLE FOR 1985-1990 DEMONSTRATION	TECHNOLOGY-BASE INFORMATION GAPS
Coal Preparation/Feeding/Fines Management			
Minimize fines from mining/preparation	Fines combusted/sold	Fines briquetting/extrusion Fines/tar injection	Systems approach to fines: Reduce fines generation in mining/preparation; total process look at fines reduction/capture/recycle
Improved/new concepts for dry and slurry systems	Lockhopper feed systems Low-coal-content (especially fines) slurry systems	Several new concepts for dry feeders Improved (use of fines) slurry systems	Technology of measuring 2- and 3-phase flows Slurry heating methods Corrosion/erosion-resistant feeders
Reactor Design/Performance			
Slag/clinker understanding/management			Understand/control slagging and clinkering phenomena
Configuration improvements	Wave I gasifiers	Wave II gasifiers	Process and scale-up understandings
Eastern and western coals data base/capability		(and advanced gasifiers from AR and TD program, 1990 onward)	Gasifier compatability for all American coals; data base on same
Fines utilization in gasifiers (including tars and oils)			Gasifier fines and tars consumption capability Minimize generation of fines/tars in gasifier
Gas Cleaning/Cooling			
Fines management downstream of gasifier (including tars and oils)	Medium-temperature capture and direct/indirect recycle: cyclones; wet systems	BGC and METC tar/fines capture recycle	High-temperature dry fines capture/recycle
	Medium-temperature waste heat boilers	W- and U-gas fines capture/recycle	High-temperature heat recovery systems
High-temperature heat exchange/recovery	Cool gas recycle	Cyclocentrifuge Hot gas particulate devices (AECT program)	N compounds management at high temperature
Hot-gas cleanup (combined-cycle use)		AECT program	
Acid-Gas Removal/Gas Shift and Conversion Data Base on SOA and Advanced Technologies	Lurgi technology	Parsons	Test unoperated systems installed in OCP pilot plants
	Standard methanation processes (minimal data base on coal-derived gases from U.S. coals)	Combined shift/methanation	Expand product-specific catalyst work
		Product-specific catalysts for indirect liquefaction	Catalyst sensitivity to coal-derived contaminants
	Water gas shift	Mobil M-gasoline	
	Fischer-Tropsch	Conoco	
Components/Materials/Instrument Development	Chemical processing industry experience	Some gas stream sensor/instrument development	Major effort on sensor/instrument development
Process stream sensors/analyzers/flow measurement/refractories/metals/materials	Chemical processing industry experience Chemical processing industry experience	Fossil-energy coordination of data experiences	Expanded/integrated program on development and tests of refractories/metals/materials
Valves	Chemical processing industry experience	METC SOA and advanced valve projects	Field test program; expanded SOA valve improvement program
Liquids/slurry pumps	Chemical processing industry experience	Direct liquefaction pilot plants experiences Direct liquefaction pilot plants experiences Slurry pipe lines experience	Program for gasification needs
Oxygen compressor (high flow/pressure)	Chemical processing industry experience	Fossil Energy composition materials program	Compressor development project
Controls/systems integration	Chemical processing industry experience		Program for development of controls/systems integration

Table 2-1. Information Gaps in the Technology-Base Areas Required to Support Commercialization Of Coal Gasification (Continued)

TECHNOLOGY-BASE NEEDS FOR COMMERCIALIZATION OF GASIFICATION PROCESSES	STATE-OF-THE-ART TECHNOLOGY	TECHNOLOGY-BASE DEVELOPMENT NEEDS	
		CURRENT DOE AND PRIVATE-SECTOR DEVELOPMENTS AVAILABLE FOR 1985-1990 DEMONSTRATION	TECHNOLOGY-BASE INFORMATION GAPS
Health/Environmental/Safety			
Process streams/effluents characterization	Coke-oven experience Wave I gasifiers data base	Pilot plant data base Liquefaction pilot/demo plant base Wave II gasifiers data base	Expanded pilot plant data base Demo plant data Data from tests of U.S. coals in foreign plants
Liquid/gas effluent treatment/disposal; slag/ash leaching/disposal; water reuse strategy	Coke-oven experience Wave I gasifiers data base	Pilot plant data base Liquefaction pilot/demo plant base Wave II gasifiers data base Advanced Environmental Control Technology/RCRA	Expanded pilot plant data base Demo plant data Data from tests of U.S. coals in foreign plants Major program to identify/address EPA/OSHA concerns Integrated operations of SOA and advanced wastewater unit operations Zero-discharge strategy Solids leaching tests Worker exposure limits for effluents/process streams PCGD's for all processes
Improved monitoring instrumentation	Chemical processing industry experience EPA developments	EPA programs	Coordination with EPA on needs/program Fossil Energy strategy/program for instrumentation development needs
Process design changes to minimize dangerous streams/effluents	By-product recovery coke ovens Chemical processing industry experience	CONOCO/BGC tar/oil/fines capture/recycle METC/GFETC tar/oil/fines capture/recycle W and U-gas fines capture recycle	Major design review of all gasifiers and processes to develop process design changes to minimize health/safety/environmental concerns/effluents Use of second gasifier (entrained) to gasify/dispose of effluents and hazardous wastes
General			
Modeling/scale-up/optimization economic evaluations	Current industrial/business practices Public/private sector efforts on gasification evaluations over past 20 years	Multitude of public/private sector efforts in these areas	Centralized/focused/coordinated/long-term Fossil Energy program to pull together these functions, to provide a consistent common basis, and to develop/maintain/disseminate data base
Lack of access to process proprietary data	Wave I gasifier/process data in private domain subject to secrecy agreements that limit public/private access to process understanding/evaluation	Wave II gasifier/process data in private domain subject to secrecy agreements that limit public/private access to process understanding/evaluation	Fossil Energy embarks on effort to purchase data rights to all processes in private domain, to aid in gov't ability to develop/execute a commercialization strategy/program (including SFC support)
Regulatory environment for sales of gasification plant outputs	Current DOE/ERA (Economic Regulatory Administration) regulations and existing legislation	DOE/ERA ruling on ANR gas sales Future DOE/ERA rulings	Coordinated government strategy on synfuels pricing
Coal availability, including transportation	Excess mining capability for short term Inadequate rail/slurry pipeline systems		Coordinated federal strategy/program to develop coal production and transportation

3.0 SUPPORT OF GASIFICATION COMMERCIALIZATION TECHNOLOGY NEEDS

These technology needs may be referred to as "targets of opportunity" in Advanced-Gasification Research and Development as follows:

- *Novel gasification concepts, chemistries, and processes* to obtain low-Btu gas used for power generation, medium-Btu gas used as a synthesis gas for indirect liquefaction and a source of hydrogen and other industrial chemicals in addition to power generation, and high-Btu gas as a source of synthetic natural gas and other uses.

- *Improved technologies for gasifiers*, in particular advanced entrained-and fluid-bed gasification approaches. Specific technical problems include the control of slagging of the mineral matter in coal either in terms of preventing slagging on the reactor walls or, conversely, to manage removal of intentionally produced slag and the control of entrained-bed reactor operations to prevent explosions and other hazards. Important from an economic standpoint is the assessment of problems and the generation of improved approaches for the development of systems for extracting heat from effluent gas streams. An improved understanding is required of the circulation, mixing, and agglomeration of coal particles and sintering of ash particles in fluid-bed reactor operations. The required hot- and cold-bed studies and modeling calculations would have impact and support for specific processes such as the Westinghouse and IGT U-Gas processes, as well as improving the general understanding of all agglomeration and sintering phenomena.

- *Gas stream treatment and processing*, including such diverse technologies as removal systems for acid gas, particulates, and sulfur, gas-separation systems, and shift/methanation systems. Novel and improved acid-gas-removal concepts and processes are required for applications that will impact economics and supply reliable alternative technologies. Hot-gas cleanup is required for low- and medium-Btu gases for removal of sulfur, alkali, and particulates and for nitrogen (ammonia and oxides of nitrogen) control so as to impact economics and improve thermal efficiencies in combined power generation and improve fuel-cell applications. Development of combined acid-gas removal and gas-separation technologies is required to impact the economics of medium- and high-Btu gasification processes and indirect liquefaction processes as well as to provide for improved combinations of gasification and indirect liquefaction technologies. The development of separation technology for medium-Btu gas is required for adjustment of the hydrogen/carbon-monoxide ratios used for various indirect liquefaction processes and for the extraction of methane from synthesis gas for use as synthetic natural gas.

- *Wastewater effluent and handling*, including the characterization of wastewater streams, the definition of specific problems, the development of novel wastewater treatment-unit operations at the bench-scale level, and the subsequent development of optimum wastewater integrated-process configurations. The assessment of solid-waste leaching problems and the development of concepts and strategies for solutions to these problems is also involved.

The DOE/FE surface-gasification program has in place over 55 research and development type projects with industries, research institutes, national laboratories, energy technology centers, and universities, which cover the "targets of opportunities." Table 3-1 summarizes these projects according to abbreviated titles and participants over the four opportunity areas. Table 3-2 further relates the advanced-gasification program (also, referred to as "Advanced Research and Technology Development Program") to the needs of the current commercialization efforts in fixed-, fluid-, and entrained-bed gasification, examples of which are given in the columns in the right of the table. Some examples of the more

than 55 research projects currently in place are presented in the center of the table.

This comprehensive approach covers the broad technology needs of the gasification program. Further R&D projects can be initiated and those eliminated which are completed or unsuccessful in order to provide solutions to current or developmental problems as well as novel and improved processing schemes for the future.

Table 3-1. Advanced-Gasification Projects

Novel Gasification Concepts/ Chemistries/Processes	Improved Technologies for Gasifiers	Gas Stream Treatment and Processing
Molten Salt—Rockwell Beacon Concepts—TRW Advanced Concepts—METC Hydropyrolysis—BNL Hydropyrolysis—IGT Alternative Schemes—BNL Support Studies—IGT	**Entrained-Bed Gasification** High Mass Flux—Bell High Rate Entrained—Mountain Fuel **Fluid-Bed Gasification** Fast Fluid Bed—HRI Tri-Gas—BCR **Fluid-Bed Studies/Modeling** Cold Model—PETC Computer Model—S^3 Computer Model—Jaycor Riser Modeling—ERT Solids Circulation—IIT Solids Circulation—Lehigh Solids Circulation—Kansas State Analytical Modeling—U. Houston **Catalytic Gasification** Catalytic Enhancement—Columbia Gas Catalysis Mechanisms—GE Catalysis Mechanisms—SRI Catalyis Mechanisms—Rockwell Incorporated Catalysts—BCL Catalytic Effects—Sandia Catalytic Gasification—PETC Catalytic Conversion—LANL **Gasification Support Studies** C/CO_2 Reactions—WVU Rapid Pyrolysis—MIT Kinetics of Pyrolysis—Penn State Char Gasification—CWRU Entrained Gasification—BYU Improved Techniques—CCNY Oxidative Pretreatment—U. Penn. Molten Phosphates—CIT Coal Gasification—U. Utah Particle Structure—Vanderbilt	**Novel Acid Gas Removal** CNG Process—CNG Research **Particulate Removal** Spray Scrubbers—APT Laminar Flow Cyclone—GE Alkali/Particulates—Westinghouse **Sulfur Removal** Solid Absorption Process—Battelle NW Improved Methods—IGT **Tar Conversion** Catalysts for Reforming—R.M. Parsons Dew Point of Hot Gas—U. California Catalytic Cracking—Clark U. Rapid Pyrolysis—MIT **Gas Separation** Hydrogen/Methane Separation—PETC Hydrogen/Methane Separation—SUNY Separation Low-Btu Gas—Dravo **Shift/Methanation** Shift/Methanation—SRI S/M Fluidized-Bed—BCR Liquid Phase S/M—Chem Systems Iron Deactivation—U. Wisconsin **Support Studies** Combustion Low-Btu Gas—IGT Thermodynamic Tables—Dow
Wastewater and Effluent Handling Process Wastewater—PETC Wastewater Treatment Effluent Handling—IGT Effluent Production—PETC		

Table 3-2. Current Advanced-Research (AR) and Technology-Development (TD) Projects that Support Gasification Commercialization Technology Needs

"TARGETS OF OPPORTUNITY" RESEARCH AREAS FOR THE ADVANCED-RESEARCH AND TECHNOLOGY-DEVELOPMENT PROGRAM	RESEARCH PROJECTS CURRENTLY IN PLACE IN THE AR AND TD PROGRAM			TYPICAL SUPPORTED PROJECTS								
	RESEARCH ORGANIZATION	PROJECT DESCRIPTION	SCHEDULE (FY) 80 81 82 83 84 85 86 87	FIXED BED		FLUID BED			ENTRAINED BED			
				ANR	CONOCO	ICGG	EXXON CAT.	U-GAS	SO CALED	GRACE/ TEXACO	C-E	KT AND SKT
1. Novel gasification concepts/chemistries/ processes, for: low- and medium-Btu gas for power generation, liquids, H_2, SNG, chemicals	Rockwell	Molten salt gasification										
	TRW	Beacon process										
	METC	Fixed-bed gasification with Na catalysis		X	X							
2. Improved technologies for entrained gasifiers												
A. Prevention of slagging on reactor walls	Bell	HMF gasifier									X	X
B. Control systems for explosion hazards	TBD/PRDA	Sensor/controls development							X	X	X	X
C. Gas stream heat extraction	Mountain Fuel	Heat exchanger data/entrained gasifier						X	X	X	X	X
	TBD/PRDA	Novel/improved heat extraction system		X	X		X	X	X	X	X	⊛
D. Low-Btu/high-pressure entrained gasifier	TBD/PRDA	Low-Btu high-pressure entrained gas for power generation							X		X	
3. Fluid-bed agglomeration phenomena and scale-up	TBD/PRDA	Fluid-bed agglomeration and scale-up understandings				X	X	X				
4. Gas stream treatment and processing												
A. Novel/improved acid gas removal processes	CNG	Cryogenic AGR and CH_4 separation for low- and high-content CO_2 syngas		X	X		X	X				
B. Hot gas cleanup: S; alkali; particulates; NO_x												
1. Westinghouse alkali and particulate and removal concept	Westinghouse	Combined alkali/particulate removal concept						X	X			X
2. Hot S removal with alkali and alkaline earth salts on porous media	TBD/PRDA	Hot S removal with alkali/alkaline salts						X	X			X
3. S removal with Zn and transition Bimetallic complexes on porous supports		S-removal with transition complexes						X	X			X
4. Alkali and particulates removal under AECT program	As stated	Bench-scale feasibility tests				X	X	X	X			X
a. Exxon granular bed filter						X	X	X	X			X
b. GE electrostatically-enhanced granular-bed filter						X	X	X	X			X
c. Westinghouse ceramic cross-flow membrane filter						X	X	X	X			X
d. SCEA acoustic agglomerator						X	X	X	X			X
e. APT dry plate scrubber						X	X	X	X			X
f. GE electrocyclone						X	X	X	X			X
g. Westinghouse granular-bed filter with puffback cleaning						X	X	X	X			X
h. Research Cottrell high-temperature electrostatic precipitator						X	X	X	X			X
i. Accurex ceramic bag filter						X	X	X	X			X
5. Integrated iron/zinc oxide process	METC	High-temperature sulfur removal							X			
6. Alkali entrapment	ANL					X		X	X			X
7. Sorbent screening test for sulfur removal	ANL					X		X	X	X	X	X

Table 3-2. Current Advanced-Research (AR) and Technology-Development (TD) Projects that Support Gasification Commercialization Technology Needs (Continued)

"TARGETS OF OPPORTUNITY" RESEARCH AREAS FOR THE ADVANCED-RESEARCH AND TECHNOLOGY-DEVELOPMENT PROGRAM	RESEARCH PROJECTS CURRENTLY IN PLACE IN THE AR AND TD PROGRAM										TYPICAL SUPPORTED PROJECTS								
	RESEARCH ORGANIZATION	PROJECT DESCRIPTION	SCHEDULE (FY)								FIXED BED		FLUID BED			ENTRAINED BED			
			80	81	82	83	84	85	86	87	ANR	CONOCO	ICGG	EXXON CAT.	U-GAS	SO CALED	GRACE/ TEXACO	C-E	KT AND SKT
4. Gas stream treatment and processing (Continued)																			
C. Combined acid gas removal/shift/ separation																			
1. CNG process	CNG	Methane and sulfur separation									X	X		X					
2. Hypersorption	PETC										X	X	X	X	X		X		X
3. Hypersorption	DRAVO										X	X	X	X	X		X		X
5. Wastewater and effluent handling																			
A. Wastewater characterization fixed-bed liquids	METC/GFETC	Identify wastewater species									X	X							
B. Novel unit OPS for wastewater treatment	TBD										X	X	X	X	X	X	X	X	X
1. Biomass defloculation-activated sludges and O_2 uptake rate determinations	PETC/others										X	X	X	X	X				
2. Test Celanese anaerobic process on GFETC gasifier water	PETC										X	X	X	X	X				
3. Biochemical oxidation of thiocyanates	PETC/others										X	X	X	X	X				
4. Ultrafiltration concepts for solid-liquid separations	IGT										X	X	X	X	X	X	X	X	X
5. Reverse osmosis concepts for gasification wastewaters	IGT										X	X	X	X	X	X	X	X	X
6. Biological treatability studies on wastewaters	GFETC/others										X	X	X	X	X	X	X	X	X
C. Optimum wastewater treatment																			
1. Concentration effects of phenol/ NH_3/thiocyanate on microbes	PETC/others										X	X	X	X	X	X	X	X	X
2. Trade-off studies relative to reverse osmosis and thermal evaporators	IGT										X	X	X	X	X	X	X	X	X
D. Solid wastes leaching problems; solid wastes handling	TBD										X	X	X	X	X	X	X	X	X

4.0 DISCUSSION OF PROJECTS AND RELATIONSHIPS IN GASIFICATION DATA BASE

Each project in Advanced Gasification is summarized in Sections 4.1 through 4.4 below according to technology needs; furthermore, the project's impact is assessed on current and emerging commercial-gasification programs. Section 4.5 is a glossary of terms for the abbreviations used in Sections 4.1 through 4.4.

