ENVIRONMENTAL REVIEW of SYNTHETIC FUELS

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY

VOL. 1, NO. 2 JUNE 1978 RESEARCH TRIANGLE PARK, NC 27711

INTRODUCTION

In response to the shift in the U.S. energy supply priorities from natural gas and oil to coal, the Environmental Protection Agency (EPA) has initiated a comprehensive assessment program to evaluate the environmental impacts of synthetic fuel processes having a high potential for commercial application. This overall assessment program is being directed by the Fuel Process Branch of EPA's Industrial Environmental Research Laboratory, Research Triangle Park (IERL-RTP).

The primary objectives of the EPA Synthetic Fuels Environmental Assessment/Control Technology Development Program are: 1) to define the environmental effects of synthetic fuel technologies with respect to their multimedia discharge streams and their health and ecological impacts, and 2) to define control technology needs for an environmentally sound synthetic fuel industry. The synthetic fuel technologies being studied in this program include low/medium-Btu gasification, high-Btu gasification, and liquefaction. To achieve the program's overall objectives, the EPA has defined six major task areas that are discussed in this review. The contractors involved in the overall program, their EPA Project Officers, and the start and completion dates of each contract are tabulated on page 8 .

This is the second publication in a series of periodic reviews of recent activities in the EPA's assessment program of synthetic fuel processes. Included are activities of the EPA's contractors, summaries of major symposia, summaries of commercial and/or technical developments, a calendar of upcoming meetings and a list of major publications. This issue also features a summary of a technology overview report of low- and medium-Btu coal gasification. The third in this series is scheduled for distribution in late summer, 1978. Comments or suggestions which will improve the content or format of these reviews are welcomed. Such comments should be directed to the EPA or Radian Corporation personnel named on page 15 of this Review.

CURRENT PROCESS TECHNOLOGY BACKGROUND

High-Btu Gasification

High-Btu Gasification Overview and Environmental Assessment Data Base Reports — TRW, Inc., is completing a technology summary report as a first step in its environmental assessment of high-Btu gasification. A draft of the report is expected this spring.

A draft of the environmental assessment data base report for high-Btu gasification should also be completed this spring. Draft data sheets have been prepared for all ten gasification processes selected for detailed analysis, including HYGAS, BI-GAS, COGAS, Hydrane, Synthane, Texaco, CO_2-Acceptor, Self-Agglomerating Ash, Lurgi, and Koppers-Totzek. Some of the gasification processes (*e.g.*, Texaco and Koppers-Totzek) are more suitable for the production of low- or medium-Btu gas. However, they are included in this study because they have features and processing steps similar to those employed in the production of high-Btu gas. Also, some of the environmental data on these technologies can be used in the environmental assessment of high-Btu gasification. Work is continuing on the preparation of data sheets for gas treatment, air pollution control, water pollution control, methanation, and shift conversion processes. To date, draft data sheets have been prepared for 19 gas treatment processes, 9 air pollution control processes, 4 water pollution control processes, 3 methanation processes, and 1 shift conversion process. Most of these data sheets have been forwarded to the process developers for review and comment. Comments already received from process developers are being reviewed and will be incorporated into the data sheets where appropriate.

Costs for a Koppers-Totzek gasifier are summarized in a draft data sheet included in TRW's "Environmental Assessment of High-Btu Gasification: Annual Report" (EPA-600/7-78-025, February 1978; NTIS PB 278-175/AS). **The costs were reported** by D. M. Mitsak (et al.) at the Third International Conference on Coal Gasification and Liquefaction (August 3-5, 1976). The costs describe 15 four-headed K-T gasifiers operating at 1.2 MPa (170 psig) to produce 12.6 million Nm^3 (470 million scf)/d of gas from 8220 metric tons (9700 tons) coal/d. The gas has a heating value of 11 MJ/Nm^3 (300 Btu/scf). The costs include the costs of the following downstream equipment: a water spray at the exit of the gasifier to solidify molten entrained particulates, a waste heat boiler, a venturi scrubber/washer cooler, a Thiesen disintegrator, and a mist eliminator. Capital costs are reported to be $454 million (1976). Annual operating costs are reported to be $95 million per year.

ENVIRONMENTAL DATA ACQUISITION

General Topics

Pollutants from a Laboratory Gasifier — Research Triangle Institute (RTI) is continuing a parametric evaluation of pollutants from a laboratory gasifier. Screening studies are underway to investigate the pollutants produced during various reactor operating conditions, including the operating conditions of existing or proposed large-scale gasifiers. Most recently, gasification tests using Illinois No. 6 coal have been conducted.

The RTI gasifier has been operating at higher steam-to-coal ratios and lower temperatures than Morgantown Energy Research Center and synthane gasifier pilot units. Future test runs will vary the steam rates and temperatures to simulate more closely the larger gasifiers.

Control Assay Development — Catalytic, Inc., has continued work on Control Assay Development (CAD) for coal conversion processes. The objective is to provide quick screening treatments on streams suspected of containing pollutants which require control. Analyses will be made before and after treatment to evaluate the effectiveness of pollutant control. The program is expected to shorten the period of time between problem identification (through Level 1 assessment) and final recommendations for application of control technology.

It is proposed to accomplish the wastewater CAD in three steps:

- Pretreatment, when appropriate, to remove gross quantities of known pollutants normally recovered by commercial synfuel processes and those not present in the wastewater in significant concentrations.
- Pre-screening with materials such as activated carbon and ion exchange resins to establish operating parameters for specific wastewater characteristics.
- Screening to determine which treatment methodology will effect pollution removal.

Technologies under consideration in the wastewater CAD are filtration, coagulation, flocculation and sedimentation, carbon adsorption, bio-oxidation, and ion exchange. Drafts of prescreening and screening methodologies have been completed on all but ion exchange.

CAD for air emissions has been initiated. The screening methodology will include elements for particulate removal and sorption of organic and inorganic gases.

Field Manual for Sampling the Stretford Sulfur Recovery Process — Catalytic, Inc., is preparing a manual containing the procedures to be used in the field by a sampling team conducting Level 1 environmental assessment testing of the Stretford process. The test plan presents sampling techniques for gases, particulates, liquids, solids and fugitive emissions. Analytical procedures for tests that can be readily performed in a mobile field laboratory are also presented. Sample handling techniques are given for those samples that must be shipped to an off-site laboratory for completion of Level 1 testing.

Low/Medium-Btu Gasification

Environmental Testing — Radian Corporation arranged to conduct environmental tests at four low/medium-Btu gasification plants. In 1977, tests of Chapman (Wilputte) gasifiers were completed. Testing of a Wellman-Galusha gasifier was completed in April 1978. A series of tests of Lurgi gasifiers at the Kosovo Kombine in Pristina, Yugoslavia, began in late 1977 and will continue through the spring of 1979. In late 1978, tests of a Foster Wheeler/Stoic gasifier will be conducted.

At the facility using Chapman (Wilputte) gasifiers, low-Btu gas is produced from bituminous coal by fixed-bed single-stage gasifiers operating at atmospheric pressure. Each gasifier is equipped with a cyclone for particulate removal. The hot gas leaving the gasifier is quenched by a series of sprays inside the exit lines from each cyclone. The gas is scrubbed and further cooled in tray and spray scrubbers. Tars and oils are separated from the quenching and scrubbing liquors in a liquor separator.

The main goal of this test program was to characterize the multimedia discharge streams leaving the gasification facility. When possible, waste stream characterization was accomplished through the use of the EPA's Level 1 methodology. A second objective of the test program was to evaluate the sampling and analytical techniques defined by Level 1 procedures to determine their applicability to the waste streams from low-Btu gasification plants. In some instances, more detailed and/or specific methods were used to supplement the information provided by the Level 1 procedures. In addition to waste stream characterization, some data were obtained to determine the origin and fate of potentially hazardous components which were identified in the samples collected. In particular, the performance of the hot cyclone as a particulate and trace contaminant removal device was studied. The samples collected during Radian's test program were the coal feedstock, barrel valve (coal feeder) vent gases, ash, separator vent gas, cyclone dust, separator liquor, by-product tars and oils, product gas, and the cyclone inlet and outlet gas streams.