Appendix A gives additional, more specific information on each project such as title, contractor, objectives, results and accomplishments, applications, etc.

Appendix B provides further details on the projects from the listed references, which are comprised of published papers and reports, and papers presented at scientific or engineering meetings. All of these are based on work done in the specified projects.

4.1 Novel Gasification Concepts/Chemistries/Processes

4.1.1 Molten Salt, Rockwell—The object of this project is to develop a molten-salt bath-gasifier concept for low- and medium-Btu applications. Successful development of this novel process could favorably impact a wide variety of problems, including control of particulates, sulfur, and nitrogen, control of explosion hazards (safe turndown for load following), and efficient recovery of sensible heat. It is expected that the data base on low-Btu gasification will be completed around September 1981, and assessment of the data base to evaluate the scope of the technology in solving economic and technological problems will be completed around June 1982, if medium-Btu gasification runs are conducted as currently planned.

4.1.2 Beacon Concepts/Technology, TRW—The object of this project is to develop novel medium- and high-Btu gasification processes along with power generation. These particular concepts may result in a process for medium- and high-Btu gas production with cogeneration of power through a combined power-cycle operation, incorporating a significantly higher thermal efficiency. It is expected that demonstrations on laboratory, bench, and process development unit (PDU) scales will be made during 1980 through 1982, followed by assessment of the data base and process implications and the broadening of PDU data to be completed during 1983 for pilot-plant design.

4.1.3 Advanced Concepts, METC—This project consists of development of advanced-gasification concepts for entrained-bed reactors. The studies anticipated under this project may provide a fundamental understanding of carbonization, pyrolysis, and hydropyrolysis reactions, and devolatilization product-stabilization reactions. All of these reactions may impact the development of advanced entrained-bed reactors. It is expected that site-development work for the bench-scale reactors will be completed during Fiscal Year 1981, including high-pressure cells, blast walls, and control room. During Fiscal Year 1982, reactor assemblies and instrumentation will be completed and test runs initiated.

4.1.4 Hydropyrolysis, BNL and IGT—The objective of these projects is to develop short residence time hydropyrolysis/hydrogasification processes for optimized yields of liquid hydrocarbon products (high-octane gasoline-blending stocks), along with high yields of gaseous hydrocarbons (methane and ethane for synthetic natural gas). BNL has provided reliable yield and kinetic data upon which reactors can be designed. The work by IGT implements the exploration and development of hydropyrolysis concepts for cogeneration of SNG and liquid products. All of this hydropyrolysis work may impact the development of the novel concept of the simultaneous production of two high-value products in high yields.

4.1.5 Alternative Schemes (BNL) and Support Studies (IGT)—The objective of these projects is to develop new gasification concepts and new processing techniques. BNL demonstrated the higher carbon utilization and higher thermal efficiency of catalytic gasification and hydrogasification approaches. Minimum energies for complete separation of the effluent mixtures from these processes were obtained. IGT examined a novel pretreatment of caking coal to eliminate agglomeration and obtained novel correlations of jet penetration as a function of pressure in the fluidization of chars. This work by both BNL and IGT may increase the basic

understanding of coal-process technology leading to new improved processes.

4.1.6 Electrolytic Hydrogen, BNL—The purpose of this project is investigation of the feasibility of electrolytic production of hydrogen from coal-water slurries flowing through a magnetic field. This novel concept is based on the production of an electrical potential by a magnetic hydrodynamic effect due to rapid flow of the slurry in the field. Development of this concept might offer an inexpensive source of hydrogen for energy or chemical use.

4.2 Improved Technologies for Gasifiers

4.2.1 Entrained-Bed Gasification—Advanced-Gasification Projects for entrained-bed gasification include:

- *High-Mass Flux, Bell:* Development of a gasifier with dry dense-phase coal feeding at high rates. By greatly reducing the reactor volume, this approach allows the use of more durable/expensive materials of construction with overall cost savings. This work on dry dense-phase feeding by rocket-injector technology may impact other entrained-bed coal-gasification systems.

- *High-Rate Entrained, Mountain Fuel:* Development of a high-temperature, pressurized, high-rate downflow gasifier. This process offers the potential for significant advantages in lower capital costs and higher overall energy-conversion efficiency. It is expected that performance data on the heat-exchange system will be acquired by about June 1982. The goal is the demonstration of sufficient waste-heat recovery to produce an overall energy-conversion efficiency of 70 percent.

4.2.2 Fluid-Bed Gasification—Advanced-Gasification projects for fluid-bed gasification include:

- *Fast Fluid-Bed, HRI:* Development of a gasification process with fast (5 to 20 feet per second) fluid-bed velocities. Fast fluid-bed technology has the potential for gasification of caking coals at about 10 times the feed rate for existing fluid-bed gasifiers with superior turndown (load following) characteristics. Technical reliability and operating costs both may be favorably impacted by this technology.

- *TRI-GAS, BCR:* Development of an integrated triple-reactor process for fluid-bed gasification of caking coals to produce a tar-free low-Btu gas. The problems inherent in complex fluidized-bed systems have been thoroughly investigated and the results can impact fluid-bed reactor design and operation.

4.2.3 Fluid-Bed Studies/Modeling—Advanced-Gasification projects for fluid-bed studies and modeling include:

- *Cold Model, PETC:* Experimental determination of fluidization characteristics in a cold-flow mode. This project could provide information needed for design of fluid-bed gasifiers.

- *Computer Model, S^3 and Jaycor:* Development of general computer models for fluid-bed gasifiers. S^3 has developed a model for fluid-bed phenomena in good agreement with Westinghouse experimental data. This may prove useful for predicting gasifier behavior and scale-up effects. Jaycor has developed a model for mixing, pyrolysis, and agglomeration processes which is being applied to simulate runs on the Westinghouse devolatilizer reactor. This may also prove useful for predicting fluid-bed gasifier behavior.

- *Riser Modeling, ERT:* Development of a model from experimental data for predicting the degree of chemical-reaction conversion in a riser reactor. The results may be applicable to the design of fast-fluid bed reactors and understanding their performance.

- *Solids Circulation, IIT, Lehigh, and Kansas State:* Determination of the local properties of a jet in fluidized-bed gasifiers and development of hydrodynamic models. The results may be fundamental to the proper design, operation, and scale-up of reactant gas-

feed jets in fluid-bed gasifiers and their effects on the circulation and other phenomena of the bed of coal char.

- *Analytical Modeling, University of Houston:* Development of a model for the combustion zone of a fluid bed of char. The results may be applicable to the design of fluid-bed reactors and the prediction of their behavior.

4.2.4 Catalytic Gasification—Advanced-Gasification projects for catalytic gasification include:

- *Catalytic Enhancement, Columbia Gas:* Determination of the effects of sodium-carbonate catalyst in a fixed-bed gasifier. A data base is being obtained in a 3-inch bench-scale unit during 1980 and into 1983, and an assessment of the potential for the concept will be made in 1983. Use of a catalyst in fixed-bed gasifiers has the potential for improved reaction rates, reduced operating temperature, lower oxygen-to-coal ratios, reduced-steam feed, higher methane yield, and higher tar conversion. These results, if achieved, would mean lower operating costs and fewer cleanup problems for fixed-bed gasifiers.

- *Catalysis Mechanisms, GE, SRI, and Rockwell:* Determination of the mechanisms of gasification reactions in the catalysis of coal and char. By elucidating the mechanisms of action of alkali and alkaline earth catalysts, and identifying the controlling parameters in catalytic gasification reactions, a better understanding of the phenomena and fundamentals of catalytic reactors is possible. This work, therefore, has the possibility of the impacting design and operation of catalytic-gasification systems.

- *Incorporated Catalysts, BCL:* Development of a coal-pretreatment process involving lime and small amounts of sodium hydroxide in the presence of water. This approach, if successfully developed, has the potential for an economically favorable process for enhancing gasification while preventing agglomeration of caking coals.

- *Catalytic Effects, Sandia:* Determination of the catalytic effects of inherent mineral matter on the devolatilization and subsequent gasification of coal. By clarifying the role of mineral matter in gasification, it may be possible to select coals and/or the degree of coal cleaning most favorable to optimum operation of coal gasifiers.

- *Catalytic Gasification, PETC:* Determination of the catalytic effects of combination of specific cations and anions. This work might elucidate the catalytic trends inherent in the chemical composition of a wide variety of materials and suggest optimum choices for catalysts.

- *Catalytic Conversion, LANL:* Determination of the changes in coal structure produced by heating in the presence of various catalysts and gas atmospheres. This work has the potential for elucidating the chemical changes in coal that occur upon heating in the presence of catalysts up to the onset of gasification reactions. The results might impact the selection of catalysts for producing structural changes preceding gasification, including devolatilization reactions.

4.2.5 Gasification Support Studies—Gasification support studies include:

- *C/CO_2 Reactions, WVU:* Determination of the role of the char/carbon-dioxide reaction, its kinetics, and the effects of mineral matter and fluidization variables. The results might impact the selection of gasifier operating conditions.

- *Rapid Pyrolysis, MIT:* Determination of the effects of various operating factors on the rapid pyrolysis and hydropyrolysis of coal. Coal type, particle size, mineral matter, temperature, hydrogen partial pressure, and reactions of volatiles have all been found to influence the choice of gasifier operating conditions for optimum results.

- *Kinetics of Pyrolysis, Penn State:* Determination of the kinetics of isothermal pyrolysis and gasification in

steam of as-received and pretreated coals. Rapid heating and short contact times in nitrogen, steam, and synthesis gas atmospheres are involved in pretreatment. The results suggest that structural changes in the coal accompanying gasification might play a major role in gasification rates and, therefore, could influence the choice of coal pretreatment and/or gasification conditions.

- *Char Gasification, CWRU:* Determination of the rates of char gasification in various reactant gases and the effects of char physical structure. The results with a novel thermo-balance reactor might supply more accurate kinetics data than currently available and aid in gasifier design and operation.

- *Entrained Gasification, BYU:* Determination of detailed gas and char-particle characteristic profiles in a bench-scale entrained-bed gasifier. Mixing and particle reaction data may make it possible to develop a coal-gasification model that might impact entrained-bed gasifier design and operation.

- *Improved Techniques, CCNY:* Development of experimental data for flash pyrolysis (hydrolysis) of coal in steam and steam-hydrogen mixtures. This approach shows promise for the cogeneration of gaseous fuel and a high market-value, light-liquid fuel.

- *Oxidative Pretreatment, U. Penn:* Determination of the kinetics and modeling of mild gas-phase oxidative pretreatment of coal. Highly caking coals were rendered virtually noncaking by mild (200°C, 392°F) oxidation. a better understanding of the factors for optimum pretreatment of agglomerating coals under economical conditions could make it possible to use caking coals in some fixed-bed gasifiers and other gasifiers that cannot accept caking coals.

- *Molten Phosphates, CIT:* Determine gasification reactions in a molten bath of sodium phosphate. The phosphate salt was found to significantly catalyze the reaction of steam with subbituminous coal char. The results might favorably impact the development of molten-salt gasifier technology.

- *Coal Gasification, U. Utah:* Development of a concept for simultaneous gasification and liquefaction of slurries of coal in hydrogen-donor sovents in the presence of metal-sulfide catalysts. The results could help in the design of processes for cogeneration of fuel gas and liquid fuels. These processes could have certain economic advantages if high-value products are obtained in high yields.

- *Particle Structure, Vanderbilt:* Determine the changes in the particle structure of coal/char in the reaction with carbon dioxide. The relationships between conversion in the reaction and the particle surface area and effective diffusivity of gaseous reactant and product through the pores of the particle are being analyzed. A better understanding of the influence of changing particle structure on the rate of gas-solid gasification reactions could help in the design and operation of gasifiers.

4.3 Gas-Stream Treatment and Processing

4.3.1 Novel Acid-Gas Removal—Novel acid-gas removal projects include:

- *CNG Process, CNG Research:* Development of proprietary concepts for low-temperature cryogenic processes for the removal of acid gases from high- and low-CO_2 content medium-Btu gases. The development of concepts is expected to progress to the acquisition of bench-scale data on various CO_2-content synthesis gases by about September 1982 to assessment of the economics and technical feasibilities by about December 1982 followed by design and construction of a continuous PDU-scale unit by about June 1983 and acquisition of PDU-scale data by about December 1984. These novel concepts have the potential for development of more efficient and less capital-intensive acid-gas removal processes required for the manufacture of high-Btu gas and

the production of acceptable gas feedstocks for indirect liquefaction or chemical synthesis.

4.3.2 Particulate Removal—Particulate-removal projects include:

- *Spray Scrubbers, APT:* Determination of collection efficiency and power consumption of venturi scrubbers for removing particulates from high-pressure gas streams. This project might supply the data base for assessment of available spray scrubbers for use on the high-pressure product gases generated by the more advanced gasifiers.

- *Laminar Flow Cyclone, GE:* Development of a concept for a laminar flow cyclone with high inlet velocity. This concept, if successfully implemented, might make it feasible to increase gas throughput per unit volume and greatly reduce the size of the particulate-containing gas fractions while improving collection efficiency and thereby reducing costs.

- *Alkali/Particulates, Westinghouse:* Development of a hot-gas cleaning-process concept for simultaneous removal of alkali and particulates by use of porous, high-surface-area aluminosilicate gettering materials (i.e., the capture and removal of undesirable components). The preliminary data base and systems performance analysis were completed in September 1980, and it is expected that the parametric aspects of the studies will be broadened to include all process variables by about June 1982. Testing of the process of a pilot-plant gasifier mini-slip stream is expected by about September 1983. Removal of alkali and particulates from hot medium- or low-Btu gas streams intended for use in turbines in combined-cycle power-generation plants is necessary to prevent serious damage to the turbine materials. This project might fill one of the major technology gaps in this advanced power-generation method.

4.3.3 Sulfur Removal — Sulfur-removal projects include:

- *Solid Absorption Process, Battelle NW:* Development of a process concept for removing sulfur from hot reducing-gas streams by the use of molten alkali and alkaline earth eutectic mixtures held in the pores of stable refractory materials. Completion of sulfur-removal and sorbent-regeneration data, with assessment of the concept, is expected by about December 1981. Removal of sulfur from hot medium- or low-Btu gas streams intended for combustion in power-generation plants is necessary to meet environmental standards for sulfur-oxide emissions. This project's results, coupled with those of the Westinghouse alkali/particulates project, might impact the emplacement of gasifier/combined-cycle generation plants.

- *Improved Methods, IGT:* Development of a concept for desulfurization of high-temperature synthesis gases with regenerable solid sorbents having a zinc-oxide/zinc-chromite base. Acquisition of sulfur-removal and solid-sorbent regeneration data is expected to be completed about June 1982. This process concept, if successfully developed, has the possibility of recovering the sulfur entirely in the elemental state, with technical, economic, and environmental advantages over recovery as sulfur oxides.

4.3.4 Tar Conversion — Tar-conversion projects include:

- *Catalysts for Reforming, R. M. Parsons:* Development of a catalyst for conversion of tars or heavy oils to synthesis gas and light liquids by high-temperature steam reforming. The catalysts in shift/methanation reactors are subject to deactivation by coke deposits if tars or oils are present in the synthesis-gas feedstock. Tar-conversion/removal processes are required for the products from a number of existing gasifiers.

- *Dew Point of Hot Gas, U. California:* Determination of fundamental physical-chemical and thermodynamic data for condensation of tars from hot gases.

The data being acquired might make it feasible to design heat exchangers for the recovery of sensible heat from hot, pressurized, tar-containing gas, thereby increasing the thermal efficiency of the gasification process.