The following conclusions and recommendations can be drawn from the preliminary results of the test program:

- Waste streams having high concentrations of tar, such as the barrel valve vent stream, will require modifications to the Level 1 procedures for collecting particulate and gas samples. Electrostatic precipitation is one recommended method for collecting tar and particulate samples and for purifying the stream for subsequent gas sample analysis. This sampling technique may have the added benefit of reducing the tar-gas contact time which may reduce the possibility of certain gaseous species (such as H_2S, COS) being sorbed in the tar.
- Streams having high moisture contents, such as the separator vent stream, require additional cooling in the source assessment sampling system (SASS train) organic module. This can be accomplished by circulating ice water through both the outer and inner cooling jackets and/or by increasing the cooling surface area.
- Pretreating XAD-2 resin by washing the resin with water, methanol, pyridine, and ether reduces amounts of impurities in the resin blank. Storing the resin in methanol improves the resin's handling characteristics and reduces the possibility of substrate cracking.
- Placing the XAD-2 resin cartridge at the exit of the SASS train organic module allows the condensibles to be collected before the gas passes through the resin cartridge. This modification should increase the resin loading time and decrease the potential for gas channeling.
- In-line alundum thimbles for determining particulate loadings in the gas entering and exiting the hot cyclone appear to give reasonable results. The total particulate collection efficiency for the hot cyclone was calculated to be 60%.
- Impingers should be used to collect samples for HCN and NH_3 because concentrations of these species are much lower than the detection limits of the analytical device prescribed by Level 1 methodology.
- Sample containers and injection syringes for sampling and analyzing gaseous sulfur species should be preconditioned with a standard gas containing H_2S and SO_2. This will reduce the sorption of these species on the walls of the containers and syringes.
- The preliminary analytical results indicate that if the dilution air were eliminated from the barrel valve and separator vent streams, the composition of the resulting stream would be similar to that of the raw product gas.

At the facility using Wellman-Galusha gasifiers, low-Btu gas is produced form anthracite coal by a new, fixed-bed single-stage gasifier operating at atmospheric pressure. The gasifier is equipped with a cyclone for particulate removal. The hot gas leaving the cyclone is combusted.

This test program includes environmental assessment tests, a material balance test, and a control technology characterization test. The objectives of the environmental assessment tests are to determine the composition and potential biological activity of waste streams leaving the gasification facility, and to characterize the combustion products of low-Btu gas produced from anthracite coal. Results of the environmental assessment tests will be reported according to EPA Level 1 methodology. The objective of the material balance test is to determine the origin and fate of major, minor and trace elements around the Wellman-Galusha gasifier. Elemental balances will be performed for carbon, hydrogen, sulfur, nitrogen, ash, volatile trace elements (antimony, arsenic, mercury, and selenium), and five additional trace elements. The goal of the control technology characterization test is to determine the total particulate collection efficiency of the hot cyclone and to remove particulates from the product low-Btu gas. Streams sampled at the facility are the coal feed, dry ash, cyclone inlet and outlet gases, cyclone dust, combustion gases, coal hopper gases, poke hole gases, gasifier inlet air, combustion air, jacket water, ash sluice water, and service water.

At the Kosovo plant, medium-Btu gas for an industrial complex is produced from lignite by pressurized, oxygen-blown Lurgi gasifiers. Major operations at Kosovo are gasification, gas cooling, gas purification, tar separation, and phenol extraction.

Raw gas removed from near the top of the gasifier is water-quenched and cooled to 25°C and routed to gas purification. Hydrocarbons, H_2S, and CO_2 are sorbed form the raw gas by cold methanol in a Rectisol gas purification unit. An H_2S-rich waste gas stream is produced by thermally regenerating the methanol sorbent and is then incinerated.

Liquid products from quenching, cooling, and Rectisol gas cleaning are separated into tar, oil, and phenolic water during tar separation. Phenols are removed from process wastewaters by the Phenosolvan process.

The objectives of the Kosovo test program have been defined as follows:

- Phase I: To measure the emission levels of specific major and minor pollutants emitted from the Kosovo plant.
- Phase II: To characterize the emissions of minor and trace pollutants from the Kosovo plant.

During Phase I, the mass emissions of specific pollutants are being determined on 36 effluent streams. During Phase II, appropriate streams are to be analyzed for trace elements, trace organics, and particulate characteristics. The Phase II program involves 18 streams plus fugitive emissions at 3 in-plant locations.

High-Btu Gasification

Preparation for Testing — TRW has identified seven sites for potential environmental testing. The potential test sites include: a Lurgi dry ash gasifier at Sasolburg, South Africa; a Lurgi slagging gasifier at Westfield, Scotland; a Koppers-Totzek low-Btu gasifier at Modderfontein, South Africa; a HYGAS gasifier in Chicago, Illinois; a BI-GAS gasifier in Homer City, Pennsylvania; a Synthane gasifier in Pittsburgh, Pennsylvania; and a Texaco gasifier in Montebello, California. A secrecy agreement is currently being negotiated with Krupp-Koppers as a first step in acquiring data on the Koppers-Totzek coal gasification facility in Modderfontein, South Africa. TRW has also contacted the American Lurgi Corporation and the South African Coal, Oil, and Gas Company to plan and perform an environmental assessment of the Lurgi gasification complex in Sasolburg, South Africa. Through discussions with the DOE, TRW is arranging testing at the DOE HYGAS and Synthane pilot plants. Environmental test plans are currently being developed for testing at the HYGAS, Synthane, Koppers-Totzek, and Lurgi dry ash gasification plants.

Liquefaction

Analysis of Coal Liquefaction Samples — Hittman Associates, Inc., has completed an analysis of coal and SRC test samples to determine the presence and distribution of radionuclides. The final report of the radionuclide analysis is currently being prepared. Other laboratory analyses of coal liquefaction process streams and waste materials are continuing.

Characterization of Coal Liquefaction Process Modules — Hittman is developing a methodology to characterize the effluents from coal liquefaction processes as functions of process variables. A draft preliminary report identifying priority process variables and pertinent process variables has been written and is currently under review. Efforts to visit and sample coal liquefaction pilot plants are continuing.

CURRENT ENVIRONMENTAL BACKGROUND

General Topics

Environmental Standards — Under EPA contract, Pullman Kellogg, a division of Pullman, Inc., has compiled existing and proposed Federal standards for air emissions, water effluents, and solids disposal. Standards for the 22 states in which coal conversion plants are likely to be located have also been compiled. A draft of this standards report is currently being revised by EPA. The "most stringent standards" have been summarized from the list of Federal and state standards. Continuing work is directed at incorporating regional and international standards into the summary of "most stringent standards," and comparing those regulations with the EPA's Multimedia Environmental Goals.

ENVIRONMENTAL OBJECTIVES DEVELOPMENT

General Topics

MEG's Development Status — RTI is currently preparing a supplement to "Multimedia Environmental Goals for Environmental Assessment" (EPA-600/7-77-136 a and b, November 1977, NTIS PB 276-919/AS and PB 276-920/AS). Drafts of background information summaries are now complete for 175 compounds. Literature searches are continuing for information describing the less common species.

Process Assessment Methodology for Environmental Assessment — Hittman has nearly completed development of a methodology which ranks candidate processes according to the need for further attention in an environmental assessment. For processes of concern to EPA, assessment criteria include the likelihood, timing, and extent of commercialization, and the resulting environmental impacts of commercialization. Hittman chose the Decision Alternative Rational Evaluation (DARE) model to assist in the weighing of process assessment criteria.

Using the general methodology for process assessment, candidate systems in coal liquefaction technology were ranked as follows: Solvent Refined Coal (highest priority), H-coal, Exxon Donor Solvent, Synthoil, COED, COSTEAM, Clean Coke, Fischer-Tropsch, ORC (Garrett), Coalcon, Methanol Synthesis, TOSCOAL, and Bergius (lowest priority). This is a preliminary list and does not reflect more recent developments.

CONTROL TECHNOLOGY ASSESSMENT

General Topics

Applicability of Petroleum Refinery Control Technology to Synfuels Processes — TRW's control technology assessment activities to date comprise a comparison of refinery waste streams to coal conversion plant streams, and an evaluation of refinery control equipment and technology for application in coal conversion facilities. Streams from refinery sour gas treatment operations are similar to acid gases and treated streams encountered in the production of synthetic fuels. Characteristics of streams encountered in refinery sour gas treatment operations have been reported by TRW in the "Environmental Assessment of High-Btu Gasification: Annual Report" (EPA-600/7-78-025, February, 1978, NTIS PB 278-175/AS). Feeds to refinery sour gas treatment operations contain 16-63% H_2S and substantial quantities of CO_2 and hydrocarbons. In refineries, acid gases have been recovered via MEA, Sulfinol, ADIP, DGA, and Selexol processes. Sulfur recovery processes used in refinery sour gas treatment operations are the Claus and Stretford processes. The Scott and Beavon/Stretford processes have been employed in refineries to clean the tail gas from sulfur recovery. The vent from tail gas clean-up contains up to 0.03% H_2S, 250 ppm COS, and 1 ppm CS_2.

Process streams from the individual refinery process units are still under study for counterparts in synthetic fuels upgrading.

Facility Concept for Product/By-Product Streams — Catalytic, inc., has conducted a preliminary evaluation which indicates that a mobile test facility housing bench-scale equipment can provide data suitable for studying coal conversion systems product/by-product stream characteristics and their control requirements. The mobile laboratory facility, located in a single, self-contained van, would have capabilities for investigating major unit operations/processes including absorption, adsorption, distillation, extraction, filtration, hydrodealkylation, hydrotreating, methanation, precipitation, scrubbing, sedimentation, and shift conversion.

The facility would be equipped to conduct studies in the following areas:

- Recovery of by-products from liquid and gaseous streams.
- Upgrading of products/by-products from coal conversion systems.
- Evaluation of feasible processing schemes and their environmental effects.
- Evaluation of the effectiveness of pollutant removal/control methods.
- Development of improved control measures where needed.

Assessment of Stretford Process for Removing H_2S From Acid Gases — Catalytic Inc., has completed a draft report on the Stretford process for gas purification and sulfur recovery. The Stretford process is well-proven commercially and can reduce the H_2S content of acid gases to less than 1 ppm by volume. H_2S can be recovered as pure sulfur from gas streams containing various ratios of H_2S:CO_2. The process can be operated over wide pressure ranges (0.1-7.0 MPa, 0-1000 psig) and can accept variations in the characteristics of acid gases. However, organic sulfur species, such as COS, commonly encountered in acid gases from coal conversion processes cannot be removed. Pre- or post-treatment may be required to remove organic sulfur. Pretreatment is also required for feeds containing large quantities of SO_2, HCN, or heavy hydrocarbons. The system produces a large purge stream containing vanadium compounds, anthraquinone disulfonic acid, thiocyanates, and thiosulfates which then requires further treatment. The process operates at low temperatures (ambient to 49°C, 120°F) and is usually uneconomic for treating gases containing more than 15 vol % H_2S.

Catalytic has reported the capital and operating costs for two Stretford plants. The costs are those prepared by J.F. Pritchard and Co. (a Stretford process licensee) and are based on 1974 data. Both plants operate at a pressure of 0.72-1.03 MPa (90-135 psig). One plant removes H_2S from 1.5 million Nm^3/d (55 million scf/d) of natural gas. The H_2S loading is reduced from 1490 ppmv to 2.5 ppmv. Capital costs are shown to be $800,000; annualized costs are $166,000. The second plant removes H_2S from 1.3 million Nm^3/d (49 million scf/d) of a refinery synthesis gas. The H_2S loading is reduced from 14,000 ppmv to 10 ppmv. Capital costs are shown to be $1,100,000; annualized costs are $274,000. The overall cost of operation for the second plant is $30/ton sulfur.

Application of Coke Oven Controls to Coal Conversion Systems — The environmental aspects of by-product coke ovens and coal conversion systems have many similarities. Catalytic Inc., has begun a study to compare the process and waste stream characteristics of the two systems and to determine the applicability of coke oven controls and processes to coal conversion systems.

Process wastewaters from by-product coke plants and coal conversion plants contain phenol, ammonia, sulfide, cyanide, oil, and grease. At by-product coke plants, ammonia is typically removed and recovered from process wastewaters by using steam stripping and distillation, or by Phosam-W. This latter process from U.S. Steel uses ammonium phosphate scrubbing and distillation to produce an anhydrous ammonia product. Phenols are typically removed by solvent extraction, steam stripping and/or biological oxidation. Biological oxidation has successfully removed phenols, oil, grease, and suspended solids from coke oven wastewaters.

Both coke ovens and coal conversion systems produce gases containing hydrogen sulfide. Processes used to remove hydrogen sulfide from coke oven gas include the dry oxidation process using iron oxide, the Vacuum Carbonate process, the Stretford process, the Claus process and, more recently, the Sulfiban process.

Control Technology for Particulates and Tar Emissions — Hydrocarbon Research, Inc. (HRI) has initiated a study of control technology for particulates and tar emissions from coal conversion processes. A literature search is in progress to characterize particulates and tar emissions from various coal converters. The study objectives are (1) to determine the ultimate fate of particulates and tars, (2) to estimate the costs of alternate control technologies, and (3) to develop a prioritization R&D plan for particulates and tar control technology.

Control Engineering Handbook — Under EPA contract, Cameron Engineers is compiling a "Multi-media Environmental Control Engineering Handbook." The handbook includes a detailed description of environmental control technologies applicable to coal conversion. Objectives of the handbook are:

- To categorize all commercially available control technologies into a readily accessible systematic format.
- To provide technical data for each process, including process description, ranges of application, efficiencies, and capital and operating costs.
- To supply a list of specific equipment vendors and/or technology licensees.

Cameron has completed approximately 35 specific device data sheets.

Control Technology for Waste Utilization and Disposal — Pullman Kellogg has identified the compositions and quantities of the gaseous, liquid, and solid waste streams from coal conversion processes in sufficient detail to study treatment and disposal options. Waste stream treatment techniques and the efficiencies, costs, and future needs associated with these techniques are currently being studied.

The draft of the final report on this study is scheduled for completion this summer. The report will compare available and developing control technologies to projected environmental goals of 2, 5, and 10 years in the future. In instances where available and developing technologies do not meet the environmental goals, other alternatives such as extending existing technology or developing new technology will be evaluated.

Assessment and Control of Wastewater Contaminants from the Production of Synthetic Fuels — Under EPA contract, the University of North Carolina has initiated bench-scale testing of processes which treat wastewaters resulting from the production of synthetic fuels from coal. In recent tests, two of the three activated sludge reactors receiving synthetic wastewater failed to degrade organic constituents in the wastes. The cause of the failure has not yet been determined. Aquatic bioassay testing of the synthetic wastewater has been initiated using algae and daphnia as test organisms.

Adsorption isotherms have been developed for the adsorption of phénol, the isomers of cresol, and xylenols from synthetic wastewaters. Studies involving the adsorption of alkyl phenol mixtures are continuing. Coagulation studies on a sample of coal gasification wastewater are also continuing. In one test, total organic carbon was reduced by 15-20%. The goal of current studies is to identify the species removed by coagulation.

Coal Gasification

Coal Gasification — Gas Cleaning Plant — The coal gasification — gas cleaning plant at North Carolina State University is scheduled to be completed in August 1978. The facility consists of a continuous fluidized bed gasifier; a cyclone and scrubbers for removing particulates, condensables, and soluble matter from raw synthesis gas; and an acid gas removal system. The gasifier operates at pressures up to 0.8 MPa (100 psig) with a capacity of 23 kg (50 lb) coal/h. The gasifier uses either steam-O_2 or steam-air feeds to produce 0.67 Nm_3 (25 scf)/min of product gas. The acid gas removal system will test at least four processes for the removal of acid gases: refrigerated methanol, hot potassium carbonate, monethanolamine, and dimethylether of polyethylene glycol.

The overall objectives of the project are to characterize completely the gaseous and condensed phase emissions from typical coal gasification cleaning processes, and to determine how emissions depend upon various process parameters. The gasifier will be operated for the first 6 months using a chemical grade coke. The first tests of acid gas removal will use a synthetic feed gas mixture.

Study of Hot Gas Desulfurization Technology — HRI has initiated a study of hot gas cleanup processes. Twelve processes have been identified that use a variety of absorbents including dolomite, molten salts and metals, and iron and copper oxides. Detailed process descriptions are being prepared for each process. Advantages of hot gas cleanup will be assessed relative to low temperature cleanup.

Control Technology Report for a Koppers-Totzek Gasification Plant — Catalytic, Inc., has recently completed a draft report for a Koppers-Totzek gasifier used in the production of ammonia or methanol. The report gives a multimedia summary of environmental requirements, guidelines, and control/disposal options for a K-T gasification plant under design consideration.

Liquefaction

Control Requirements of the H-Coal and Exxon Donor Solvent Processes — HRI has assessed process design information of the H-Coal pilot plant and has prepared a process flow diagram detailing the control requirements of each process operation. Similar information is being collected for the Exxon Donor Solvent Pilot Plant.

Control Technology Report for SRC Liquefaction — Hittman is revising a control technology report for SRC-1 Liquefaction to incorporate review comments from the EPA. The report is intended to provide a multimedia summary of environmental requirements and control/disposal options applicable to solvent refined coal plants.

Wastewater Treatment for Coal Liquefaction — Hittman is currently comparing alternative integrated raw water and wastewater treatment schemes for coal liquefaction. Wastewaters from different liquefaction processes have been characterized. Ultimately, Hittman will develop an integrated water management plan based on the worst wastewater characterizations.

Zero Discharge in Coal Liquefaction — Hittman is evaluating existing and proposed zero discharge options in related industries to determine the applicability of such options to the SRC process. Work to date involves a search of publications, periodicals, and literature from equipment manufacturers.