- *Catalytic Cracking, Clark U:* Determine the thermal-cracking behavior of gasifier tars in the presence of gasifier chars, ash, and other byproduct solids. This work might supply a data base for an inexpensive catalytic process for tar conversion to gas and char.

- *Rapid Pyrolysis, MIT:* Determine the effects of dolomite and lime on the conversion of tar by rapid pyrolysis. This work might supply a data base for an inexpensive catalytic conversion of tar to light liquid while removing hydrogen sulfide.

4.3.5 Gas Separation—Gas-separation projects include:

- *Hydrogen/Methane Separation, PETC:* Determine the feasibility of separating hydrogen/methane mixtures by adsorption on activated carbons. Hydrogen or hydrogen/carbon monoxide are currently to be separated from product methane (SNG) for recycle to the gasifier by means of cryogenic processes, which are becoming more energy intensive because of increasing electric-power costs. Adsorptive fractionation on activated carbons (hypersorption process) is being investigated for its applicability to coal-derived gases as a possible process alternative.

- *Hydrogen/Methane Separation, SUNY:* Determination of the feasibility of using heat-treated coals in place of activated carbons for a combined H_2/CH_4 separation and H_2S removal technique. This project has the potential for defining an inexpensive alternative for activated carbon in a possible combined separation-cleanup process.

- *Separation of Low- and Medium-Btu Gas, Dravo:* Determination of the engineering design and economic feasibility for application of the hypersorption process to the separation of low-Btu and medium-Btu gases. These calculations might define the possible applications of adsorptive fractionation on activated carbon for gas separation, such as adjustment of H_2 / CO ratios for indirect liquefaction or chemical manufacture.

4.3.6 Shift/Methanation—Shift/methanation projects include:

Shift/Methanation, SRI: Determination of the improvement in sulfur resistance by using an iridium-promoted methanation catalyst. This work has shown that a nearly threefold increase in catalyst reactor life is possible by promoting commercial nickel catalyst with iridium, thereby making it possible to cut operating costs.

- *S/M Fluidized-Bed, BCR:* Demonstration of the feasibility of gas-phase, fluidized-bed, shift/methanation with various catalysts. Combined shift and methanation in a single reactor has the potential for technical and economic benefits. Gas-phase fluidized-bed operation has the potential for good temperature control of the exothermic reaction and inhibited rates of carbon deposition at elevated temperatures.

- *Liquid Phase S/M, Chem Systems:* Determination of the rates of carbon formation on various shift/methanation catalysts and evaluation of the hydrodynamics of a liquid-phase, fluidized-bed S/M reactor. The results might lead to improvement in catalyst activity and catalyst life, thereby reducing operating costs.

- *Iron Deactivation, U. Wisconsin:* Determination of the mechanisms of deactivation of nickel methanation catalysts by metallic iron deposited from iron-carbonyl gas. This work might define operational limits for controlling iron deactivation, thereby prolonging catalyst activity and catalyst life.

4.3.7 Support Studies—Support studies include:

- *Combustion of Low-Btu Gas, IGT:* Demonstration of the feasibility of re-

trofitting industrial natural-gas burners to operate on low-Btu gas. Data collected under this project might allow an assessment of the applicability of replacing natural gas with low-Btu gas in industrial process burners.

- *Thermodynamic Tables, Dow:* Derivation of tables of data for thermodynamic properties of substances involved in coal-conversion processes. These thermodynamic tables impact the development and operation of gasifiers, gas cleanup and separation units, methanators, and other reactors.

4.4 Wastewater and Effluent Handling

4.4.1 Process Wastewater, PETC—The purpose of this project is development of environmental control strategies for gasifier wastewater through laboratory and bench-scale studies. Included are measurement of biomass defloculation of activated sludges, oxygen-uptake rates, inhibition of respiration by toxic constituents, biochemical and chemical oxidation, anaerobic conversion of organic constituents to methane, solvent extraction of organics, and other biological and physiochemical treatments. The wide range of data being obtained with a variety of gasifier wastewaters shows promise for the development of an integrated treatment program that will be realistic and meet future as well as current environmental standards.

4.4.2 Wastewater Treatment, GFETC—The purpose of this project is investigation of the treatment of the wastewater from the GFETC slagging fixed-bed gasifier, biotreatment with activated carbon addition, solvent extraction, lime-soda softening, oxygen-activated sludge, anaerobic digestion, and leachable components from gasifier slag. The data obtained will make it possible to compare effluents process-train requirements as a function of the gasifier operating conditions and the coals used as feed to the gasifier. Information of this sort is required by industry to anticipate environmental problems for commercial gasification and develop/design an energy-efficient integrated treatment process.

4.4.3 Effluent Handling, IGT—The purpose of this project is to determine the feasibility of using ultrafiltration/reverse-osmosis membranes for separation/concentration of solids in gasifier wastewater. The successful demonstration of the applicability of reverse osmosis to gasifier wastewater might result in a cost benefit over conventional methods for concentrating solids, such as thermal evaporators.

4.4.4 Effluent Production, PETC—The purpose of this project is to determine the effects of fluidized-bed gasifier operating conditions on the production of nitrogen- and sulfur-compound pollutants in the effluents. The data base developed might enable designers of gasifiers to choose process variables that limit the production of environmentally undesirable compounds, thus allowing cost-effective designs of the cleanup systems.

4.5 Glossary of Terms for Abbreviations Used in Sections 4.1 Through 4.5

Abbreviations used in Sections 4.1 through 4.4 are defined below:

APT—Air Pollution Technology, Inc.
Battelle NW—Battelle Pacific Northwest Laboratories
BCL—Battelle-Columbus Laboratories
BCR—Bituminous Coal Research, Inc.
Bell—Bell Aerospace-Textron
BNL—Brookhaven National Laboratory
BYU—Brigham Young University
CCNY—City College (The City University) of New York
Chem Systems—Chem Systems, Inc.
CIT—California Institute of Technology
Clark U.—Clark University
CNG Research—Consolidated Natural Gas Research Company
Columbia Gas—Columbia Gas System Service Corporation
CWRU—Case Western Reserve University
Dow—Dow Chemical Company
Dravo—Dravo Corporation
ERT—Environmental Research and Technology
GE—General Electric Company
GFETC—Grand Forks Energy Technology Center, U.S. Department of Energy
HRI—Hydrocarbon Research, Inc.
IGT—Institute of Gas Technology
IIT—Illinois Institute of Technolgy
Jaycor—JAYCOR
Kansas State—Kansas State University

LANL–Los Alamos National Laboratory
Lehigh–Lehigh University
METC–Morgantown Energy Technology Center, U.S. Department of Energy
MIT–Massachusetts Institute of Technology
Mountain Fuel–Mountain Fuel Resources, Inc.
R.M. Parsons–Ralph M. Parsons Company
Penn State–Pennsylvania State University
PETC–Pittsburgh Energy Technology Center, U.S. Department of Energy
Rockwell–Rockwell International
Sandia–Sandia National Laboratories
SRI–SRI International
S^3 –System, Science, and Software
SUNY–State University of New York at Buffalo
TRW–TRW, Inc.
U. California–University of California at Berkeley
U. of Penn–University of Pennsylvania
U. of Utah–University of Utah
U. of Wisconsin–University of Wisconsin
Vanderbilt–Vanderbilt University
Westinghouse–Westinghouse Electric Corporation
WVU–West Virginia University

APPENDIX A–ADVANCED-GASIFICATION PROJECTS

A.1 NOVEL GASIFICATION CONCEPTS/ CHEMISTRIES/PROCESSES

TITLE

Molten-Salt Coal Gasification Process Development

PERFORMER

Rockwell International, Canoga Park, CA

OBJECTIVE

The objective is to demonstrate the feasibility of the molten-salt (sodium-carbonate) coal gasification process for use in the production of low-Btu gas, using a 1-ton-of-coal per hour PDU at about 1800°F and pressures up to 20 atm, with recovery and recycle of the salt.

ACCOMPLISHMENTS

In this process a blend of crushed coal and sodium carbonate is transported by compressed air through four down-sloping injector nozzles beneath the molten-salt bed, creating a highly turbulent mixture. The molten salt acts as both a heat sink and heat source. A portion of the melt is continuously removed by overflowing into an aqueous quench tank. Figure 1 shows the basic process features. A total of five test runs were made on the PDU before the contract expired on March 31, 1980. Run 4 was the first PDU gasification test under pressure (13.7 psig); the ash-removal, sulfur-removal, and carbonate-regeneration systems were not used. After only 14 hours of melt-overflow operation, the melt-withdrawal orifice plugged. Run 5, the last under the contracted work, lasted 112 hours and was terminated because of persistent unsteady flow of the melt. The coal flow rate was 1,492 lb/hr with a salt feed rate of 260 lb/hr, at an operating pressure of 10.5 atm. The product gas had a Btu value of 113.9 with an H_2S content of 57 ppm.

CURRENT WORK

A major unsolved problem is plugging of the melt-withdrawal outlet. In addition, the existing measurement and control for the melt level in the gasifier are inadequate. In the two pressured runs the ash-removal, sulfur-removal, and sodium-carbonate-regeneration systems were not on line. Thus, the overall objective of demonstration, the feasibility of a pressurized molten-salt gasifier, has not been fully accomplished. Because of this Rockwell International submitted a proposal for a 12-month follow-on program intended for award in June 1980, aimed at completing development of the process for the production of low-Btu gas.

APPLICATION

This process has the potential for a way of producing low-Btu gas for electric power generation that is free of significant amounts of phenols, tars, char, ash, H_2S, NO_x, and NH_3 using all coals, including highly-caking and high-sulfur, as well as coal fines. The hot reservoir of catalytic melt allows coal-feed fluctuations for load following turndown to be conducted safely, and the relatively clean product gas allows efficient recovery of sensible heat.

TITLE

Development of Beacon Technology

PERFORMER

TRW, Inc., Redondo Beach, CA

OBJECTIVE

The objective is to develop the Beacon Concept(s) to evolve process configurations for the cogeneration of medium/high-Btu gases and power from low-Btu gases. The project incorporates objectives for: (1) the further development and testing of catalysts for the transformations necessary in converting low-Btu gas to medium/ high-Btu gas, (2) bench-scale batch experiments on carbon deposition and gasification to elucidate parametric aspects of the process concept(s), (3) PDU-scale testing under continuous process conditions to generate data suitable for engineering analysis of the process concept(s), and (4) engineering analysis of the process concepts.

ACCOMPLISHMENTS

Small-scale exploratory catalyst-testing experiments have yielded both catalyst-perfor-

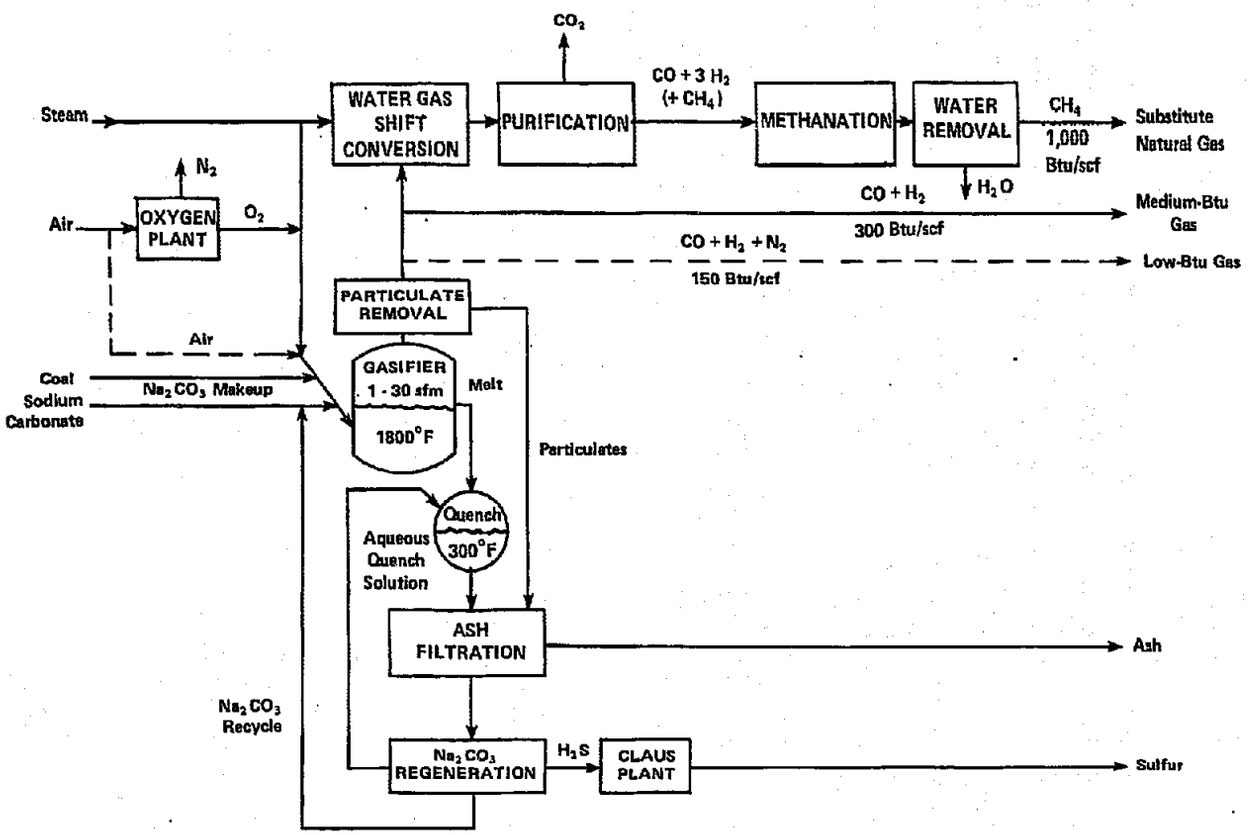

Figure 1. Rockwell Molten-Salt Gasification Process-Development Systems

mance characteristics as well as qualitative carbon-deposition and gasification data on some catalysts. Work has been proceeding on the bench-scale runs to test some of the more promising catalysts identified during the small-scale testing and screening experiments. Parametric data under transient-state conditions has also been generated.

CURRENT WORK

For the next two years the work contemplated under all the objectives set for this program is anticipated to proceed with equal emphasis on each objective.

APPLICATION

The process concepts and configurations being explored and defined are in line with DOE's goals of continuously exploring and developing possible new or novel medium- and high-Btu gasification processes which show technical feasibilities and economic potential substantially better than for those currently available.

These particular concepts may result in the development of a process for medium- and high-Btu gas production with cogeneration of power through combined power cycle operation. The process is anticipated to have significantly higher thermal efficiencies compared to those found in existing processes.

TITLE

Advanced-Gasification Concepts

PERFORMER

Morgantown Energy Technology Center, Morgantown, WV

OBJECTIVE

The objective is to conduct an integrated effort comprised of both in-house and contractor activities that explores new concepts in gasification and provides a data base and technical support for development of advanced concepts in gasification.

ACCOMPLISHMENTS

An in-house research facility designated as the Advanced-Gasification Concepts (AGC) facility was partially constructed during FY 80. The facility, as designed, consists of bench-scale (10-lb/hr) entrained-bed reactors which will have the capability and flexibility to investigate the complex physical, chemical, and kinetic behavior of coals through a broad range of processing conditions. During the design and construction phases of the AGC facility, in-house experimental and contractor activities were carried out. In-house experimentation made use of an existing thermobalance reactor to determine the effects of catalyst type, loading, and impregnation techniques/ degree on coal- and char-related gasification reactivities. Eleven R&D contracts were initiated spanning a broad range of subjects such as computer application, instrumentation development, and basic studies in coal pyrolysis and agglomeration.

CURRENT WORK

Primary emphasis is being placed on completing the construction of the AGC facility. The construction contractor, selected during FY 80, will complete the site-preparation work during FY 81 which includes elements such as construction of high-pressure cells, blast walls, a control room and tube trailer area, and making the necessary piping and utility tie-ins. Supporting equipment and instrumentation will be installed in time to receive the reactor assemblies.

APPLICATION

The entrained reactor system was designed to investigate: upper-stage reactions of two-stage, air-blown entrained gasifiers; carbonization/pyroloysis/hydropyrolysis reactions; and devolatilization product-stabilization reactions. The reactor system will have the versatility and capability of handling other areas that, as yet, have not even been identified. The studies anticipated under this project may provide fundamental understanding of gasification reactions, and may thus aid in the development of advanced-gasification concepts.

TITLE

Hydrogasification/Hydropyrolysis of Coal

PERFORMER

Brookhaven National Laboratory, Upton, NY

OBJECTIVE

The objective is to obtain process chemistry information for the rapid hydrogasification and hydropyrolysis of coal to primarily gaseous and liquid hydrocarbon products.