TECHNOLOGY AND/OR COMMERCIAL DEVELOPMENT

Coalex Demonstration Plant Started Up — In February, Coalex Energy Corp. started up a coal gasification demonstration plant producing 4.2 GJ (4 million Btu)/h of low-Btu gas (4.8-5.6 MJ/Nm^3, 130-150 Btu/scf). The Coalex process features an air-entrained slagging gasifier that operates at atmospheric pressure. The process also includes a proprietary additive that is mixed with pulverized coal prior to gasification. The additive promotes gasification of fixed carbon, lowers the ash fusion temperature, and improves the capture of sulfur in the slag. Coalex maintains that the gas produced from the gasification of high-sulfur coals can be combusted without violation of NSPS (for the combustion of coal). Commercial gasifier units producing 63 GJ (60 million Btu)/h are expected to cost $485,000, not including the cost of the coal-feeding mechanism. The quoted price includes the cost of retrofitting combusion systems to permit burning of the low-Btu gas.

ARCO Plans Test of In-Situ Gasification — This summer, ARCO's Synthetic Crude and Minerals Division will test the in-situ gasification of coal in a 21 meter (70 foot) thick seam south of Gillette, Wyoming. ARCO will use the linked vertical wall method developed by DOE's Laramie Energy Research Center (LERC). ARCO's work will differ from that performed by LERC because the hydrology, thickness, and fractures of the coal seam at ARCO's test site are different from those encountered by LERC. In this summer's tests, air will be used to produce a low-Btu gas. If the summer tests are successful, future tests may use oxygen to produce a medium-Btu gas.

Gulf Plans Tests in In-Situ Gasification — Through a $13.5 million cost-sharing contract with DOE, Gulf Research and Development Corp. is beginning a 5-year program to test in-situ coal gasification. In contrast to tests conducted by the Lawrence Livermore Laboratory and the Laramie Energy Research Center, Gulf's tests will involve steeply-dipping coal seams. Field testing will start next summer.

Pilot Plant Produces High-Octane Gasoline from Methanol — Mobil Research and Development Corporation has demonstrated a process for the direct catalytic conversion of methanol to high-octane gasoline. In a pilot plant operation at Paulsboro, N.J., Mobil has produced 0.24 m^3 (1.5 barrels) of gasoline daily from 0.64 m^3 (4 barrels) of methanol. The cost of converting methanol to gasoline via Mobil's process is about 5 to 10 cents per gallon of gasoline produced. Using a methanol feedstock produced from coal, gasoline produced by Mobil's process would cost about 40 to 50 cents per gallon more than gasoline produced from crude oil in the U.S. today.

Laboratory Testing of Materials for Coal Gasifiers — Southwest Research Institute of San Antonio, Texas, is conducting an experimental program to identify materials of construction best suited for use in coal gasifiers. The new laboratory used in this program will eventually contain 34 test retorts, 12 of which are currently operational. A matrix of 2760 tests on 9 different alloys will be developed to determine the suitability of the materials for use in corrosive environments at temperatures up to 980°C (1800°F) and pressures up to 7 MPa (1000 psig).

Foster Wheeler to Engineer U-Gas Process for Memphis Light, Gas, and Water — Memphis Light, Gas, and Water Division (MLGW) has awarded a $14.4 million contract to Foster Wheeler Energy Corp. to engineer and provide construction supervision for a commercial-scale industrial gas-from-coal demonstration plant. The plant will feature the U-Gas process developed by the Institute of Gas Technology.

The initial phase of the contract involves the expenditure of $3 million over a 20-month period for process development, definitive design, and project cost estimates. Then, if DOE selects the Memphis project over a competing project being developed by W.R. Grace. Foster Wheeler will receive the balance of the $14.4 million. The plant will be designed to produce 50 million m^3 (175 million cf)/d of gas with a heating value of 11.2 MJ/Nm^3 (300 Btu/scf) for use by industrial customers. The total project cost of $179.5 million over a 6-year period would be shared by DOE and MLGW.

Conoco Coal Development and Shell Development Complete Liquefaction Pilot Plant — Conoco Coal Development and Shell Development have completed a $2.5 million pilot plant for the catalytic hydrogenation of coal to fuel gas, gasoline-range naphtha, and oil. The pilot plant is part of an $11 million program with the Department of Energy. Conoco and Shell are each contributing 5% to the cost of the project. The pilot plant will process 0.9 metric tons (1 ton) of coal daily. In the process, coal is hydrogenated in the presence of molten zinc chloride catalyst at 343-441°C (650-825°F) and 10-31 MPa (1500-4500 psig). Initial tests will use solvent refined coal (SRC) from the Ft. Lewis (Wash.) SRC pilot plant. Coal will not be processed directly until next fall.

Allis Chalmers to Design Kilngas Gasification Plants — Allis Chalmers Corp. has agreed to prepare preliminary engineering designs of Kilngas gasification plants for Illinois Power Co. and Ohio Edison Co. The Kilngas plants are to be located in Wood River, Illinois, and West Lorain, Ohio. The Kilngas process is claimed to operate at sufficiently high pressure to be easily integrated with the more efficient combined gas and steam turbine cycle power plants expected to be available in the 1980's. Allis Chalmers is currently operating a 36 metric ton (40 ton) per day pilot plant in Oak Creek, Wisconsin.

Texas A&M Tests In-Situ Gasification — Petroleum engineers at Texas A&M University are conducting tests of the in-situ gasification of lignite. The test involve a technique similar to the linked vertical wall method developed by DOE's Laramie Energy Research Center. The initial tests will produce methane, carbon monoxide, and hydrogen gases with energy equivalent to 7000 m^3 (250,000 cf)/d of natural gas.

Bell Aerospace Tests Low-Btu Gasifier — Under a contract with DOE, Bell Aerospace Textron has developed and tested a gasifier producing low-Btu gas from coal. A test unit designed to gasify a half ton of coal an hour has been operated in runs of up to an hour in length. Commercial prospects of the Bell gasifier have not been discussed.

DOE and Combustion Engineering Evaluate Synthane Processes — Data released by DOE and C-E Lummus, a subsidiary of Combustion Engineering, show that pipeline-quality substitute natural gas can be produced by the Synthane process at a cost of $3.20 per GJ ($3.40 per million Btu). A commercial plant producing 265 TJ (250 billion Btu) of pipeline-quality gas daily would cost about $1 billion. Operation of the pilot plant has demonstrated a carbon conversion of 65-80 percent, an efficient high-pressure dry coal feed system, and an effective method for removing char by-product. The raw product gas contains few tars and heavy oils and has an H_2 to CO ratio of 3:1. This ratio is high enough to eliminate the need for a separate CO shift conversion unit ahead of a methanator.

Texas Lignite Gasified in Lurgi Gasifier — Texas lignite has been gasified in a Lurgi gasifier operated by the South African Coal, Oil, and Gas Corp. Exxon Corp. is encouraged by the preliminary results of the tests in Sasolburg, South Africa. Exxon expects to complete technical evaluations of the test run by spring. If the process is economical, Exxon may build a 38,000 metric ton (42,000 ton)/d plant at Troup, Texas in the early 1980's. The plant could produce 23 million m^3 (800 million cu ft) of 15 MJ/Nm^3 (400 Btu/scf) synthesis gas and 1600 m^3 (10,000 barrels) of a fuel-like liquid product daily.

NRC Advises DOE Not to Build Coal Liquefaction Demonstration Plants — A panel formed by the National Research Council has recommended that DOE forego plans to build coal liquefaction demonstration plants. The panel maintains, "if a demonstration plant is too small to be economical for continued commercial operation after the demonstration period, it should not be built. Instead, the pilot plant should be carefully designed and operated so that the data obtained can be used in the design of at least a single train of a commercial plant."

Specifically, the panel suggests that the successful development of either the H-Coal or Exxon Donor Solvent process should be followed with construction of at least one commercial unit. Demonstration plants for other liquefaction plants should not be constructed until small-scale and pilot plant results demonstrate substantial advantages over the Exxon and H-Coal processes. The panel also recommends consideration of the construction of a Fischer-Tropsch plant based on the latest developments from operations in South Africa. Promising areas for improved technology are the direct catalytic conversion of synthesis gas to high-octane gasoline, and the direct catalytic conversion of coal to aromatic and isoparaffin distillates.

Fluor Contends Gasoline-From-Coal Plant Commercially Feasible in Near Future — In a study conducted for the DOE, Fluor Engineers and Constructors, Inc., concluded that an advanced coal liquefaction plant using a hydrogen donor process could produce gasoline for $152/m³ ($24.35/bbl). That cost can be compared to the current refinery price for gasoline of $100-$112/m³ ($16-18/bbl). A plant producing 11,000 m³ (66,000 bbl)/d of unleaded gasoline, 2.4 million Nm³ (84 million cf)/d of SNG, and lesser amounts of butane, propane, sulfur, and ammonia would cost about $2.5 billion.

Combustion Engineering Completes Nation's Largest Low-Btu Gasifier — During the fall of last year, Combustion Engineering and DOE dedicated the Nation's largest low-Btu gasifier at Windsor, Conn. The gasifier features a two-stage entrained bed and operates at atmospheric pressure. From a feed of 4.5 metric tons (5 tons)/h pulverized coal, the gasifier produced 25,000 Nm³ (890,000 scf)/h of gas with a heating value of 3.7-4.6 MJ/Nm³ (100-125 Btu/scf). The cost of the $25 million plant was shared by DOE, Combustion Engineering, and EPRI.

Cities Service Tests Coal Liquefaction — Cities Service Energy Research Laboratory in Cranbury, N.J., has begun pilot-plant operations of a process producing light aromatic liquids from coal. The process converts pulverized coal directly to methane gas and light aromatic liquids by hydrogenation at high pressures and temperatures. The pilot-plant tests are being funded by DOE.

UK Coal Plans Demonstration Plant to Convert Coal to Naphtha and Gasoline — The National Coal Board of the United Kingdom plans to build a demonstration plant producing naphtha and gasoline from coal. The plant will process 10 tons of coal daily and obtain coal conversion efficiencies as high as 70%. Naphtha produced at the plant will not need to be reformed and will cost about the same as naphtha produced from petroleum. Gasoline will be more expensive than that produced from petroleum. The demonstration plant will be part of a 4-year program examining the commercial potential of the process.

H-Coal Product on Schedule — Hydrocarbon Research Inc.'s H-Coal liquefaction project at Catlettsburg, Kentucky, is scheduled for a startup later this year. The commercial-scale pilot plant is funded by the DOE, the Commonwealth of Kentucky, HRI, and four oil companies. The plant will have a capacity to produce 350 m³ (2200 barrels) of oil per day and will be operated on an experimental basis for 2 years. In the H-Coal process, light distillate and heavy fuel oils, and hydrocarbon gases are produced from the catalytic hydrogenation of coal. Both the liquid and gas fractions could be used as petrochemical feedstocks. Product yields are expected to be about 3 barrels of liquid fuels per ton of coal (0.5 m³ liquid/10³ kg coal).

UK National Coal Board Builds Supercritical Coal Extraction Pilot Plant — The National Coal Board has completed a $1.3 million pilot plant to extract hydrocarbon components from coal. The extraction uses inexpensive solvents such as toluene under supercritical conditions (above the solvent's critical temperature and pressure). As much as 40 percent of the coal can be recovered in the hydrocarbon extract. The extract can be easily hydrogenated to a distillate oil. The pilot plant processes 20 kg of coal per hour. A 1 metric ton/hour plant may be built later at a cost of $26 million.

TVA Selects Texaco Process for Coal-to-Ammonia Project — Tennessee Valley Authority has chosen Texaco's gasification process for a coal-to-ammonia demonstration plant at Muscle Shoals, Alabama. The demonstration plant, to be completed in the early fall of 1979, will produce 123 metric tons (135 tons) of ammonia per day from a coal feed of 6.5 metric tons (7 tons) per hour.

U.S. and Germany to Form Joint Coal-Research Venture — The U.S. and West Germany have signed an agreement for coordination of coal liquefaction research. The coordination effort will avoid duplication, accelerate technical progress, and allow German participation in a planned large-scale U.S. refinery for liquefied coal products. In addition, the U.S. will participate in modifications to a high-temperature gasification pilot plant to be operated by Saarbergwerke AG (Saarbruecken) and Dr. C. Otto & Co. GmbH (Bochum). The plant will convert 5 metric tons of coal per hour into 10,000 m³ of low-Btu gas. The U.S. is expected to assume 40% of the $12 million cost.

Erie Mining to Build Gasification Demonstration Plant — Erie Mining Co. is designing a small-scale coal gasification demonstration plant under a $2.2 million DOE contract. The plant, which will be located in Hoyt Lakes, Minnesota, will use the Woodall-Duckam process to convert 450 metric tons (500 tons)/d of high sulfur coal into gas with a heating value of 6.0-6.7 MJ/Nm³ (160-180 Btu/scf). The gas will be used in a nearby taconite plant.

W.R. Grace Designs Ammonia-from-Coal Plant — Under a $10.2 million contract from DOE, W.R. Grace and Co. is preparing a conceptual design of a medium-Btu coal gasification plant for use in the manufacture of ammonia. The plant, which is to be located in Baskett, Kentucky, will use the Texaco Coal Gasification process to gasify 1500 metric tons (1700 tons)/d of coal for the production of 1100 metric tons (1200 tons)/d of ammonia. The project is competing for final construction funding with a gasification project by Memphis Light, Gas, and Water.

Coal Gasification Combined Cycle Demonstration Plant Planned — Southern California Edison Co. and Texaco, Inc., are planning an integrated gasification combined cycle power plant to be located near Barstow, California. The plant will process 900 metric tons (1000 tons) of coal daily and will cost about $300 million. SCE and Texaco hope to attract other private and governmental participants to the project.

Initially, medium-Btu gas produced by Texaco's oxygen-blown gasifier will fire an existing conventional 65 MW steam-turbine/generator that is currently fired by oil or natural gas. New burners will be required to burn the 10-11 MJ/Nm³ (270-300 Btu/scf) gas.

In the second phase of the demonstration, the gasifier will be coupled to a combined cycle generator rated at about 90 MW: 60 MW from a gas turbine and 30 MW from a steam turbine. Special equipment is being designed to introduce waste heat to the steam turbine system from both gas turbine exahust and gasifier product cooling. Construction of the plant could start at the end of 1979; the gasifier could begin operations in 1982.

DOE Tests Coal Liquefaction Process — The Department of Energy's Morgantown Energy Research Center is researching a coal liquefaction process involving the catalytic hydrogenation of coal/oil slurries. The catalyst is applied as an inner coating in a tubular reactor made of permeable or porous metal. Under heat and pressure, hydrogen diffuses through the wall from the outside.

MERC has tested tubes made of nickel, which is permeable to hydrogen, and of porous nickel-molybdenum and cobalt-molybdenum. The interiors of the tubes are coated with a catalytic-metal sulfide layer. In one experiment, powdered coal slurried in a coal-derived oil (one part coal, three parts oil) achieved 80% conversion to benzene-soluble material at a temperature of 425°C and a pressure of 10 MPa (1500 psig). At least 95% of the available hydrogen was consumed by the coal. The process is said to avoid carbon deposition, a common mode of catalyst deactivation.

PROJECT TITLES, CONTRACTORS, AND EPA PROJECT OFFICERS IN FUEL PROCESS BRANCH ASSESSMENT PROGRAM

Project Title	Contractor	EPA Project Officer
Environmental Assessment of Low/Medium-Btu Gasification (March 1976-March 1979)	Radian Corporation 8500 Shoal Creek Blvd. Austin, Texas 78758 (512) 454-4797 (E.C. Cavanaugh/G.C. Page)	William J. Rhodes IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
Environmental Assessment of High-Btu Gasification (April 1977-April 1980)	TRW, Inc. 1 Space Park Redondo Beach, CA 90278 (213) 536-4105 (Chuck Murray)	William J. Rhodes IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
Environmental Assessment of Coal Liquefaction (August 1976-August 1979)	Hittman Associates 9190 Red Branch Road Columbia, MD 21043 (301) 730-7800 (Dwight Emerson)	William J. Rhodes IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
Control Technology For Products/By-Products (September 1976-September 1979)	Catalytic, Inc. 1500 Market Street Center Square West Philadelphia, PA 19102 (215) 864-8104 (A.B. Cherry)	Chester A. Vogel IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
Control Technology For Converter Output (January 1977-January 1980)	Hydrocarbon Research, Inc. P.O. Box 2391 334 Madison Avenue Morristown, NJ 07960 (609) 896-1300 (John Kunesh)	Chester A. Vogel IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
Waste Stream Disposal and Utilization (April 1977-April 1980)	Pullman Kellogg Research and Development Center 16200 Park Row Industrial Park Terrace Houston, Texas 77054 (713) 493-0291 (Louis Bostwick)	Chester A. Vogel IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
General Support (April 1976-1978)	Cameron Engineers, Inc. 1315 South Clarkson Street Denver, CO 80210 (303) 777-2525 (Ted Borer)	L. David Tamny IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2709
Acid Gas Cleaning Bench Scale Unit (October 1976-September 1981) (Grant)	North Carolina State Univ. Department of Chemical Engineering Raleigh, NC 27607 (919) 737-2324 (Dr. James Ferrell)	Thomas W. Petrie IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2708
Water Treating Bench Scale Unit (November 1976-October 1981) (Grant)	Univ. of North Carolina Department of Environmental Sciences and Engineering School of Public Health Chapel Hill, NC 27514 (919) 966-1052 (Dr. Philip Singer)	Thomas W. Petrie IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2708
Pollutant Identification From A Bench Scale Unit (November 1976-October 1981) (Grant)	Research Triangle Institute P.O. Box 12194 Research Triangle Park, North Carolina 27709 (919) 541-6000 (Dr. Forest Mixon)	Thomas W. Petrie IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2708

MEETING CALENDAR

EPA Energy Conference, May 31-June 2, 1978, Washington, DC. Contact: Kathleen Dixon, EPA-OEMI, Washington, DC. 20460.