ACCOMPLISHMENTS

A highly instrumented 1-inch I.D. tubular reactor system capable of operating up to 900°C and 4,000 psi was designed and constructed. Coal can be fed to the unit up to 2 lb/hr and hydrogen can be fed up to 5 lb/hr. On-line product analysis is made with a programmable gas chromatograph every 8 minutes.

A complete parametric study has been completed using two noncaking coals. At 900°C and 1,000-psi hydrogen pressure, New Mexico subbituminous coal was found to be much more reactive than North Dakota lignite, producing approximately 55-percent gaseous hydrocarbon (CH_4 and C_2H_6) yield (on carbon) versus 35 percent yield for the lignite. The maximum gaseous yield for both coals was observed at 900°C and 2,500 psi and was approximately the same at 80 to 90 percent conversion. Also, coal-particle residence times of 2.5 to 7 seconds were necessary to produce these maximum yields. The liquid yields were obtained at temperatures of 750° to 825°C and pressures of 2,000 to 2,500 psi. The maximum liquid yield for both coals was observed to be approximately 20 percent. With the subbituminous coal, 75 percent of the liquid was BTX and the other 25 percent was heavier aromatics, while the lignite produced equal amounts of BTX and heavier aromatics. Coal-particle residence times of 4 to 5 seconds were found necessary for the production of maximum liquid yields.

CURRENT WORK

The present series of experiments is being conducted with Montana Rosebud subbituminous coal at low hydrogen-to-coal-feed ratios (< 0.5 lb/lb) and short residence times (< 2 sec). Particular attention is being given to complete mass balances and to characterization of the liquid products formed.

APPLICATION

The results of these process chemistry studies and the correlations provide data upon which direct processes for conversion of coal to synthetic fuels can be designed and evaluated. This project provides reliable yield and kinetic data upon which reactors and process equipment can be designed. The information has already been used to evaluate various direct rapid hydrogenation reactions.

TITLE

Research and Development of Rapid Hydrogenation for Coal Conversion to Synthetic Motor Fuels (Riser Cracking of Coal)

PERFORMER

Institute of Gas Technology, Chicago, IL

OBJECTIVE

The objective is to develop the technology of short residence-time hydropyrolysis of lignites and coals for optimized yields of high-octane gasoline-blending stocks. The scope includes the design, construction and operation of a bench-scale unit (5 to 10 lb/hr) and a process-development unit (50 to 100 lb/hr). Evaluation of the technical and economic aspects of large-scale operation is included.

ACCOMPLISHMENTS

The bench-scale experiments on the riser concept for hydrocracking coal have been completed. The experiments show that programed heating of coal at 1,500- to 2,000-psig pressure using different coal-to-hydrogen ratios can yield a wide distribution of products ranging from light hydrocarbon gases and carbon oxides to liquid products. The liquid product yields a mixture of BTX, heavier hydrocarbons, and oxygenated compounds. About half of the liquid product can be in a boiling range below 400°F. Lignites can be processed without pretreatment. However, caking coals have to be either pretreated with catalysts and subsequently dried, or have to be diluted with char,

sand, or clays to prevent caking and agglomeration problems during the hydropyrolysis. Initial PDU-scale testing shows similar trends, although PDU operational problems have not been fully resolved.

CURRENT WORK

Work is progressing to solve combustor and injection-point agglomeration and clogging problems. PDU-scale experiments to obtain parametric data to confirm and reproduce bench-scale results are being continued. On the basis of this PDU-scale data, an assessment of the technical and economic potential will be attempted. Bench-scale data and some preliminary PDU-scale data show that the liquids obtained contain significant quantities of phenols and other oxygenates. Although controlling the temperature and programing it to different levels in different parts of the reactor through several oxygen-injection points is possible, the required total pressure of 2,000 psig for the process concept is higher compared to pressures used in other gasification processes. For caking coals, pretreatment with catalysts appears to be unavoidable to prevent agglomeration or caking problems.

APPLICATION

The work involved on this concept complements other DOE activities in the exploration and development of hydropyrolysis concepts for cogeneration of SNG and liquid products.

TITLE

Alternative Process Schemes for Coal Gasification

PERFORMER

Brookhaven National Laboratory, Upton, NY

OBJECTIVE

The objective is to study existing and developing coal gasification processes with the goal of identifying areas in which process improvements are possible and to initiate studies on potentially attractive new gasification concepts. The scope of the work includes both engineering studies and bench-scale experimental work.

ACCOMPLISHMENTS

On the basis of simple, first-approximation calculations, it was shown that catalytic gasification and hydrogasification are inherently superior to conventional gasification with respect to carbon utilization and thermal efficiency. These processes will require a step for the separation of product SNG (methane) from a recycle stream of hydrogen or carbon monoxide and hydrogen. The energetics of such separations were studied. Minimum energies for complete separation of representative effluent mixtures for these processes were calculated as well as energies of separation into product and recycle streams. This required separation calculations for cryogenic, clathrate (gas-hydrate), and absorption/stripping separation processes. The results were compared with ideal gas-mixture cases. A summary report of existing and developing coal gasification processes was issued. The relative merits of gasifier type, heating method, operating mode, process conditions, and gasifying media were considered and a qualitative appraisal of these processes was performed.

CURRENT WORK

Current work has been directed toward the development of new initiatives to achieve a more basic understanding of coal gasification.

APPLICATION

This project can lead to improvements in existing coal gasification and, by increasing the basic understanding of the chemistry of coal gasification, can lead to new improved processes.

TITLE

Coal Gasification Pilot-Plant Support Studies

PERFORMER

Institute of Gas Technology (IGT), Chicago, IL

OBJECTIVE

The objective is to investigate advance coal gasification technology through a series of related studies that support the pilot-plant

development efforts. These studies, involving both analytical and experimental aspects at actual conditions encountered in pilot-plant operations, will either generate missing basic design data or develop new processing techniques for direct application to overall process improvements and cost reductions.

ACCOMPLISHMENTS

In this multitask studies project, the accomplishments include: improved methods of grinding and treating caking coal for the gasifier, design information on fluidization and solids transfer in pipes, evaluation of shift catalysts performance, and development of fundamental kinetic information on char-gasification reactions. The results of the study on wet grinding of run-of-mine Illinois No. 6 coal in a cone crusher showed advantages over dry crushing. The wet-grinding process produced less fines and the power input was reduced as compared to the dry-grinding process. Coal-water slurries, containing 40 to 60 percent solids produced from wet-grinding processes were successfully pumped and three slurry dewatering devices were evaluated for high-pressure operation, one being found satisfactory. Studies on pretreatment of caking coals to eliminate agglomeration tendencies showed that certain process-derived light solvents can be used. Evaluations of four commercially available shift catalysts have shown that the catalyst can tolerate up to 0.3-percent ammonia in the gas stream, and the minimum steam/gas ratio was determined to be 0.5. A benzene concentration of 2 percent in the gas stream produced coke on the catalyst and some catalysts were poisoned by phenol. Among the four catalysts studied, only one had high activity for the shift reaction.

The previously developed kinetic model for coal gasification was updated. Studies on fluidization of chars have resulted in correlations on jet penetration as a function of pressure (0 to 750 psig), particle size, jet velocity, nozzle diameter, and fluidization velocity. The effect of standpipe length (4 to 23 feet of 1.5-inch pipe) on solids flow rate from a hopper was determined for both restricted and unrestricted standpipe flow. Correlations were developed for predicting aeration requirements and pressure drops of nonmechanical valves. Studies on the effect of fluidization velocity on clinker formation have shown that higher gasification temperatures can be achieved, without clinker formation, provided the fluidization velocity is also increased.

CURRENT WORK

The objectives of the ongoing experimental work have been redirected such that there is emphasis on studies on fluid-bed phenomena, hot-gas cleanup, and shift catalyst performance and catalyst deactivators.

APPLICATION

The findings of these IGT studies have been and are being used to direct and assist other DOE programs in coal technology. The fluidization results are being studied by PETC with regard to their new pressure-fluidization work and System Science Software is using IGT jet-penetration data in their fluid-bed model.

TITLE

Production of Hydrogen Using Coal-Water Slurries

PERFORMER

Brookhaven National Laboratories, Upton, NY

OBJECTIVE

The objective is to investigate the feasibility of producing hydrogen from coal-water slurries by pumping such slurries through the magnetic field of a permanent magnet.

BACKGROUND

Superconducting magnets are available that can be used for such a process. By adding coal particulates as a slurry in water, it has been observed that the voltage for the water electrolysis reaction falls to slightly below 0.3V. If a coal-water slurry containing small conducting wires, insulated except for their ends, flows perpendicular to an externally applied magnetic field, sufficient voltage will be generated across the wires to electrolyze the slurry.

CURRENT WORK

The project started in FY 1981 and the necessary equipment is being assembled for this feasibility study.

APPLICATION

Development of this concept might lead to an inexpensive source of hydrogen.

A.2 IMPROVED TECHNOLOGIES FOR GASIFIERS – ENTRAINED-BED GASIFICATION

TITLE

High-Mass Flux (HMF) Gasifier

PERFORMER

Bell Aerospace-Textron, Buffalo, NY

OBJECTIVE

The objective is to demonstrate the applicability of dry dense-phase coal feeding with rocket-injector technology to gasify coal at mass flux rates an order of magnitude higher than existing processes.

ACCOMPLISHMENTS

The High-Mass Flux Gasifier is a pressurized, entrained-flow, slagging gasifier that reacts pulverized coal with air or oxygen to produce low- and medium-Btu gas. A schematic of the test facility is presented in Figure 2. The process calls for a dry, dense-phase coal-feed stream to be introduced into the reactor through injectors based on Bell's experience with rocket-injector technology. These injectors are designed to promote intense gas-coal mixing and uniform particle distribution over the reactor cross section allowing short residence time and high mass throughput per unit of reactor volume. To date, Bell has designed and operated an air-blown HMF gasifier with an internal volume of 0.5 cubic foot which operates at 15 atmospheres pressure and processes 0.5 ton of coal per hour. Tests up to 1-hour duration were conducted using North Dakota lignite, Montana Rosebud, and Pittsburgh-seam coals. At nominal mass-flux rates of 10,000 pounds per cubic foot per hour the North Dakota lignite and Montana Rosebud yielded carbon conversions up to 90 percent. The less reactive Pittsburgh-seam coal yielded only 65-percent carbon conversion.

CURRENT WORK

The current effort is directed toward demonstrating oxygen-blown operation of the gasifier. The oxygen-blown gasification tests are aimed at establishing the viability of the gasifier concept as an efficient syngas producer in a system using bituminous coal, oxygen, and steam. This work will address the problem of low conversion experiences in the air-blown program with Pittsburgh-seam coal.

APPLICATION

The work performed under the HMF contract will impact on two gasification areas: (1) the reactor may be reduced due to the high-mass flux of the process, which would allow the use of more durable and expensive materials of construction; (2) the dry dense-phase coal-feed and injector technology can be applied to other entrained-bed systems.

TITLE

Development of a High-Rate Entrained-Flow Coal Gasification Process

PERFORMER

Mountain Fuel Resources, Inc., Salt Lake City, UT

OBJECTIVE

The objective is to construct and operate an experimental coal gasification system for development of a high-temperature, pressurized, high-rate entrained-downflow coal gasification process. The work is intended to demonstrate the ability to scale-up an existing 0.5-ton per day design, to provide data for further scale-up, and to carry out a test program on advanced equipment components (i.e., coal dry-feed and new-design heat exchangers).

ACCOMPLISHMENTS

Development of this process has proceeded from extensive laboratory testing to the detailed design on a 30-ton per day Process Development Unit (PDU) and to process design studies on a 600-ton per day commercial unit. In the laboratory work an integrated system capable of continuous operation at feed rates up to 0.5-ton per day was constructed and extensive testing carried out. Operation in an oxygen-blown mode yielded raw gas consisting principally of CO and H_2. An overall process efficiency of 74 percent is projected from a commercial unit. Detailed

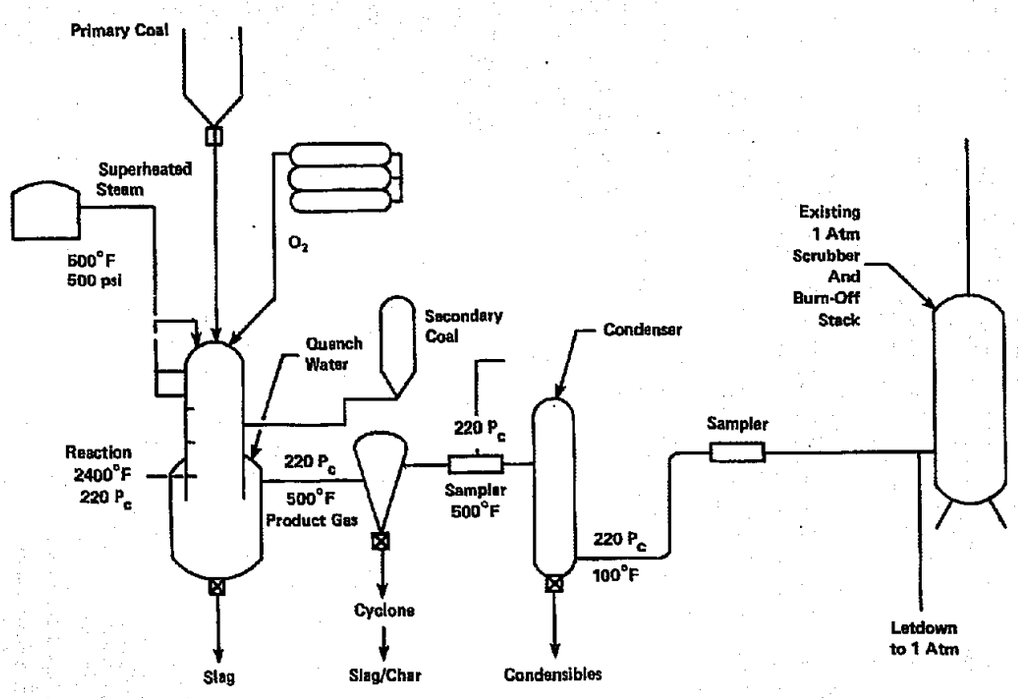

Figure 2. Bell HMF Test-Facility Schematic

engineering work on the 30-ton per day PDU is approximately 80 percent completed. The basic features of this PDU are shown in Figure 3.

CURRENT WORK

DOE is currently preparing to contract with Mountain Fuel Resources, Inc. (with Ford, Bacon, and Davis Utah, Inc., as a subcontractor), on a 50/50 cost-share basis, for the construction and operation of a 30-ton-per-day PDU. The detailed design of the 30-ton-per-day PDU is nearing completion. The cofunded project will take approximately 2½ years.

APPLICATION

The work done to date indicates that the process offers the potential for two significant advantages over the current coal gasification technology. These advantages are lower capital costs and higher overall energy-conversion efficiency. More specifically, the work is intended to demonstrate the capability of sustained operation of the scaled-up equipment for at least 100 hours of continuous operation with both caking and noncaking coals, the demonstration of cold-gas energy-conversion efficiencies of 75 percent, and the demonstration of sufficient steam generation from waste heat recovery to produce a calculated overall energy-conversion efficiency of 70 percent.

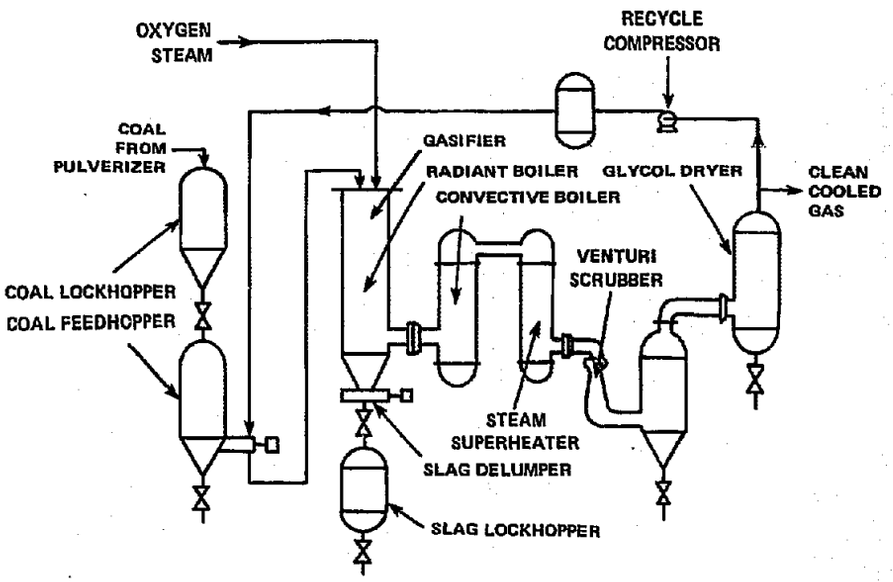

Figure 3. Mountain Fuel Resources 30-Ton/Day Process-Development Unit

A.3 IMPROVED TECHNOLOGIES FOR GASIFIERS–FLUID-BED GASIFICATION

TITLE

Development of Fast Fluid-Bed (FFB) Gasifier

PERFORMER

Hydrocarbon Research Inc., Lawrenceville, NJ

OBJECTIVE

The objective is to develop a low-Btu coal gasification process utilizing the principle of fast fluid-bed operation.