85th National AIChE Meeting, June 4-8, 1978, Philadelphia, PA. Mtg. Prog. Chmn.: A.A. Winkler, CPC International, Moffett Technical Center, Box 345, Argo, IL, 60501.

Intersociety Energy Conversion Engineering Conference, August 20-25, 1978, San Diego, CA. Contact: Floyd A. Wyczalek, Eng. Staff, General Motors, GM Technical Center, Warren, MI, 48090.

176th National Meeting of the American Chemical Society, September 10-15, 1978. Contact: A.T. Winstead, ACS, Washington, DC, 20036.

EPA Coal Cleaning to Achieve Energy and Environmental Goals, September 11-15, 1978, Hollywood, FL. Contact: J.D. Kilgroe, EPA, IERL-RTP, Research Triangle Park, NC, 27711.

International Coal Utilization Exhibition and Conference, October 17-19, 1978, Houston, TX. Contact: David I.Johnson, 6006 Bellaire Blvd., Rm. No. 101, Houston, TX, 77081.

AIChE 71st National Convention, November 13-16, 1978, Miami, FL. Write: AIChE, 345 E. 47th St., New York, NY, 10017.

RECENT MAJOR MEETINGS

Process Measurements for Environmental Assessment

The Process Measurements for Environmental Assessment Symposium was held February 13-15, 1978, in Atlanta, Georgia, under the sponsorship of U.S. EPA's IERL-RTP. The symposium consisted of sessions defining the uses of environmental assessment data, the techniques for acquiring data, and users' field experiences with environmental assessment measurement programs.

The initial sessions provided an overview of environmental assessment programs. The EPA environmental assessment program has been developing a data base capable of supporting standards for air emissions, water effluents, and solid waste disposal practices. The environmental assessment program includes:

- Evaluation of emission rates.
- Evaluation of the degree of control attainable with conventional control equipment.
- Evaluation of the biological activity of waste stream samples.
- Estimation of "safe" emission rates.

When control technology required to attain "safe" emission rates is unavailable, inadequate, uneconomical, or otherwise unacceptable, funding is provided for the development of the needed control techniques. The Integrated Environmental Assessment Programs of the DOE and related EPRI programs were also discussed.

Later sessions of the symposium emphasized the sampling and analytical techniques used to acquire data for environmental assessments. Applicable measurement technologies for environmental assessments were reviewed and critiqued. Procedures were presented for the measurement of inorganic, organic, and fugitive emissions. Modifications to EPA Level 1 Analysis Methods were suggested, based on experience in characterizing emissions from coal gasification plants.

The last session focused on experiences with environmental assessment measurements in industrial and energy process applications. The industrial applications sessions discussed: assessments of atmospheric emissions from petroleum refining, wastewater effluents from nonferrous metal processing, emissions from conventional combustion systems, and emissions from glass manufacturing furnaces. Assessments of emissions from fluidized bed combustion processes, multimedia emissions from the HYGAS gasification process, and multimedia emissions from a Paraho shale oil demonstration plant were discussed in the session on energy process applications. Characterization of the Synthoil and Synthane processes was also discussed.

Ninth Synthetic Pipeline Gas Symposium

The Ninth Synthetic Pipeline Gas Symposium was held October 31-November 2, 1977, in Chicago, Illinois. Sponsored by the American Gas Association, DOE, and the International Gas Union, the symposium included sessions on the coal gasification pilot plant program, methanation and combined shift methanation, gasification, biomass and hydrogen, materials engineering, and environmental considerations.

The first session of the symposium featured a panel review of the coal gasification pilot plant program. Solids flow control using a non-mechanical L-valve was also discussed.

In the afternoon session, a panel review of methanation and combined shift methanation was presented. Featured topics included a one-stage combined shift-conversion and partial methanation process, and the Ralph M. Parsons process for methanation.

Underground coal gasification and the A.G.A. oil shale hydrogasification program were discussed during the session on gasification. Additional topics of this session included the production of SNG from peat and factors influencing the utilization of SNG. German experience in the fixed-bed gasification of brown coal, and gas production from coal for hydrogen synthesis were also discussed. A later session featured a panel discussion on materials used in gasification, and included examinations of refractory applications in gasifiers and quench system corrosion research.

The final session considered the environmental consequences of coal gasification. The principal topic addressed in this session was the removal of acid gases from coal gas. A recently developed permselective membrane for acid gas scrubbing was reviewed. Additional topics of discussion included new source performance standards for Lurgi gasifiers, and the gasification pilot plant environmental assessment program.

RECENT MAJOR PAPERS AND PUBLICATIONS

Gasification Technology

Anastasia, L.J., W.G. Bair, and D.P. Olson, "Environmental Assessment Program for the HYGAS Process," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Bakker, W.T., "Refractory Applications in Gasifiers," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago, IL, October 31-November 2, 1977.

Beychok, M.R., "New Source Performance Guidelines for Lurgi Gasification Plants," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago, IL, October 31-November 2, 1977.

Bombaugh, Karl J., "Analyses of Grab Samples from Fixed-Bed Coal Gasification Processes," EPA-600/7-77-141, NTIS No. PB 276-608/AS, Austin, TX, Radian Corp., December 1977.

Cavanaugh, E.C. and W.C. Thomas, "Environmental Assessment of Low/Medium-Btu Gasification: Annual Report," EPA-600/7-77-142, NTIS No. PB 276-580/AS, Austin, TX, Radian Corp., December 1977.

Christensen, K.G., "Acid Gas Removal in Coal Gasification Plants," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago IL, October 31-November 2, 1977.

Ferrell, J.K., R.M. Felder, R.W. Rousseau, and D.W. Alexander, "A Coal Gasification — Gas Cleaning Pilot Plant at North Carolina State University," Presented at the Miami International Conference on Alternative Energy Sources, Miami Beach, FL, December 5-7, 1977.

Flockenhaus, C., "One Stage Combined Shift-Conversion and Partial Methanation Process for Upgrading Synthetic Gas to Pipeline Quality," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago, IL, October 31-November 2, 1977.

Ghassemi, M., and C. Murray, "Environmental Assessment of High-Btu Gasification: Annual Report," EPA-600/7-78-025, NTIS No. PB 278-175/AS, Redondo Beach, CA, TRW, Inc., February 1978.

Hoogendoorn, J.C., "Gas from Coal for Synthesis of Hydrocarbons," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago, IL, October 31-November 2, 1977.

Jarvis, J., "Economics of Low-Btu Gasification," Presented at the Fifth Energy Resource Conference, Lexington, KY, January 10-11, 1978.

Kimura, S.G., "Permselective Membrane for Acid Gas Scrubbing from Coal Cas," Presented at the Ninth Synthetic Pipeline Gas Symposium," Chicago, IL, October 31-November 2, 1977.

Luthy, Richard G., "Manual of Methods: Preservation and Analysis of Coal Gasification Wastewaters," FE-2496-8. ERDA Contract E(49-18)-2496. Cargenie-Mellon University, Environmental Studies Institute, July 1977.

Massey, M.J., "Gasification Pilot Plant Environmental Assessment Program: A Status Report," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago IL, October 31-November 2, 1977.

Matson, Stephen L., Carlyle S. Herrick, and William J. Ward, III, "Progress on the Selective Removal of H_2S from Gasified Coal Using an Immobilized Liquid Membrane," ***Ind. Eng. Chem., Process Des. Dev. 16*** (3), 370-374 (1977).

National Research Council, Commission on Sociotechnical Systems, Ad Hoc Panel on Low-Btu Gasification of Coal of the Committee on Processing and Utilization of Fossil Fuels, "Assessment of Low- and Intermediate-Btu Gasification of Coal." ERDA Contract E(49-18)-1216. National Academy of Sciences, 1977.

Seifert, G., "German Democratic Republic Experience in Fixed-Bed Gasificatioan of Brown Coal," Presented at the Ninth Synthetic Pipeline Gas Sympoisum, Chicago, IL, October 31-November 2, 1977.

Seward, W.H., "Process Alternatives for Sulfur Management in Coal Gasification," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago, IL, October 31-November 2, 1977.

Sparacino, Charles M., "Synthetic Fuels Production: Analysis of Process By-Products from a Laboratory Scale Coal Gasifier," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Stearns-Roger Engineering Company, "Conceptual Design and Cost Estimate, CO_2 Acceptor Coal Gasification Process Commercial Plant." FE-1734-10. ERDA Contract EX-76-C-01-1734, 3 vols., October 1977.