ACCOMPLISHMENTS

A PDU with a 600-lb/hr coal-feed rate was built and operated. The fast fluid bed (FFB) was operated for short intervals and in a continuous air-blown mode for 97 hours. A low-Btu gas product with a heating value of 130 Btu/scf was achieved. The gasifier was operated in the temperature range of 1600° to 1800°F at pressures of 115 to 120 psia. The maximum fluidization velocity in the FFB was 13.7 ft/sec. The product gas was continuously monitored. The significant unit operations in the PDU are shown in Figure 4.

CURRENT WORK

The current work is directed toward the operation of the PDU on caking coals to produce a gas with a minimum heating value of 100 Btu/scf, with coal conversions of up to 80 percent in the air-blown mode. Fines produced in the fast fluid-bed operation will be separated and reinjected into the fast fluid bed.

APPLICATIONS

The FFB coal gasification technology when developed may have a capacity at least 10 times greater than fixed- or fluid-bed gasifiers. When fully developed, such gasifiers may be able to process all types of coals, including caking coals. Other advantages of an FFB gasifier may be: (1) excellent turndown characteristics (the throughput can be changed to meet the needs), (2) no tar production, (3) high thermal efficiency, and (4) amenability to scale-up, such that the development of the FFB may not require progressive scale-up steps from a process-development unit to a commercial unit. The results from the present phase of the evaluation may show that FFB can gasify caking coals at high feed rates per cross section with superior turndown characteristics to produce a product gas low in tars and oils.

TITLE

TRI-GAS Low-Btu Coal Gasification Process

PERFORMER

Bituminous Coal Research, Inc., Monroeville, PA

OBJECTIVE

The objective is to develop a fluidized-bed coal gasification process for the production of low-Btu fuel gas from caking as well as noncaking coals without producing by-product liquids, tar, or char using three reactors connected in series for a continuous integrated operation.

ACCOMPLISHMENTS

Key operations of a 100-lb/hr PDU have been demonstrated, including the following. Illinois No. 6 caking coal has been successfully devolatilized in the Stage 1 reactor, supplying a free-flowing char to Stage 2. In Stage 2, char and volatile tars from Stage 1 have been gasified with air and steam to produce an approximately 150-Btu, tar-free fuel gas. Char from Stage 2 has been further gasified in Stage 3 to produce a high-ash solids discharge and a hot-gas effluent for the gas feed to the devolatilization stage. All three stages have been operated in a completely integrated mode with transfer of solids and gas through the successive stages.

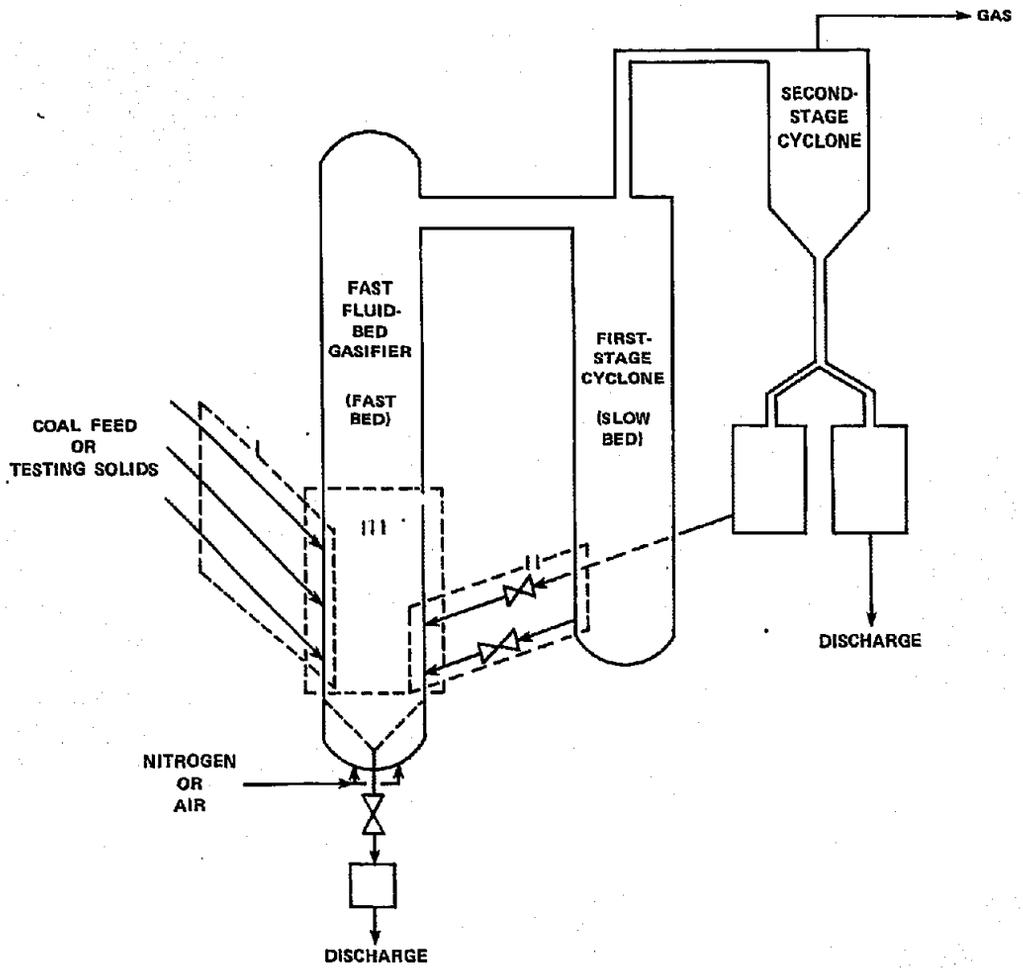

Figure 4. Hydrocarbon Research Fast Fluid-Bed System

CURRENT WORK

A continuing series of equipment malfunctions, many traceable back to deficiencies in the original PDU design, have resulted in only a few integrated runs and these mostly for only a few hours at steady-state conditions. This has necessitated an additional current no-cost extension of the project for a total of 9 months in all in order to carry out all the key runs required under the contract.

APPLICATION

Many observations about fluidized-bed-reactor design and operation are transferrable from the reports on this project to other DOE fluidized-bed coal gasification projects, mostly in terms of problems that can arise and how to avoid or solve them. The three-stage reactor approach on balance does not appear to be an advantageous process, however, because of inherent technical complexities.

A.4 IMPROVED TECHNOLOGIES FOR GASIFIERS – FLUID-BED STUDIES/MODELING

TITLE

Gasification Cold Model

PERFORMER

Pittsburgh Energy Technology Center, U.S. DOE, Pittsburgh, PA

OBJECTIVE

The objective is to determine the fluidization characteristics of various coals and chars in a cold-flow mode. Measurements and visual observations will be made to determine the velocity for minimum and complete fluidization. Jet-penetration parameters will also be investigated.

ACCOMPLISHMENTS

A large cold-flow fluidized bed equipped to operate at pressures up to 1,000 psig and containing 24 observation windows is in operation. Preliminary results are available on pressure drop and fluidization velocity as a function of particle size and operating pressure. Complete fluidization velocity for the -48 + 100 mesh-size particles was found to be strongly dependent on system pressure.

CURRENT WORK

The fluidization work is in progress. In the near future, data on jet penetration and the influence of system pressure on fluidization characteristics will be available.

APPLICATION

The high-pressure fluidization unit at PETC is one of two in existence (the other is at IGT) and will provide information necessary to design fluidized-bed gasifiers.

TITLE

Computer Modeling of Coal Gasification Reactors

PERFORMER

Systems, Science, and Software (S^3), LaJolla, CA

OBJECTIVE

The objective is to develop a general computer model for coal gasification reactors. The model will combine theoretical descriptions of the thermomechanical interactions between the solid and gas phases with a kinetic model of chemical reactions based on the best experimental data available at the time of program development.

ACCOMPLISHMENTS

A one-dimensional model for the fluid bed was completed in 1976 and a program was written for the model for chemical reactions in the fluidized bed. Preliminary two-dimensional bubbling calculations in a gasifier environment simulating the Synthane gasifier were initiated in 1978. A three-dimensional, time-dependent calculation of swirling vortex flow in a simplified combustor was completed for the entrained-flow coal gasification model. The fluid-bed model is being used to predict certain fluid-bed phenomena in fluid-bed cold-flow work at Westinghouse and IGT. The preliminary results for the Westinghouse 18-inch fluid bed indicate that the jet-penetration and bubble-growth dimensions calculated by the S^3 model show good agreement with Westinghouse experimental data. The S^3 fluid-bed model codes have been successfully transferred to the METC computer system. This transfer of the S^3 model codes is one of the objectives of the project.

CURRENT WORK

The work is now directed toward the application of the S^3 fluid-bed model to the prediction of fluid-bed phenomena and gasifier performance.

APPLICATION

The S^3 fluid model may prove useful for predicting fluid-bed gasifier behavior and for possible applicability in scale-up efforts.

TITLE

Computer Modeling of Mixing and Agglomeration in Coal Conversion Reactors

PERFORMER

Jaycor, Del Mar, CA

OBJECTIVE

The objective is to develop a multi-dimensional, time-dependent computer model of mixing, pyrolysis, and agglomeration processes in coal conversion reactors. The reactor to be modeled is the Westinghouse devolatilizer unit.

ACCOMPLISHMENTS

A computer code has been developed for modeling fluid flows containing agglomerating particles. The physical and chemical processes modeled in the computer code range from fluid and particle flow with heat transfer, to pyrolysis, mixing, and agglomeration of the coal.

CURRENT WORK

The model is being applied to simulate a specific set of runs on the Westinghouse devolatilizer to study the flow patterns of incoming coal and recirculation in the bed.

APPLICATION

The model may prove useful for predicting fluid-bed-gasifier behavior.

TITLE

Riser Reactor Studies and Modeling

PERFORMER

Environmental Research and Technology (ERT), Pittsburgh, PA

OBJECTIVE

The objective is to develop a model that will predict the conversion of a chemical reaction occurring in a riser reactor containing a flowing gas-solid suspension. The model is to be developed from experimental studies to be performed by ERT.

ACCOMPLISHMENTS

Under this new contract, experimental studies are underway to identify the wall effects in the riser reactor by characterizing the performance of reactors of 3-, 4.25-, and 6-inch diameter.

CURRENT WORK

ERT is conducting an experimental program to determine: (1) the gas-solid contacting efficiency and residence-time distributions, (2) geometric effects and, thus, relationship to equipment scaling, (3) the role of particle characteristics, and (4) the role of electrostatic effects in the riser reactor. The data obtained from this experimental effort will be used to generate a model of the riser reactor which is capable of predicting the conversion of a chemical reaction occurring in the reactor.

APPLICATION

The model will assist in understanding the performance of the fast-fluid bed gasifier.

Illinois Institute of Technology, Chicago, IL

Solids Circulation Around a Jet in a Fluidized Bed

The objective of this research is to develop an experimentally verified hydrodynamic model to predict solids circulation around a jet in a fluidized-bed gasifier. Hydrodynamic models of fluidization use the principles of conservation of mass, momentum, and energy. To account for unequal velocities of solid and fluid phases, separate phase-momentum balances are needed. The problem of circulation around a jet was broken down into several parts to aid in the analysis. Solids in the jet were assumed to be transported up the jet by pneumatic transport. The pneumatic-transport problem was solved first without reaction and then with reaction for the case of char gasification. To quantitatively understand the reason for circulation, an approximate analytical formula was derived and compared to Westinghouse gasifier studies. An effort is underway to solve the two-dimensional steady and unsteady equations for two-phase flow. Preliminary results produced the expected behavior for dilute phase pneumatic transport, recirculation

patterns, finite jet penetration, and gas mixing. The effect of particle size is being studied by comparing three models with data for pneumatic conveying.

Lehigh University, Bethelhem, PA

Solid Circulation Around a Jet in a Fluidized-Bed Gasifier

The objective of this research is the measurement of particle and gas velocities in the grid region of a fluidized bed using a dual-focus laser velocimeter. A fiber-optic probe was developed for measuring particle velocity in two dimensions. Calibration of this probe was completed using laser Doppler anemometry. The probe is currently being used in a two-dimensional model to determine local particle velocities and thus derive a velocity map for the jet region. A modified probe in a three-dimensional fluidized bed of coal char is being installed for use.

Kansas State University, Manhattan, KS

Local Solids Velocity and Pressure Fluctuation Around a Jet in a Fluidized-Bed Gasifier

The objective of this research is to determine the local properties of a jet in a fluidized-bed gasifier by measuring local particle velocities, local pressure, and pressure fluctuations around the jet, and analyzing these fluctuations using fiber optic and pressure transducer techniques coupled with correlation methods. To date a study was made on the effects of gas velocity, bed height, particle size, and distributor design on the frequency and amplitude of the pressure fluctuations in a fluidized bed. The results indicate that the jet flow immediately above the distributor, the formation of small bubbles near the distributor, the formation of large bubbles in the middle of the bed, and the motion of bubbles at the top of the bed are the major causes of pressure fluctuation in fluidized beds. A dynamic model was derived to describe pressure fluctuations in a gas-solid fluidized bed, and a semi-empirical stochastic model was derived for the dynamics of expansion of the bed.

University of Houston, Houston, TX

Analytical Modeling of Gasification Processes

The objective of this research is to develop a model for a fluid-bed combustor which takes into account the essential features of the system and to examine the relative importance of some model parameters. The model, which uses a fuel feed of char, is based on the two-phase theory of fluidization, and assumes plug flow for the bubble phase and perfect mixing for the dense-phase gas. Preliminary results were obtained using the single-film diffusion-limited model. The influence of mass-transfer units, char-particle size in the feed, and the bed temperature was determined. The model is being further developed using other mechanisms of char combustion.

A.5 IMPROVED TECHNOLOGIES FOR GASIFIERS – CATALYTIC GASIFICATION

TITLE

Catalytic Enhancement of Coal Gasification

PERFORMER

Columbia Gas System, Columbus, OH

OBJECTIVE

The objective is to assess the possible benefits of using a catalyst (sodium carbonate) in the gasification of coal in a fixed-bed gasifier.

ACCOMPLISHMENTS

A bench-scale facility has been constructed and shake-down runs on a Husky char have been completed. Preliminary results indicate that nonslagging operation can be achieved with relativly high levels of sodium-carbonate addition (10 percent by weight sodium on MAF char). At this time, work is progressing on investigation of the effects of the catalyst on nonagglomerating coals.

CURRENT WORK

The current effort consists of 60 experimental coal gasification runs in a large bench-scale facility. The effects of catalyst concentration, catalyst-application technique, coal-particle size, and gasifier temperature and pressure will be assessed for the gasification of a nonagglomerating and an agglomerating coal. The specific areas of interest are tar decomposition by the catalyst, possible reduction in steam and oxygen consumption, and improvements in reactor capacity. In parallel with the gasification experiments, two complementary programs will be implemented to establish a catalyst-recovery process and to determine the effect of the catalyst on the ash-fusion temperature.

APPLICATION

Utilization of a catalyst, Na_2CO_3, in the operation of a fixed-bed gasifier is expected to improve the reaction rates and thus reduce the operating temperature of the gasifier with several beneficial effects. The lower operating temperature will allow less oxygen per pound of coal than in the noncatalyzed gasification of coal. Reduced steam feed will be possible because the lower operating temperature will require less steam to moderate temperatures and the steam that is supplied will be more effectively used through catalytic action. A lower operating temperature can be expected to improve the methane yield from the gasifier as well. Finally, the addition of the catalyst may aid in the decomposition of the tars produced, thus reducing the downstream cleanup problems and possibly providing some useful liquid products without further treatment.

TITLE

Mechanisms of Gasification Reactions in the Catalysis of Coal, Char, and Other Carbonaceous Materials

PERFORMERS

General Electric Company, R&D Center, Schenectady, NY
SRI International, Menlo Park, CA
Rockwell International Corporation, Canoga Park, CA

INTRODUCTION

The development of advanced gasification technologies/process(es) based on catalytic gasification is a major activity in the DOE gasification program both at the PDU-scale level as well as bench-scale level. Catalytic gasification has been found to be one of the more attractive options for producing high-Btu gases. A process under advanced state of development (Exxon catalytic) forms a significant part of DOE's activity in the high-Btu area. Catalytic gasification may also provide sufficient justifications for the development of other concepts in gasification. In spite of the advanced state of development of the DOE-supported Exxon catalytic-gasification process, a clear understanding of the role of key phenomena, mechanisms, and critical parameters in catalytic-gasification reactions does not exist at this time.