White, G.A., "The RMProcess for Methanation," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago, IL, October 31-November 2, 1977.

Wieber, P.R., "Prospects for Producing Synthetic Natural Gas Through Underground Coal Gasification," Presented at the Ninth Synthetic Pipeline Gas Sympoisum, Chicago, IL, October 31-November 2, 1977.

Liquefaction Technology

Brown, Frank, "Make Ammonia from Coal," ***Hydrocarbon Processing, 56*** (11), 361-66 (1977).

Budden, Ken T., and Werner H. Ziegler, "Environmental Assessment of Coal Liquefaction: Annual Report," EPA-600/7-78-019, NTIS No. PB 278-333/AS, Columbia, MD, Hittman Associates, February 1978.

Jones, J.E., "Cost of Synfuels from Coal," Presented at the Fifth Energy Resource Conference, Lexington, KY, January 10-11, 1978.

National Research Council, Commission on Sociotechnical Systems, Ad Hoc Panel on Liquefaction of Coal of the Committee on Processing and Utilization of Fossil Fuels, "Assessment of Technology for the Liquefaction of Coal." ERDA Contract E(49-18)-1216. National Academy of Sciences, 1977.

Netzer, David and James Moc, "Ammonia from Coal," ***Chem. Eng., 84*** (23), 129-32 (1977).

Schiller, Joseph E., "Composition of Coal Liquefaction Products," ***Hydrocarbon Processing, 56*** (1), 147-52 (1977).

Sharkey, A.G., Jr., "Characterization of Synthoil/Synthane Processes," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Taupitz, K.D., "Making Liquids from Solid Fuels," ***Hydrocarbon Processing, 56*** (9), 219-25 (1977).

Other

Berkau, Eugene E., "An Integrated Approach to the Assessment and Control of Industrial Pollution Problems," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Blake, David and J.M. Kennedy, "Source Assessment Sampling System Design and Development," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Bombaugh, Karl, "Alternative Level 1 Analysis Methods," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Duke, Kenneth M., "Biological Testing Methodology," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Hamel, F.B., "Quench System Corrosion Research Program," Presented at the Ninth Synthetic Pipeline Gas Sympsoium, Chicago, IL, October 31-November 2, 1977.

Harral, J.K.A., "Comparison of Energy Options: Coal Gas or Electricity," Presented at the Fifth Energy Resource Conference, Lexington, KY, January 10-11, 1978.

Hughes, Thomas W., "Source Assessment Methodology," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Jones, Peter W. and Robert J. Jakobsen, "A Critique of Organic Level 1 Analysis," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Knowlton, T.M., "Solids Flow Control Using a Non-Mechanical L-Valve," Presented at the Ninth Synthetic Pipeline Gas Symposium, Chicago, IL, October 31-November 2, 1977.

Kolnsberg, Henry J., "Fugitive Emissions Measurement Techniques for Environmental Assessments," Presented at the Process Measurements for Environmental Assessment Symposium, February 13-15, 1978.

Levins, Philip L., "Measurement of Organic Emissions for Environmental Assessment," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Maddalone, Ray F., and Lorraine E. Ryan, "Inorganic Emissions Measurements," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, Ga, February 13-15, 1978.

Page, Gordon C., "Source Unit Operations," Presented at the IERL-RTP Environmental Assessment Methodology Projects Meeting, Research Triangle Park, NC, October 20-21, 1977.

Page, Gordon, C. and Paul W. Spaite, "Technology Overview Reports," Presented at the IERL-RTP Environmental Assessment Methodology Projects Meeting, Research Triangle Park, NC, October 20-21, 1977.

Rhoads, Richard G., "EPA Air Programs' Use of Environmental Assessments," Presented at the Process Measurements for Environmental Asessment Symposium, Atlanta, GA, February 13-15, 1978.

Schmeal, W.R., A.J. MacNab, and P.R. Rhodes, "Corrosion in Amine/Sour Gas Treating Contactors," ***Chem. Eng. Prog., 74*** (3), 37-42, March 1978.

Smith, Franklin, Eva D. Estes, and Denny E. Eagoner, "Field Evaluation of the SASS Train and Level 1 Procedures," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Statnick, Robert M. and Dave Berg, "OEMI Overview of Environmental Assessment," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

Telliard, William A., "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants," Presented at the Process Measurements for Environmental Assessment Symposium, Atlanta, GA, February 13-15, 1978.

REPORT SUMMARY

Technology Overview: Low- and Medium-Btu Coal Gasification Systems

by

P.W. Spaite and G.C. Page

The technology overview of low- and medium-Btu coal gasification is one of a series of overviews of coal conversion technologies being prepared by the EPA. Each technology overview is intended to describe a system or combination of processes that are likely to be used in coal conversion. The overview consists of:

- An assessment of the status and future prospects of the conversion technology.
- A description of the conversion technology and associated processes likely to be commercially employed.
- A summary of the environmental impacts associated with the conversion technology.

The technology overview of low- and medium-Btu gasification is largely based on Radian Corp.'s "Environmental Assessment Data Base for Low/Medium-Btu Gasification Technology" (EPA-600/7-77-125 a and b, November, 1977; NTIS PB 274-844/AS and PB 274-843/AS). The major portions of the technology overview are summarized in the following paragraphs.

Technology Status

Technology for the production of low- and medium-Btu gas from coal has existed since the 1800's. In the mid 1920's, about 11,000 gasifiers were in service in the U.S. Most of these were retired when cheap natural gas became available.

Future development and commercialization of low/medium-Btu gasification are dependent on several factors such as the cost of the product gas and the energy efficiency of gasification. Other variables affecting future development and commercialization include the applicability of gasification technology to different end-uses, the progress of on-going development, and factors related to the large-scale introduction of gasification systems.

Relatively simple systems that gasify low-sulfur coal and use hot cyclones for particulate removal can produce fuel gas costing $2.50/GJ ($2.60/million Btu). Sophisticated gas cleaning (including sulfur removal) could increase costs by $1-$2/GJ ($1.05-$2.10/million Btu). Low-Btu gasification used in conjunction with combined cycle power generation would produce approximately 1.8 GJ/sec (150 billion Btu/d), cost $250-$400 million, and produce gas costing 2 to 3 times the price of coal (about $2-$3/GJ or $2.10-$3.15/million Btu).

Energy efficiencies of present low/medium-Btu gasification systems are on the order of 60-65%. Future improved gasifiers will probably attain efficiencies near 75%. Gasification with combined-cycle power generation can be more efficient than direct coal-fired power plants with flue gas desulfurization; however, advances in boiler and turbine technology are needed for significant improvement in efficiency.

In the near term, the most promising use of low- and medium-Btu gas are as a synthesis gas in the production of ammonia and methanol and as fuel for direct process heat (as in brick and lime kilns). Use as fuel in industrial boilers is less promising, since retrofit of the existing boilers may be impractical. However, combustion of low-Btu gas in boilers designed for its use may be economically attractive in the near future. Medium-Btu gas distributed to new and existing boilers from a central gasification plant may also become economical. Use of low-Btu gas in combined-cycle, electric generating plants may become competitive with fluidized-bed combustion of coal, or the direct combustion of coal with desulfurization of the flue gas.

Extensive operating experience has been obtained with coal gasification systems. Present research is directed towards characterizing the environmental impacts from plant discharges and developing high temperature product gas cleanup systems. Investigations also aim to improve coal feeding and ash removing mechanisms (for pressurized gasifiers), to improve gasifier designs and water treatments, and to develop better construction materials. Most research involves adapting existing technology to newly identified markets. However, fundamental studies of gasification are needed. Additionally, tolerable environmental discharges need definition.

Until recently, only a few vendors were actively marketing gasification systems. Immediate growth in the coal gasification industry will thus probably be limited by the time needed to design and build the specialized equipment required by gasification plants. Commercial application of central gasification plants supplying medium-Btu gas may be limited by large capital requirements, siting constraints, and complicated marketing arrangements. Commercial development of combined cycle systems requires improvements in gasifier and gas turbine efficiencies. Those gasification systems most likely to attain widespread use are:

- Pressurized systems producing low-Btu gas for use in combined cycles.
- Pressurized systems producing medium-Btu gas as fuel for off-site boilers and process heat or synthesis gas for both on- and off-site use.
- Systems operating at atmospheric pressure and producing low-Btu gas as fuel for on-site boilers and process heat, or reducing gas for on-site use.

Technology Description

The coal gasification system consists of three operations: coal pretreatment, coal gasification, and raw gas cleaning. Generally, any coal can be gasified if proper pretreatment is employed. With some high-moisture coals, coal drying may be desirable. For some caking coals, partial oxidation may be employed to simplify gasifier operation. Other pretreatment operations include crushing and sizing, and briquetting of fines for feed to fixed-bed gasifiers. The coal feed is pulverized for fluid- or entrained-bed gasifiers.