OBJECTIVE

The objective of these studies is to: (1) elucidate the mechanisms of action of the alkali

and alkaline earth-based catalysts in catalytic-gasification reactions, (2) identify controlling parameters in catalytic-gasification reactions of coal/char, and (3) obtain the relative activities of the alkali and alkaline earth catalysts in gasification reactions.

ACCOMPLISHMENTS

The studies under these contracts have just been initiated. These studies will continue for 2 years to develop understanding of the catalytic-gasification mechanisms and critical parameters in the reactions of coal/char with different gases.

APPLICATION

These studies are intended to provide a better understanding of phenomena and fundamentals for prereactor and reactor operations in catalytic-gasification processes. The studies may provide information on optimum conditions for catalyst impregnation on coal/char as well as the operation of catalytic-gasification reactors.

TITLE

Coal Gasification Using Chemically Incorporated Catalysts

PERFORMER

Battelle-Columbus Laboratories, Columbus, OH

OBJECTIVE

The objective is to evaluate the hydrogasification and steam-oxygen gasification characteristics of caking coals subjected to a mild pretreatment process involving lime and small amounts of sodium hydroxide in the presence of water and to determine the effectiveness of this impregnation pretreatment for enhancing gasification while preventing agglomeration of caking coals.

ACCOMPLISHMENTS

Caking coals, such as Illinois No. 6, when impregnation-pretreated with 0.15 part lime and 0.01 part sodium hydroxide in water to one part coal, showed steam reactivities up to 10 times greater and hydrogasification reactivities up to 50 times greater than the raw coal. The agglomerating index was reduced and there were no caking problems in at least some runs in the 4-inch fluidized-bed steam-oxygen gasifier at the Pittsburgh Energy Technology Center and in the 2.8-inch continuous-tubular hydrogasification reactor at Battelle. Mild to severe caking was observed on some runs due to either tar condensation during hydrogasification or coal-particle size in excess of 50 mesh during steam-oxygen gasification.

CURRENT WORK

A series of tests is being completed to obtain correlations between treatment conditions for chemically incorporated catalysts in caking coals and their effectiveness in promoting gasification with either steam/oxygen or hydrogen in the absence of agglomeration of the feedstock. A comprehensive final report is being prepared summarizing all the project work.

APPLICATION

The results of this study are complementary to some other studies on coal gasification with catalysts, such as that being conducted at PETC. Due to the potentially favorable economics of a lime-based catalytic process, other gasification processes might benefit by utilization of a cheaper catalyst and/or might use eastern caking coals. However, technical problems appear to limit these potential applications of the Battelle process.

TITLE

Catalytic Effects in Coal Gasification

PERFORMER

Sandia National Laboratories, Albuquerque, NM

OBJECTIVE

The objective is to initiate a study of catalytic effects in coal gasification. Emphasis will be placed on determining the role of inherent mineral matter on the devolatilization and subsequent gasification of coal. The work will be directed toward a fundamental understanding of the mechanisms of catalytic gasification and will attempt to correlate

the properties of several coals with their behavior under various gasification conditions. The ultimate objective will be to develop an understanding of mineral-matter effects and other catalytic effects in coal gasification.

ACCOMPLISHMENTS

Five high-volatile bituminous coals whose mineral matter content varies from about 5 to 25 percent have been selected for this study. Each coal has been chemically and physically characterized. Baseline studies of the gasification rates of these coals in nitrogen and hydrogen have been completed at 600°, 800°, and 1000°C. A gas-sampling device has been constructed for a thermogravimetric-analysis (TGA) system which will sample the product-gas stream at selected time intervals, followed by gas-chromatographic (GC) determination of gas composition.

CURRENT WORK

The gasification rates of demineralized coals, prepared using float-sink techniques, are being measured under gasification conditions used in the baseline studies. The effect of added mineral matter on demineralized coals and on low-ash coals for the gasification rate and product-gas distribution is being determined. In addition to studying the gasification rate following devolatilization, the mineral-matter effects during the rapid devolatilization period of coal gasification are being investigated through the use of a rapid-pyrolysis unit which is connected to the input of a gas chromatograph. Raw coal, demineralized coal, and coal with added mineral matter are being used under various rapid-pyrolysis conditions.

APPLICATION

This program is providing technical support to coal gasification processes in general by clarifying the effect of mineral matter in the gasification of coal. The primary thrust for this work is to obtain a fundamental understanding of the mechanism of catalytic action of mineral matter in coal gasification.

TITLE

Catalytic Gasification

PERFORMER

Pittsburgh Energy Technology Center, U.S. DOE, Pittsburgh, PA

OBJECTIVE

This project is providing further information on the catalytic gasification of coals by studying the catalytic effects of the cations and anions present in the catalysts.

ACCOMPLISHMENTS

Gasification results are available for coals impregnated with 5-percent concentration of monocatalysts. A total of 160 runs has been made. The experimental data from all the bench-scale experiments is being entered in computer files. The continuous 4-inch fluid-bed gasifier has been used to evaluate catalyst-impregnated coals prepared under DOE programs, such as Battelle Treated Coal (BTC).

CURRENT WORK

Experiments are in progress to ascertain the effect of various feed gases on the gasification kinetics of K_2CO_3-impregnated coals. Coal samples impregnated with bi-catalysts are being prepared for the 4-inch gasifier.

APPLICATION

The gasification results from the bench-scale and 4-inch gasifier provide useful data for the DOE catalytic-gasification program.

TITLE

Catalytic Coal Conversion Support

PERFORMER

Los Alamos National Laboratory, Los Alamos, NM

OBJECTIVE

The objective is to determine the changes in coal structure produced by heating in the presence of catalysts and gas atmospheres typical of various candidate processes for catalytic coal conversion.

ACCOMPLISHMENTS

Various coals were heated in the presence of atmospheres of He, N_2, H_2, CO, CO_2, or H_2O to fixed temperatures over the range of 100° to 600°C. The same coals were impregnated with aqueous solutions of various alkaline, alkaline earth, and transition metal salts before heating. Comparisons in coal-structure changes were made by means of fragmentation of the coal structure by beams from CO_2 and Nd lasers, and analysis of the fragments was made by gas-liquid chromatography and mass spectrometry. Significant changes in the proportions of aliphatic, aromatic, and heteroaton (S,O,N) building blocks in the coal structure occurred by heating in the presence of the catalysts. These preliminary results indicate that specific changes in coal structure catalyzed by materials used in catalytic processes under study by other contractors (such as Battelle-Columbus and Columbia Gas) can possibly be determined and these processes thereby be better understood.

CURRENT WORK

The structural changes in coal are being compared with those in polymeric models of known structure simulating that of coal. For example, the natural polymeric precursor of coal, wood lignin, not only yields remnants of its building blocks, such as methoxyphenol, during heating, but also indene, a product of ring closure reactions which is produced by heating coal as well.

APPLICATION

This project has the potential for elucidating hitherto unknown changes in coal structure during heating and the catalysis of these changes during coal-conversion processes.

A.6 IMPROVED TECHNOLOGIES FOR GASIFIERS – GASIFICATION SUPPORT STUDIES

West Virginia University, Morgantown, WV

The Role of the CO-CO_2 Reactions in the Gasification of Coal and Char

The objective of these studies is to: (1) investigate the role of coal mineral matter in the gasification reactions of char at different gasification conditions and (2) study entrainment and bed properties in fluidized beds. Results available up to this time show that Ca plays a very significant role in the gasification reaction. A kinetic model relating the kinetics to the gas composition as well as the concentration of Ca in the char materials has been established. A preliminary model relating effect of fluidization variables to the amount of entrained solids has been established. Current and future work will continue to refine the kinetic models for applicability to the C-CO_2 reactions at temperature ranges analogous to entrained-gasification situations. The work on the fluidized-bed studies will broaden the investigation to include a wider set of fluidized-bed operating conditions to evolve more generalized entrainment correlations.

Massachusetts Institute of Technology, Cambridge, MA

Critical Studies in the Rapid Pyrolysis and Hydropyrolis of Coal (Task Order No. 26)

The objective of this research is to determine the effects on product yields, compositions, and rates of formation in the rapid pyrolysis/hydropyrolysis of coal of the following factors: coal types, temperature, H_2 partial pressure, coal-particle diameter, mineral matter, and extent of secondary reactions of volatiles. Results available at this time show that almost all of these factors influence product distributions and compositions. Particle swelling and agglomeration is more pronounced for small particle diameters. The presence of added amounts of certain mineral matters reduced the yields of heavier hydrocarbon gases and light hydrocarbon liquids at relatively long residence times. For close to zero holding times, the results on the yields of light hydrocarbon gases shows increased as well as decreased yields depending on the type of additives used. Work is being continued to elucidate and complete data on the effects of other factors.

Pennsylvania State University, University Park, PA

Kinetics of Coal Pyrolysis and Gasification

The major objectives of this research are: (1) to study pyrolysis and gasification of as-received and pretreated coals following their rapid heating and short contact times at maximum temperature in N_2, steam, and syngas atmospheres by following coal weight loss and physical properties of the resulting chars, (2) to measure continuously the major gases produced during the isothermal pyrolysis and gasification of as-received and pretreated coals in high-pressure steam following their rapid heating to maximum temperature, (3) to measure the catalytic activity of inorganic constituents in chars derived from as-received and pretreated coals for the concurrent methanation and hydrogasification reactions, and (4) to cross-correlate all data. Currently, kinetic data on the gasification rates of pretreated char is being evaluated. Preliminary results with char gasification suggest that structural changes accompanying gasification might play a major role in gasification rates.

Case Western Reserve University, Clevland, OH

Kinetics of Coal-Char Gasification at Process Conditions

The objective of this work is to provide a better data base for coal gasification processes by determining the rate of coal-char gasification with steam, carbon dioxide, carbon monoxide, and hydrogen at practical process conditions. To date a novel third-generation thermobalance has been designed and assembled to provide more accurate kinetics data. The new design allows good gas-solid contacting and should produce kinetic data that is directly applicable to gasification under processing conditions. The current effort will utilize this thermobalance to determine the effect of the char-particle surface area,

porosity, and morphology on the gasification rate.

Brigham Young University, Provo, UT

Prediction and Measurement of Optimum Operating Conditions for Entrained Coal Gasification Processes

The general objectives are: (1) to conduct an experimental investigation of pulverized coal gasification processes to determine optimum operating conditions, (2) to obtain detailed gasification maps of gas and particle profile data of composition inside the gasifier for a family of coal types, and (3) to complete the development of a generalized two-dimensional model. A 300-lb/hr entrained-bed gasifier is used and particle/gas samples are withdrawn from the gasifier using specially designed water-quenched probes. Mixing and particle reaction in the reactor is determined by analysis of gas streams and inert tracers. To achieve an overall goal of developing a coal gasification model, a gas-phase combustion model, a coal submodel, and a radiation submodel are currently being developed.

City College, The City University of New York, New York, NY

Studies Toward Improved Techniques for Gasifying Coal

The objective of this research is to provide an experimental basis for improving the economic attractiveness of coal gasification processes by the cogeneration of gaseous fuel and high market value, light liquid fuel, such as BTX, through flash pyrolysis in steam and steam-hydrogen mixtures. In work to date in laboratory-scale experiments on the flash (1-second) hydrolysis of Illinois No. 6 coal in 50 atmospheres of pure steam, a yield of 68 percent carbon conversion to liquid product was obtained at 900°C (120 seconds of coal heating). The gas yield was 20 percent consisting of approximately equal amounts of methane, carbon monoxide, and carbon dioxide. The residual char was only 12 percent. These conditions may prove to be optimum for maximum liquids production. Currently, determinations are being made of relative yields of liquid, gas, and char and the gas composition and the variation of these with reactant gas composition (steam, steam/hydrogen), reactant gas pressure (1 to 100 atm), heating rate (20 to 2000°C per second), vapor residence time (0.1 to 100 seconds), and solids contact time (2 to 300 seconds).

University of Pennsylvania, Philadelphia, PA

Kinetic and Modeling of the Oxidative Pre-Treatment of Coal

The objective of this research is to investigate the rates at which a variety of coals change their properties when subjected to moderate temperature drying and mild gas-phase oxidation, and to correlate the effectiveness of such treatment on the agglomerative properties of the coals. The coals pretreated at various conditions of temperature, pressure, and particle size will be evaluated by a thermomechanical expansion test for correlation with the oxidative changes. Models are to be developed that can be used to explain, predict, and interpret practical results for a wide range of coals. The physical properties of a variety of coals, specifically, the reduction in caking propensity as the result of mild oxidative pretreatment and the change in porosity and surface area as the result of moderate-temperature drying and oxidation, were determined. Highly caked coal was rendered virtually noncaking by oxidation at 200°C. Coal drying generally reduced coal porosity, surface area, and particle-size distribution. The degree of change varied directly with original water content of the coal.

California Institute of Technology, Pasadena, CA

Gasification of Residual Oils in Molten Phosphates

The objective of this research is: (1) to study gasification of residual oil in molten phosphate, wherein the residual oil may crack to low paraffins and olefins and to coke suspended in the melt, by studying major process reactions such as steam reforming of light hydrocarbons, steam gasification of coke, and air combustion of coke in the melt, (2) conduct cold-flow experiments to estimate the flow dynamics of the molten bath reactor, and (3) to combine kinetic and flow data to develop a mathematical model of the reactor

system. Steam reforming of methane experiments at 787° to 1007°C indicated that the methane decomposition reaction is kinetically controlled and the the steam-carbon reaction is relatively slow and controlled by transport processes. The molten bath of sodium phosphate significantly catalyzed steam reforming of methane so that cracking of methane was slower than steam reforming. Experiments with carbon particles (subbituminous char and petroleum coke) showed that the phosphate salt significantly catalyzed the steam-carbon reaction. The cold-model experiments were completed. Experiments with petroleum coke are continuing and the data on the cold-model experiments are being analyzed.

University of Utah, Salt Lake City, UT

Process-Development Studies in Coal Gasification

The objective of this research is to optimize a single-stage catalytic coal gasification concept for the production of high-Btu gas and to investigate the steam reforming of aromatic compounds found in coal and coal-derived liquids. In the area of catalytic gasification, coal will be slurried in a hydrogen donor solvent, tetralin, and several sulfided-metal catalysts and process variables will be investigated in an attempt to optimize the production of methane in a single-stage reactor. Work will also be undertaken to determine the reaction mechanisms and kinetics of the steam reforming of the aromatic compounds found in coal in an attempt to develop a catalyst with suitable activity and sufficient life for these reactions.

Vanderbilt University, Nashville, TN

Influence of Changing Particle Structure on the Rate of Gas-Solid Gasification Reactions

The objective of this research is to determine the changes in the particle structure of coal as it undergoes the reaction, $C + CO_2 \rightarrow CO$. Changes in the structural parameters such as surface area available for reaction, porosity, and pore size distribution will markedly affect the rate of gas-solid reactions. Accompanying these changes in structural parameters are changes in the resistance to diffusion of gaseous products and reactants through the pores of the solid. An experimental system, which combines a pulse reactor with a flow-type BET apparatus will be used to study the influence of a changing coal-solid structure on the gas-solid reaction, $C + CO_2$. The reaction will be carried out at temperatures between 500° to 1100°C and pressures up to 1 atmosphere with several coals from major seams in Kentucky, Illinois, and Tennessee. Measurements of surface area and effective diffusivity will be made prior to the reaction, and then at several solid conversions. The functional relationship between surface area and conversion, and effective diffusivity and conversion will be determined. The effect of these changing parameters will be included in the overall rate expression. A test of the validity of the overall rate expression for predicting conversion will also be performed.

A.7 GAS-STREAM TREATMENT AND PROCESSING – NOVEL ACID-GAS REMOVAL

TITLE

Development of the CNG Acid-Gas Removal Process

PERFORMER

CNG Research Company, Cleveland, OH; Subcontractor: Helipump, Inc., Cleveland, OH

OBJECTIVES

The objectives are: (1) to acquire fundamental data to further develop and define the CNG acid-gas removal process for high-CO_2 content medium-Btu gases, (2) to acquire data and test preliminary concepts for the development of low-temperature cryogenic processes for the removal of acid gases from low-CO_2 content medium-Btu gases, and (3) to conduct impact-assessment studies on gasification process upsets on the CNG acid-gas removal process.

ACCOMPLISHMENTS

The bench-scale equipment for the acquisition of vapor-liquid-solid equilibrium data has been modified and constructed. The crystallizer unit to study the crystallization implications for the process is undergoing modification. At the same time, assessment of the cryogenic implications of trace species found in gas streams on the overall process has been partially accomplished from information found in published literature.

CURRENT WORK

The current work pertains to the acquisiton of basic vapor-liquid-solid equilibrium data and crystallization data. The configurations for the acid-gas removal process with regard to medium-Btu gases with high-CO_2 contents have been established; present activites are attempts to refine the configurations and designs to obtain better separations and economics. These techniques and concepts are being applied to generate analogous configurations for the removal of acid-gases from low-CO_2 content gases.