About 70 gasifiers have been used commercially in the past or are currently under development. Seven gasifiers are presently used to satisfy commercial demand: Chapman (Wilputte), Koppers-Totzek, Lurgi, Wellman-Galusha, Wellman Incandescent, Winkler, and Woodall-Duckham/Gas Integrale. In addition to these gasifiers, seven gasifiers have been identified as "promising": Foster Wheeler/Stoic, Riley-Morgan, pressurized Wellman-Galusha (MERC), BGC/Lurgi slagging, Coalex, BI-GAS, and Texaco. These gasifiers fall into one of six classes depending on the type of bed (fixed, entrained, or fluidized), the operating pressure (pressurized or atmospheric), and the method of ash removal (as slag or dry ash). Gasifiers within each class have similar environmental impacts.

The specific processes used for raw gas cleaning are determined mainly by the type of coal processed and the product gas requirements. Essentially four gas purification processes may be required: particulate removal, tar and oil removal, gas quenching and cooling, and acid gas removal. The primary function of the particulate removal process is the removal of coal

dust, ash, and tar aerosols entrained in the raw product gas leaving the gasifier. During tar and oil removal and gas quenching and cooling, tars and oils are condensed and other impurities such as ammonia are scrubbed from raw product gas. Acid gases such as H_2S, COS, CS_2, mercaptans, and CO_2 can be removed from gas by an acid gas removal process. Where sulfur in the input coal is low, sulfur removal may not be required if the gas is used for process heat or burned in boilers. Gas in combined-cycles, synthesis gas, and gas transported in pipelines will usually require sulfur removal. Gasification systems operating above atmospheric pressure will probably use chemical solvent or direct conversion processes. The amine and alkaline salts acid gas removal processes only concentrate the acid gas, producing streams requiring the removal of sulfur. The Stretford process will convert H_2S directly into sulfur, but does not remove organic sulfur compounds such as COS, CS_2, and mercaptans.

Environmental Impacts

All of the three basic operations associated with low- and medium-Btu gasification technology (coal pretreatment, gasification, and gas cleaning) can produce discharges with potential environmental impacts. These discharges are summarized and discussed in Table 1.

Wastes from coal storage, handling, and sizing can be controlled using available techniques for reducing coal dust emissions, mineral wastes, and storage pile runoffs. Controlling air emissions from coal dryers, briquetting, and partial oxidation processes is more difficult because of the volatile hydrocarbons and possible trace metals which are liberated as the coal is heated. The potential toxicities of these wastes have not been determined.

The coal gasification process itself appears to be the most serious source of potential pollution problems. The feeding of coal and the withdrawal of ash release emissions of coal or ash dust and organic and inorganic gases that are potentially toxic and carcinogenic. Because of their reduced production of tars and condensable hydrocarbons, slagging gasifiers pose less severe emission problems at the coal inlet and ash outlet. Gasifiers and associated equipment will also be sources of potentially hazardous fugitive leaks. Fugitive leaks may be more severe from pressurized gasifiers and/or gasifiers operating at high temperatures.

The gas treatment processes also present difficult control problems. Particulate collection and gas treatment produce ash, tars, and water contaminated with toxic organics and inorganics. All sulfur collection systems will produce a purge stream of contaminated sorbent liquid. In addition, volatilization or carryover of sorbent can be a potential source of air pollution. The sulfur removal processes will also produce fugitive emissions which are similar to those generated during gasificaiton. Tail gases from sulfur recovery may require further treatment before release.

Table 1. DISCHARGES FROM LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Operation

Discharge Source/Stream	Description	Remarks
Coal Pretreatment		
Storage, handling, and crushing/sizing		
Dust emissions	The air emissions from coal storage piles, crushing/sizing and handling will consist primarily of coal dust. The amount of these emissions will vary from site to site depending on wind velocities and coal size.	Asphalt and various polymers have been used to control dust emissions from coal storage piles. Water sprays and enclosed equipment have been used to control coal handling emissions. Enclosures and hoods have been used for coal crushing/sizing.
Water runoff	The amount of data are minimal on dissolved and suspended organics and inorganics in runoff water produced for coal storage piles and dust control or supression processes.	Proper runoff water management techniques have been developed. More data on the characterisitcs of this wastewater are needed to determine the necessity for treating this effluent.
Solid wastes from crushing and sizing	This stream consists of rock and mineral matter rejected from crushing and sizing coal. There is little data concerning the trace components in this stream. The potential of these components to contaminate surface and groundwaters is not known.	This waste has been disposed of in landfills. Leaching data are required to evaluate the potential environmental impacts associated with this solid waste.

(Continued)

Table 1. DISCHARGES FROM LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Continued

Operation

Discharge Source/ Stream	Description	Remarks
Coal drying, partial oxidation, and briquetting		
Vent gases	These emissions will contain coal dust and combustion gases along with a variety of organic compounds liberated as a result of coal devolatization reactions. There are currently little data on the characteristics of these organic species.	The organic compounds must be characterized to determine whether this discharge stream requires control. Afterburners in addition to particulate collection devices may be required.
Coal Gasification		
Coal feeding device		
Vent gases	There are currently no data on the characteristics of these gases. These vent gases may contain hazardous species found in the raw product gas exiting the gasifier.	Vent gases from coal feeders can represent a significant environmental and health problem. Control of these emissions is required; however, the characteristics of these gases must be determined to implement an adequate control method.
Ash removal device		
Vent gases	No data are presently available on the characteristics of this discharge stream. This stream may contain hazardous species found in the raw product gas and may require control.	Many sources of contaminated water may be used for ash quenching. Therefore, volatile organics and inorganics may be released in these vent gases. Characterization of emissions is needed to define control technology requirements.
Spent ash quench water	There are limited data on the discharge stream. This stream will contain dissolved and suspended organics and inorganics and will require control.	Characterization of this waste stream is required to define control technology requirements. Further treatment of this stream is essential.
Ash or slag	Data are limited on the characteristics of the ash and slag, especially with respect to the amount of unreacted coal, trace elements and total organics.	Leaching tests must be done on this solid waste to determine whether further treatment is necessary before final disposal. The organic content of the liquor used to quench the ash may affect the final disposal of the ash.
Coal Gasifier		
Start-up vent stream	No data currently exist on the composition of the start-up vent stream. Depending on the coal feedstock, there may be tar and oil aerosols, sulfur species, cyanides, etc., in this stream; therefore, control of pollutants generated during start-up is required.	This stream can be controlled using a flare to burn the combustible constituents. The amount of heavy tars and coal particulates in this stream will affect the performance of the flare. Problems with tars and coal particles can be minimized by using charcoal or coke as the start-up fuel.

(Continued)

Table 1. DISCHARGES FROM LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Continued

Operation

Discharge Source/Stream	Description	Remarks
Fugitive emissions	There are no data available on these emissions. They can be expected to contain hazardous species present in the raw product gas such as hydrogen sulfide, carbon monoxide, and hydrogen cyanide.	These emissions will determine the extent of workers' exposure to hazardous species and define the need for continuous area monitoring of toxic compounds and personnel protection equipment.
Gas Purification		
Particulate removal		
Collected particulate matter	Limited data are available on the characteristics of this solid waste stream. This stream will contain unreacted carbon, sulfur species, organics, and trace elements.	Characterization of this stream is necessary to determine whether it can be used as a by-product or whether further treatment is necessary before disposal. Current data indicate that there is a significant amount of unreacted carbon in this stream, and it may be used as a combustion fuel.
Gas quenching and cooling		
Spent quench liquor	Data are insufficient regarding the composition of this stream; however, existing data indicate that there are significant quantities of suspended and dissolved organics (primarily phenols) and inorganics present in this stream.	Characterization of this stream will determine the type of water pollution control techniques required to treat the spent quench liquor. These control techniques will vary depending upon the quantity and composition of this effluent stream.
Acid gas removal		
Tail gases	There are little data on the composition of these tail gases. These gases will contain sulfur species and hydrocarbons.	These gases are the primary feedstock to the sulfur recovery and control processes. Trace constituents such as hydrocarbons, trace elements, and cyanides will affect the performance of these sulfur recovery processes.
Spent sorbents and reactants	No data have been reported on these streams. These streams will contain hazardous species such as cyanides, heavy metals, and organics, and will require further treatment before disposal.	Characterization of this stream is required if it is to be treated using on-site pollution control devices.

Environmental Review of Synthetic Fuels is prepared by Radian Corporation under EPA contract 68-02-2147. Each contractor listed in the Table of Contractors on page 8 of this report contributed to this issue. The EPA/IERL-RTP Project Officer is William J. Rhodes, (919) 541-2851. The Radian Program Manager is Eugene C. Cavanaugh, (512) 454-4797. Comments on this issue, topics for inclusion in future issues, and requests for subscriptions should be communicated to them.