APPLICATION

Acid-gas removal from medium-Btu gases intended for various applications, e.g., high-Btu gas manufacture and indirect liquefaction or chemical synthesis, is one of the more costly unit operations in different gasification processes. The development of novel, more efficient, and less capital-intensive acid-gas removal processes would improve the economics of existing and new gasification processes.

A.8 GAS-STREAM TREATMENT AND PROCESSING – PARTICULATE REMOVAL

TITLE

Performance of Gas-Atomized Spray Scrubbers at High Pressure

PERFORMER

Air Pollution Technology, Inc., San Diego, CA

OBJECTIVE

The objective is to determine the performance of venturi scrubbers in removing particulates from high-pressure gas streams in terms of collection efficiency and power consumption.

ACCOMPLISHMENTS

Facility design, fabrication, and shake-down have been completed. Baseline testing at atmospheric pressure has been successfully concluded and work is progressing with elevated-pressure testing.

CURRENT WORK

Although venturi scrubbers have been considered for use in removing particulates from gasifier fuel-gas streams, theoretical calculations indicate a deterioration in scrubber performance with increasing pressure. APT is conducting a bench-scale experimental program to determine the effects of pressure, venturi-throat velocity, liquid-to-gas ratio, and scrubber geometry on the collection efficiency and power consumption of the venturi scrubber. The data generated by the effort will be used to develop a computer model to predict the performance of venturi scrubbers at high pressure and to aid in improving scrubber design.

APPLICATION

This study will assess the applicability of gas-atomized spray scrubbers for removal of particulates from high-pressure gas streams.

TITLE

Laminar Flow-Cyclone Development Program

PERFORMER

General Electric Company, Schenectady, NY

OBJECTIVE

The objective is to develop a laminar flow-cyclone concept so as to achieve relatively high operating Reynolds numbers such that high inlet velocities can be obtained in realistically sized cyclones.

ACCOMPLISHMENTS

A principal constraint to achieving high Reynolds-number laminar operation in a cyclone was presumed to be due to boundary-layer instability in the radial-inflow region. A modified water-flow model with heated walls was studied to determine the temperature differential between the heated plate and the swirling radial inflow as an indicator of boundary-layer stability. Recent testing has extended the swirl Reynolds number to 3.8×10^5 (10-fold increase) by using partial flow admission to the model. Stable flow in the radial-inflow region suggested that boundary-layer instability was not a constraint. In addition, laminar flow was not destabilized by wake turbulence, wall roughness, or skewed boundary layer.

CURRENT WORK

The present approach is to design and manufacture an axial flow-cyclone model for stability testing in the cylindrical region. Work will be directed toward studying the ability to maintain laminar flow in the radial-to-axial flow turn and on the cylindrical cyclone walls.

APPLICATION

This work is an attempt to generate a concept for affecting a marked reduction in collection "cut" size, to improve collection efficiency, to increase throughput per unit volume, and to reduce cost relative to more conventional high-efficiency collectors.

A.9 GAS-STREAM TREATMENT AND PROCESSING – ALKALI AND PARTICULATE REMOVAL

TITLE

Simultaneous High-Temperature Removal of Alkali and Particulates in a Pressurized Gasification System

PERFORMER

Westinghouse Electric Corporation, Pittsburgh, PA

OBJECTIVE

The objective is to demonstrate the feasibility of a hot-gas cleaning process to minimize the concentration of alkali in a high-temperature fuel gas with simultaneous particulate removal through the use of aluminosilicate getters. The gettering capacity for each of the selected materials will be kinetically defined, the gettering mechanism will be delineated, system performance projections for a coupled alkali and particulate-removal system will be developed, and the system performance projections will be utilized to define a plan for concept scale-up.

ACCOMPLISHMENTS

Bench-scale fixed-bed experiments have been completed for evaluating the gettering performance of kaolin, char ash, and gasifier ash. Preliminary results from these experiments show that all three materials have satisfactory gettering performance for removing alkali chlorides from simulated hot low-Btu gases. The effects of different temperature ranges on gettering capacity and the distribution of "soluble" and "insoluble" alkali on gettering materials have been established. A double-balance high-temperature and high-pressure TGA has been constructed and a few preliminary runs to establish the kinetics have been completed. Preliminary assessment of system performance for alkali and particulate removal from hot-gas streams using a kaolin fixed bed shows that alkali and particulates can be removed with almost negligible cost even if the kaolin is assumed to be nonregenerable.

CURRENT WORK

Work is being continued to complete getter characterization and performance using simulated gas-stream compositions, including water vapor, Na and K alkali hydroxides, sulfides, etc. Tests on other gettering materials, e.g., alumina, will be performed as well. Process thermodynamic projections will be made to aid in the process modeling and concept scale-up studies to be performed following the acquisition of all test data.

APPLICATION

The development of the alkali and particulate entrapment concept(s)/process will fill one of the necessary technology gaps in evolving an advanced low- or medium-Btu gasification system for integration with a combined-cycle power-generation plant. The removal of alkali and particulates from hot medium- or low-Btu gas streams intended for use in turbines is necessary to prevent corrosion, erosion, and deposition problems on turbine materials.

A. 10 GAS-STREAM TREATMENT AND PROCESSING – SULFUR REMOVAL

TITLE

Development of a Solid-Absorption Process for Removal of Sulfur from Hot Fuel Gases

PERFORMER

Battelle Pacific Northwest Laboratories, Richland, WA

OBJECTIVE

The objective is to develop and demonstrate on a bench-scale level a process for removing sulfur from reducing gases at temperatures above 700°C. The process being developed is based on the use of molten alkali and alkaline earth eutectics within the pores of selected support materials. Preliminary system-performance analysis will be conducted following completion of bench-scale sulfur-removal and sorbent-salt regeneration experiments.

ACCOMPLISHMENTS

Porous materials were screened and tested for crushing strength following long periods of exposure to alkali and alkaline earth mixtures under a hot reducing environment. Resulting tests with three porous substrates, namely, lithium aluminate, magnesium oxide, and zirconium oxide, showed no evidence of deterioration when exposed to hot reducing process environments for periods ranging from 2 to 4 weeks. Packed-bed absorber tests, using a couple of the porous substrates doped with alkali and alkaline earth salt eutectics, with simulated syngas mixtures passed through the bed, show that the levels of sulfur concentrations in effluent gases can be below 100 ppm over significantly long periods. Regeneration experiments on these packed beds with steam and carbon dioxide show that total sulfur levels within effluent hot regeneration streams can be as high as 35 percent. There is some evidence to show that during the regeneration a small fraction of the sulfur present may be converted to sulfite or sulfate which may not be regenerable.

CURRENT WORK

The work is being continued to fully explore parametric aspects of the absorption of sulfur from the hot syngas mixtures and regeneration of the doped sorbents using steam and carbon dioxide. The effect of the addition of small amounts of H_2 and/or CO in the regeneration streams to prevent sulfite/sulfate formation is being explored.

APPLICATION

The process being developed/explored can form one of the elements necessary for the cleanup of hot-gas streams for use in power-generation applications.

TITLE

Improved Methods of Removal or Recovery of Major, Minor, and Trace Elements in Coal Conversion Processes

PERFORMER

Institute of Gas Technology, Chicago, IL

OBJECTIVE

The objective is to continue the work on the removal of COS, NH_3, and H_2S from syngas. The syngas is to be desulfurized at high temperatures.

ACCOMPLISHMENTS

The previous work on COS and NH_3 removal shows that the most effective catalysts are based on beryllia, calcium oxide, and magnesia. HCN removal was also feasible with catalysts suitable for decomposing COS. The hot-desulfurization process being developed is based on regenerable solid sorbents. The solid sorbent is a mixture consisting of conventionally proven zinc oxide and other additives being developed by IGT. During the regeneration of such a sorbent, elemental sulfur is produced. When such a desulfurization process is fully developed, the by-product will be only sulfur and no oxides of sulfur.

CURRENT WORK

The desulfurization tests are being run on a PDU. The data from these tests is expected to further confirm the feasibility of hot-gas desulfurization technology.

APPLICATIONS

An extensive effort is being made at IGT for syngas desulfurization and for the removal of other contaminants, e.g., COS and NH_3. The development of such technology is expected to have widespread application in low- to high-Btu gas production, combined-cycle, and fuel-cell programs. The removal of NH_3 is becoming important because NH_3 is considered a source of nitrogen-oxide emissions in combined-cycle systems. Presently the H_2S hot-gas cleanup results are being used by METC for their hot-gas cleanup program.

A.11 GAS-STREAM TREATMENT AND PROCESSING – TAR CONVERSION

TITLE

Bench-Scale Development of Catalysts for Reforming Aromatic and Heterocyclic Hydrocarbons

PERFORMER

R. M. Parsons, Pasadena, CA

OBJECTIVE

The objective is to develop a catalyst or catalysts capable of converting coal-derived organic and heterocyclic liquids boiling above 400°F to synthesis gas (H_2, CO, CO_2, and some CH_4) and lighter liquids in the presence of sulfur.

ACCOMPLISHMENTS

The catalyst development work is being done by Engelhard. Catalysts prepared to date were evaluated for stability in a high-temperature steam environment, and two catalysts were found to be stable at 1000°F. These catalysts can tolerate up to 20 percent organics (oils) in the process gas. When the concentration of the organics becomes greater than 20 percent by volume in the process gas, coke forms on the catalyst.

CURRENT WORK

The work on the development and evaluation of the catalysts in bench and PDU scale is in progress.

APPLICATION

The development of a successful catalyst system will make it possible to convert tars and oils from the gas stream prior to the use of shift and methanation reactors.

University of California, Berkeley, CA

Dew Points of Hot Gases Containing Condensible Tars

The objective of this research is to obtain the fundamental physical-chemical and thermodynamic data for condensation of tars required for rational design of heat exchangers to recover sensible heat from hot, pressurized, tar-containing gases produced by coal gasification. To date, coal tars have been characterized and fugacity coefficients obtained for dew-point calculations. Vapor pressures have been obtained for high-molecular-weight hydrocarbons and their nitrogen or sulfur analogues, including the use of a group-contribution method. The calculation of dew points under equilibrium conditions has resulted in a thermodynamic analysis of the dew-point phenomenon at high pressures. Currently, experiments are being continued to obtain fundamental understanding and direct experimental data on the conditions where tars condense from hot gases from coal gasification processes. Appropriate theoretical models are being developed to provide a firm thermodynamic basis for the experimental information.

Clark University, Worcester, MA

Thermal and Catalytic Cracking of Tars from Coal Gasification

The objective of this research is: (1) to investigate the thermal cracking of representative coal gasification product tars in the presence and absence of various inexpensive catalysts for the purpose of determining the operating conditions for maximizing gas and char production, and (2) to screen coal gasification product chars, coal ash, aluminosilicates, clays, and iron-rich by-products to determine their effectiveness as tar-cracking catalysts. Work in this new project makes use of a laboratory-scale fixed-bed reactor for operation at 400° to 1500°C and 1 atm, with variable nitrogen or syngas/tar vapor flow rates. Included will be the determination of optimum conditions for control of carbon deposition on the catalytic materials and development of kinetic models for the cracking reactions based on the experimentally determined reaction rates.

Massachusetts Institute of Technology, Cambridge, MA

Rapid Pyrolysis of Coal by Hot Solids in a Fluidized-Bed Combustor (Task Order No. 27)

The objective of the work is to experimentally determine the extent to which pyrolysis of coal in the presence of dolomitic solids yields liquids and gases with either total or near-total removal of sulfur and CO_2. Preliminary results available show that the pyrolysis of coals in a fluidized bed in the presence of dolomitic solids: (1) yield much lighter liquid (tar) products with a higher H/C ratio; (2) is accompanied by a total removal of H_2S from the gas stream and a substantial amount of CO_2; and (3) yields a larger fraction of H_2, CH_4 and C_2's, and lower CO. Current and future work will concentrate on parametric investigations on the effect of reaction conditions on yields, distributions, and conversions. Part of the work will also be devoted to the determination of the catalysis implications of dolomites (or CaO) on tar conversion.

A.12 GAS-STREAM TREATMENT AND PROCESSING – GAS SEPARATION

TITLE

Hydrogen/Methane Separation

PERFORMER

Pittsburgh Energy Technology Center, Pittsburgh, PA

OBJECTIVE

The objective is to determine the feasibility of separating gas components by adsorption using activated carbons as an alternative to cryogenic separation in coal gasification processes. Conduct experiments in bench-scale hardware using synthesized gas mixtures representative of hydrogasifier product streams and operating pressures.

ACCOMPLISHMENTS

Construction of the experimental unit designed to investigate hydrogen/methane separation by adsorption on activated carbon was completed. Shakedown testing was begun upon completion of unit construction. Calgon provided samples of the three activated carbons that were recommended for their capacity, ease of regeneration, and physical strength.

CURRENT WORK

Mixtures of hydrogen and methane are being tested under various conditions of pressure, temperature, etc., for separation on the different activated carbons.

APPLICATION

Data on the rate and amount of adsorption of hydrogen and methane on the different activated carbons and the effects of other gas components, such as carbon monoxide and carbon dioxide, can be used to design and operate a process development hypersorber unit for practical separation tests.

State University of New York at Buffalo, Buffalo, NY

Low-Energy Process for Separating Hydrogen and Methane

The objective of this research is: (1) to compare heat-treated coals (300° to 800°C) with activated carbons for the fixed-bed adsorptive separation of methane from hydrogen and hydrogen sulfide from methane/hydrogen over the temperature range of 50° to 300°C and pressures up to 1,000 psig, and (2) to conduct a preliminary cost analysis and technical assessment of a combined separation-cleanup process. This new work is based on experimental determinations of the adsorption and desorption isotherms and isosteric heats of adsorption for methane, hydrogen, and hydrogen sulfide on heat-treated Pittsburgh bituminous and Wyoming lignite coals and a commercial activated carbon. The coal type and the heat-treatment temperature which gives the highest capacity for methane sorption and the lowest temperature difference between adsorption and stripping will be identified. An analysis of energy requirements will be made based on this temperature difference and the separation process with the lowest energy requirements and costs will be defined. Preliminary design and assessment of the combined separation-cleanup process will be made.

TITLE

Feasibility of Hypersorption for Separation of Low-Btu Gas

PERFORMER

Dravo Corporation, Pittsburgh, PA

OBJECTIVE

The objective is to evaluate and determine the feasibility of using the hypersorption adsorptive fractionation process for the separation of the components of gas derived by gasification of coal.

ACCOMPLISHMENTS

From values supplied by Calgon Corporation of adsorptivities and adsorptive capacities of selected activated carbons for the components of low-Btu gas at various temperatures and pressures, engineering calculations have been made for their theoretical separability and the operating parameters for hypersorber

towers. All components were found to be separable, including the N_2/CO combination which is theoretically the most difficult to separate. However, the separation of these two components would require an unacceptably high circulation rate of activated carbon through the tower. Thus, it was concluded that the hypersorption process cannot be used to remove nitrogen from low-Btu gas for the production of medium-Btu gas.

CURRENT WORK

This study is being continued for the remainder of the contract period to determine the feasibility of the separation of H_2 from other components, such as CO, obtained by an oxygen-blown gasifier.

APPLICATION

This study is complementary to a bench-scale experimental study at the Pittsburgh Energy Technology Center on the separation of H_2 and CH_4 by the hypersorption process using Calgon Corporation activated carbons and to a laboratory-scale experimental study at the State University of New York at Buffalo on separation of H_2, CH_4, and H_2S, using pretreated coals as adsorbents. The hypersorption process has possible advantages over other separation processes and a thorough determination of its capabilities and limitations has not previously been made for gases derived from coal.

A.13 GAS-STREAM TREATMENT AND PROCESSING – SHIFT/METHANATION

TITLE

Shift Conversion and Methanation in Coal Gasification

PERFORMER

SRI International, Menlo Park, CA

OBJECTIVE

The objective is: (1) to evaluate the performance of an iridium-promoted nickel on alumina catalyst by bench-scale tests under conditions simulating commercial plant operations; (2) to compare the performance with that of other methanation catalysts in the presence of sulfur poisons; and (3) to assess the potential of the promoted catalyst in a combined shift-methanation process.

ACCOMPLISHMENTS

An iridium-promoted nickel (25 percent) on alumina catalyst developed at SRI was compared with a commercial Ni/Al_2O_3 catalyst, using H_2/CO feeds with 1.5 ppm H_2S at 50 psig and 518°F. The catalysts were also tested with dilution with 5 parts of alumina. Deactivation rates were determined in terms of loss in conversion to methane with exposure time and the breakthrough of H_2S. After 800 hours operation of the diluted catalysts with a H_2/CO of 3.1, the commercial catalyst lost nearly 99 percent of its initial activity whereas the promoted catalyst lost only 25 percent. Comparison of poisoning rate constants from methane production rate decay and sulfur breakthrough demonstrated that the alumina diluent does not affect deactivation by H_2S.

CURRENT WORK

The project work is being concluded with a similar study of the effects of nitrogen, principally as ammonia, on the activity and useful life of the promoted catalyst in comparison with the commercial catalyst, and a final report is being prepared.

APPLICATION

Results obtained at SRI are of significance in the development of a practical process for commercial production of synthetic natural gas from synthesis gas. The promoted catalyst has been calculated to have a 25-month plant life compared to 9 months for the commercial catalyst. In addition, the promoted catalyst has high activity for the water-gas shift reaction and high methanation activity with feedstocks containing less than stoichiometric H_2/CO. Combined shift/methanation operation is expected to have technical and economic advantages over separate conversions. This project is complementary to the Bituminous Coal Research project on combined-shift conversion and methanation in coal gasification insofar as it supplies sulfur-poisoning correlations.

TITLE

Combined Shift and Methanation in a Fluidized-Bed Reactor

PERFORMER

Bituminous Coal Research, Inc., Monroeville, PA

OBJECTIVE

The objective is: (1) to demonstrate the feasibility of employing a gas-phase fluidized-bed catalytic reactor to carry out simultaneous shift and methanation reactions in a single pass, and (2) to conduct bench-scale and PDU tests with various catalysts at about 1000 psig and 800° to 1100°F, using H_2/CO of 2 (without steam addition) and H_2/CO of 1, with a steam/dry-gas ratio of about 0.1 to 0.2.

ACCOMPLISHMENTS

In the initial stage of this 15-month project, a bench-scale unit was constructed and an existing PDU (1 ft^3 catalyst capacity) partially modified for the contracted tests. Bench-scale tests with United Catalysts, Inc., proprietary catalyst and Harshaw Ni/Cu/Mo on alumina catalysts with H_2/CO of 2 showed good initial conversions, falling off during the 12-day period. A PDU test with fresh Harshaw catalyst showed 14 hours of stable operation with H_2 CO of 1 and steam/ gas of 0.1. A

PDU test with spent Harshaw catalyst (2.0 percent carbon) showed declining activity over 5 days with H_2/CO of 1 requiring a decrease of the steam/gas below 0.1. Other catalysts were investigated, such as Climax Ni/Mo.

CURRENT WORK

Brigham Young University has begun subcontracted studies of carbon desposition and catalyst regeneration. Current problems in obtaining suitable components to complete the PDU modification and in obtaining catalysts in sufficient quantity or desired formulation have resulted in delays in the testing schedule, requiring a 90-day, no-cost extension of the contract to 15 months.

APPLICATION

Results from this work can be of value in the development of processes for upgrading medium-Btu gas from the gasification of coal to pipeline quality synthetic natural gas. By combining the shift and methanation steps in a single reactor, these processes may obtain technical and economic benefits. Gas-phase fluidized-bed operation has shown good temperature control of the exothermic reaction, and inhibited rates of carbon formation at elevated temperatures (950°-1050°F) have been shown. This project is complementary to the SRI International project on combined-shift conversion and methanation in coal gasification insofar as it supplies carbon-deposition/temperature correlations.

TITLE

Liquid-Phase Methanation/Shift-Process Development

PERFORMER

Chem Systems, Inc., Fairfield, NJ

OBJECTIVE

The objective is to advance the development of the Chem Systems liquid-phase shift/methanation process by determining the rates of carbon formation on various catalysts, and by evaluating the hydrodynamics of a three-phase fluidized-bed reactor.

ACCOMPLISHMENTS

Five commercially available catalysts are each to be tested for 100, 300, 600, and 1,200 hours at 900°F and 1,000 psig with a feed gas of 63 percent hydrogen, 19 percent carbon monoxide, 2 percent carbon dioxide, and 16 percent methane (0.15 mole percent steam added). The nominal space velocity in the bench-scale test unit is 10,000 per hour. Samples of the carbon-deposited catalysts produced in these time tests will be evaluated for methanation activity on a daily basis. Regeneration tests of the 1,200-hour catalyst samples obtained both with and without steam addition will involve decoking by means of combustion with low-oxygen content gas, reduction with hydrogen, and determination of the methanation activity level. Data will be obtained and interpretation of the results made for carbon deposition during methanation, for activity determinations of the carbon-loaded catalysts, and for the catalyst-regeneration tests. The hydrodynamics of a three-phase fluidized-bed liquid-phase methanation reactor will be evaluated and a model developed. This design model is to be based on prior Chem System findings with a pilot-plant reactor.

CURRENT WORK

Carbon-deposition/activity-determination tests have been started on the bench-scale unit. Preliminary calculations on the hydro-dynamic model will be made after assembling prior pilot-plant test data.

APPLICATION

A thorough assessment of catalyst properties and composition for minimum carbon deposition, and determination of the rate of carbon deposition on various catalysts, can lead to significant improvement in catalyst activity and catalyst life in combined-shift/methanation reactors. The fluid dynamics of a three-phase system can allow poor contacting of the reactant gas with the surface of the catalyst solids suspended in the liquid. Therefore, the evaluation of the hydrodynamics of a three-phase fluidized bed could lead to a significant improvement in catalyst activity for this type of reactor. This project on a liquid-phase fluidized system is complementary to the

project with Bituminous Coal Research on a gas-phase fluidized-shift/ methanation system.

University of Wisconsin, Madison, WI

Iron-Induced Deactivation of Raney and Supported Nickel Methanation Catalysts

The objective of this research is to study the deactivation of Raney nickel and supported nickel methanation catalysts due to iron-carbonyl adsorption on and incorporation into the catalyst by a unified approach that combines chemical kinetics, dynamic adsorption measurements, and in situ spectroscopy. A region of "safe" operating conditions was defined by thermodynamic equilibrium calculations that used the $Ni(CO)_4$ partial pressure as a criterion. It was also established that the deactivation of Ni-Al_2O_3 methanation catalysts was caused by particle-size growth and surface-site blockage (probably by carbon deposition). Demonstrated also was how the particle-size growth results from the formation of volatile Ni $(CO)_4$, vapor phase transport, and subsequent decomposition of $Ni(CO)_4$. A comparison of Mossbauer spectra at various temperatures demonstrated that upon being heated to 105°C $Fe(CO)_5$ decomposed to form small metallic particles that interact with and "wet" a graphite surface. At above 167°C, these particles sintered and may have become partially carbided. The study explored the effect of carbon surface chemistry on decomposition kinetics.

A. 14 GAS-STREAM TREATMENT AND PROCESSING – SUPPORT STUDIES

TITLE

Development of Combustion Data to Utilize Low-Btu Gases as Industrial-Process Fuels

PERFORMER

Institute of Gas Technology, Chicago, IL

OBJECTIVE

The objective is to demonstrate the feasibility of retrofitting industrial natural-gas burners to operate on low-Btu gas generated through coal gasification.

ACCOMPLISHMENTS

Combustion data for three low-Btu gases, along with that of natural gas, have been obtained as a result of this program. These data demonstrated the feasibility of retrofitting existing burner equipment to the use of low-Btu gases. The low-Btu fuel gases used were Koppers-Totzek oxygen-blown (KTO) (287 Btu/scf), Wellman-Galusha air-blown (WGA) (160 Btu/scf), and Winkler air-blown (WA) (116 Btu/scf). The burners represented a broad cross section of industrial types. Each burner was first fired with natural gas in a pilot-scale furnace with the furnace load adjusted to simulate the conditions under which the burner is typically used. Data were then gathered for each fuel in terms of flame stability, flame length and shape, thermal efficiency, furnace-load heat-absorption profile, noise level, furnace-temperature profiles, radiant heat flux, post-flame emissivities, and flow direction. The 287 Btu/scf KTO fuel gas compared most favorably with natural gas. Burner modifications were not required to obtain stable flames, and the flame temperatures and thermal efficiencies were comparable to that of natural gas. The 160 Btu/scf WGA fuel gas produced stable flames with either no modifications or minor modification, in most cases. The flame temperatures and thermal efficiences were lower than those of natural gas and KTO. The 116 Btu/scf WA fuel gas required some burner modifications or a continuous pilot light to maintain a stable flame and, in two cases, modifications and down-rating of the burners were required. The flame temperatures and thermal efficiencies were lower than those obtained with natural gas, KTO, or WGA.

CURRENT WORK

This current work is an experimental effort aimed at reducing the flame length of 300-Btu/scf fuel gas by burner modification and raising the flame temperature of 110-160 Btu/scf fuel gas by blending the low-Btu gas with natural gas or by enriching combustion air with oxygen, or by a combination of both, so that the combustion performance of low-Btu fuel gas will approximate that of natural gas.

APPLICATION

Data collected under this program will allow an assessment of the applicability of replacing natural gas with low-Btu gases in industrial-process burners.

TITLE

Compilation of Thermodynamic Tables

PERFORMER

Dow Chemical Company, Midland, MI

OBJECTIVE

The objective is to produce and distribute critically evaluated tabulations of thermodynamic properties for various chemical species which are currently relevant to the interests of the United States Department of Energy (DOE). These tabulations are to be made available as part of the JANAF Thermochemical Tables. The present DOE contract extends the scope of the JANAF Thermochemical Tables to cover chemical species occurring in chemical reactors such as gasifiers, methanators, combustors, MHD generators, fuel cells, gas turbines, etc., which use coal or other fossil-fuel products as their feedstocks.

ACCOMPLISHMENTS

The project has produced 273 new tables since the contract was signed in 1976. These

tables include, for example: (1) the first coverage of the elements zinc, nickel, argon, helium, krypton, neon, xenon, deuterium, and copper; (2) a much broadened coverage of sulfur compounds including K_2S, K_2SO_4, FeS_2, Na_2SO_4, Li_2SO_4, SCl_2, etc; and (3) tables for certain special liquids such as $Ni(CO)_4$ and H_2SO_4 at various aqueous dilutions. Information on many organic and inorganic compounds was collected and used. Information of direct interest to the work included results on some alkaline earth halides, oxides, and hydroxides, and copper sulfides. JANAF Tables for water at several nonstandard-state pressures were completed. Thermochemical tables for water at 1 atm (liquid and ideal gas) were also completed.

CURRENT WORK

Work is continuing in the effort to collect and evaluate data for the chemical species of interest and to calculate tables for this data in a manner that is consistent with the standard source known as JANAF Thermochemical Tables.

APPLICATION

This work is aimed at securing certain data tabulations, in a widely respected and easily used form, which are consistent with thermodynamic principles and with such reliable measurements as have been made. More specifically, the chemical species for which thermodynamic tables are to be prepared will be species occurring in fossil-fuel utilization processes. The application for the data produced is in practically all areas of chemical engineering.

A. 15 WASTEWATER AND EFFLUENT HANDLING

TITLE

Process Wastewater

PERFORMER

Pittsburgh Energy Technology Center, U.S. DOE, Pittsburgh, PA

OBJECTIVE

The objective is to develop environmental-control strategies for wastewater through bench-scale treatment studies with gasifier effluents, including physicochemical and biological (aerobic and anaerobic) treatments.

ACCOMPLISHMENTS

An integrated wastewater-treatment unit, consisting of five 4-liter reactors, has been constructed and placed into operation for measurement of biomass concentration, oxygen uptake, phenol concentration, and settling properties. An electrolytic respirometer has been operated to determine the concentrations of phenol, ammonia, and thiocyanate in wastewaters that induce inhibition of the respiration of the microbial culture used to biochemically oxidize the organic constituents. Celanese Chemical Co. has started anaerobic treatment studies for the conversion of organic constituents in wastewaters to methane. Work under subcontract with the University of Pittsburgh was completed for the biological degradation of thiocyanates, including work on the development of a kinetic expression, and a nitrogen and sulfur balance. Work under subcontract with East Tennessee State University was completed on physicochemical and biochemical treatment.

CURRENT WORK

Work on chemical oxidation and solvent-extraction treatments is being conducted during Fiscal Year 1981.

APPLICATION

A wide range of data is being obtained that has application to development of an integrated treatment program for coal gasification wastewater. Wastewaters from the METC, PETC, GFETC, and Holston Army Ammunition gasifiers are being used in these studies to establish a realistic data base. The best possible overall wastewater-treatment plan is required for meeting future environmental standards.

TITLE

Wastewater-Treatment Studies

PERFORMER

Grand Forks Energy Technology Center, U.S. DOE, Grand Forks, ND

OBJECTIVE

The objective is to investigate treatment of the wastewater from the GFETC slagging fixed-bed gasifier. Treatment schemes to be studied include biotreatment with activated-carbon addition, solvent extraction, lime-soda softening, oxygen-activated sludge, and anaerobic digestion. Determination of leachable components from gasifier slag will be made.

ACCOMPLISHMENTS

Work under contract with Carnegie-Mellon University included determination of the fate of trace organics during biotreatment with activated-carbon addition, assessment of phenol and polynuclear aromatic hydrocarbon removal by solvent extraction, determination of the biotreatability of the solvent-extracted wastewater and the effects on biological-reactor effluents treated by lime-soda softening. The University of Pittsburgh determined leachable components from the gasifier slag and the mutagenic potential of the leachant. The University of North Dakota determined the bacterial toxicity for selected coal-specific compounds and assessed the biokinetic rates, obtained rate constants for carbon and nitrogen removal from solvent-extracted wastewater, compared rate constants for air versus oxygen-activated sludge processes, and assessed anaerobic digestion.

CURRENT WORK

The wastewater treatment studies are being continued in order to identify environmentally hazardous components in waste liquor and determine their fate and to evaluate estab-

lished technology to treat gasifier effluents.

APPLICATION

This work will make it possible to demonstrate on a pilot-plant scale an integrated process to treat gasifier effluents. Also, it will be possible to compare effluents process train requirements as a function of the gasifier and of the coals used as feed to the gasifier. By these means industry can anticipate environmental problems for commercial gasification and develop and design an energy-efficient process train.

TITLE

Improved Methods of Effluent Handling in Coal-Conversion Processes

PERFORMER

Institute of Gas Technology, Chicago, IL

OBJECTIVE

The objective is to perform tests with ultrafiltration membranes for solids-liquid separation of aqueous process streams to evaluate reverse-osmosis membranes for separating dissolved solids in aqueous process streams and to evaluate a novel process for reusing process condensate.

ACCOMPLISHMENTS

Prior work on an ultrafiltration process versus the conventional process for solid-liquid separation showed that ultrafiltration may have lower capital and operating costs. The work also showed that an even larger cost benefit may be realized if membranes with larger pore sizes were substituted for those being evaluated. The application of reverse osmosis to raw water treatment has been known, but this technology has not been applied to gasification wastewater.

CURRENT WORK

Experimental work is in process. The application of reverse osmosis, to concentrate the dissolved materials commonly found in plant water supply, may significantly reduce the energy consumption associated with treating water and may minimize the total dissolved solids generated in the plant. Flow sheets for conventional and advanced plant water-treatment schemes have been proposed by IGT.

APPLICATION

Advanced water-treatment systems are needed for reducing the overall gasification costs and also for reducing pollution from gasification plants.

TITLE

Effluent Production

PERFORMER

Pittsburgh Energy Technology Center, Pittsburgh, PA

OBJECTIVE

The objective is to correlate the fate of nitrogen, sulfur, and trace elements as a function of process variables such as pressure, coal type, char/gas contacting, temperature, and coal-heatup rates. A 4-inch-diameter fluidized-bed gasifier will be used in this study.

ACCOMPLISHMENTS

Tests required to determine the effect of pressure on the production of trace nitrogen and sulfur compounds present in gasifier effluent streams were completed. Improved sampling and analytical techniques have been implemented. Data analysis from the series of pressure tests were performed as analytical results became available. The available results indicate that an average of 13 percent of the nitrogen present in the feed coal is converted to gaseous, molecular nitrogen. The balance of the product nitrogen is composed primarily of ammonia with very small amounts of cyanides and thiocyanates. Test results also indicate that nearly all of the sulfur present in the feed coal is converted to gaseous hydrogen sulfide.

CURRENT WORK

Preparations are being made for future catalytic gasification and char/gas contacting effluent tests. Several startup and operating procedures are being developed to insure

nonagglomerating operation of samples in the gasifier. The series of tests to determine the effect of char/gas contacting on trace nitrogen and sulfur-compound production in gasifier effluent streams will compare the effect of feeding coal through the gasifier free-fall zone countercurrent to the exiting product gas to injecting coal feed directly into the fluidized bed. The test conditions have been specified. An especially designed dip tube for injecting the feed coal into the fluidized bed has been constructed.

APPLICATION

The data base will enable designers of gasifier units to choose process variables that could limit the production of environmentally undesirable compounds and to perform cost-effective designs of gas- and liquid-cleanup systems.

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