EPA

ENVIRONMENTAL REVIEW of SYNTHETIC FUELS

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY

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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. The program is evaluating the environmental impacts of synthetic fuel processes with a high potential for commercial application. It is directed by the Fuel Process Branch of EPA's Industrial Environmental Research Laboratory in Research Triangle Park, NC (IERL-RTP).

The primary objectives of the EPA Synthetic Fuels Environmental Assessment/Control Technology Development Program are 1) to define the environmental and health effects of multimedia discharge streams, and 2) to define control technology needs for an environmentally sound synthetic fuels industry. The synthetic fuels from coal technologies being studied in this program include low/medium-Btu gasification, high-Btu gasification and liquefaction. To achieve overall objectives, the EPA has defined six major task areas: current process technology background, environmental data acquisition, current environmental background, environmental objectives development, control technology assessment, and impact analysis. The contractors involved in the program, their EPA Project Officers, and the duration of each effort are tabulated on page 7.

This is the latest in a series of periodic reviews of recent activities in EPA's synthetic fuels program. Activities of EPA contractors are covered in sections on current technology background, environmental data acquisition, and control technology assessment. Highlights of technology and commercial development, major symposia, a calendar of upcoming meetings, and a list of major publications provide up-to-date information on national and international development in synthetic fuels technology. Comments or suggestions which will improve the content or format of these reviews are welcome. Such comments should be directed to the EPA or Radian Corporation personnel identified on page 16 of this review.

CURRENT PROCESS TECHNOLOGY BACKGROUND

Liquefaction

Environmental Assessment of Solvent Refined Coal (SRC) Systems — Hittman Associates, Inc., is preparing an Environmental Assessment Report (EAR) for SRC systems. The EAR examines both the SRC-I (solid product) and SRC-II (liquid product) variations of solvent refining for a hypothetical plant producing 0.09 m^3/s (50,000 bbl/day) liquefied coal products.

The EAR discusses the processes involved in SRC systems and characterizes feed materials, process streams, waste streams, products, and by-products. Based on available stream characterization data, control and disposal options are surveyed to determine their applicability to process discharges. The EAR also surveys potential regulatory requirements and compares them to after treatment discharge levels.

Multimedia Environmental Goals (MEGs) and Source Analysis Models (SAMs) are applied to determine the environmental effects of treated discharges. SAM analysis of existing data indicates that the solid wastes produced by SRC systems pose the greatest environmental problem. A major difference between SRC-I and SRC-II systems is the potential for particulate emissions in the form of SRC-I solid product dust.

Environmental Data Base for Coal Liquefaction Technology — A major portion of Hittman Associates' work in synthetic fuels is designed to establish a comprehensive environmental data base for coal liquefaction. This task involves the following areas:

- Identification and description of all major coal liquefaction schemes currently under development.
- In-depth appraisal of the most advanced liquefaction schemes from a process development standpoint.
- Quantification and characterization of waste streams associated with the most advanced processes.
- Expected environmental and health effects of coal liquefaction products.
- Pollution control options applicable to liquefaction discharge streams.
- Review of environmental standards for related fossil fuel technologies which might be applicable to liquefaction facilities.

The results of Hittman's work in these areas have been compiled in two recently completed reports (EPA-600/7-78-184a and b), which are summarized in the "Report Summaries" section of this issue. These studies, together with the *Standards of Practice Manual for the Solvent Refined Coal Liquefaction Process* (EPA-600/7-78-091, see the *Environmental Review of Synthetic Fuels*, Volume 2, Number 2) represent EPA's current data base for the environmental assessment of coal liquefaction technology.

ENVIRONMENTAL DATA ACQUISITION

General Topics

Hazards and Health Effects of Pollutants from a Laboratory Gasifier — Research Triangle Institute (RTI) has now performed more than fifty tests with a laboratory semi-batch coal gasifier. Tests have typically consisted of air blown, autothermic operation resulting in low-Btu gas. Operating parameters and pollutant levels parallel those of full-scale gasifiers.

Pollutants have been summed or averaged over all tests in order to compare coal types and reactor streams. The highest gas stream hazards result from gasifying high sulfur eastern coals. Tar and condensate hazards of western and eastern coals were comparable.

Various streams were analyzed to identify those constituents having potentially severe health effects. In tars and aqueous condensates, the hazardous effects result from oxygen-containing species and polynuclear aromatics (PNAs). In the primary gas stream, carbon monoxide, benzene, and hydrogen sulfide are of concern. Constituents in the reactor residue that might present significant hazards include specific trace elements.

Statistical correlations of the total data base have shown several relationships between coal properties, waste stream constituents, and operating parameters:

- Phenols and condensates inversely correlate with percent tar and coal rank.
- The percent of organic bases in tar increases with higher steam-to-air ratios.
- Carbonyl sulfide production increases with higher air-to-coal ratios.
- Tar hazard factors are reduced by extending the time period to reach maximum reactor temperature.
- Increased sulfate levels in coal correlate directly with quantities of sulfur in the ash after reaction.
- Percent PNAs in tar correlates poorly with coal rank and only slightly with tar mass produced.

Bioassay studies (Ames Tests) of tar fractions from two coals showed dissimilar mutagenic properties. The Western Kentucky crude tar and its fractions were three to four times more mutagenic than the corresponding Wyoming fractions. This difference is likely due to the higher content of PNAs and other known mutagens in the Kentucky tar. No mutagenicity or toxicity was observed when these same coals were tested as coal dust (raw unfractionated coal).

Experiments suggested for future work are Chinese hamster ovary cell culture for mutagenicity and cytotoxicity tests, and sister chromatid exchange to determine chromosome damage.

Gasification

Testing Completed at Glen Gery Wellman-Galusha Gasification Facility — Radian Corporation has completed a source test and evaluation (STE) program for the Wellman-Galusha gasification system at the York, Pennsylvania plant of the Glen Gery Brick Co. The objective of this program was to gather data for evaluating the environmental and health effects of the plant's multimedia waste streams and for determining the equipment required to control problem waste streams.

To meet this objective, samples of 12 process and waste streams, and flow rate and operating data were obtained. This information was used to:

- Calculate a mass balance for the facility.
- Characterize the waste streams (including the low-Btu combustion products).
- Characterize the collection efficiency of the product gas cyclone.

Process and waste streams sampled included coal feedstock, gasifier ash, ash sluice water, coal hopper gases, pokehole gases, cyclone dust, and clean product gas.

Overall results from chemical analyses indicate that all waste streams sampled contain organic and/or inorganic constituents in potentially hazardous concentrations according to SAM/IA evaluation. However, a non-tar/oil producing anthracite coal is used at this facility, and the potential hazards of these streams are much lower than those of the waste streams produced by gasifying bituminous coal.

The study recommends priorities, based on SAM/IA evaluation, for future chemical analyses of each waste stream. Control recommendations for most waste streams are also given. In addition, the study recommends that the hazardous organics be identified for those waste streams where the organics are the major contributors to the total stream discharge severity.

Phase I Testing Completed at Overseas Gasifier — The first of two phases of testing has been completed at the Lurgi gasification facility (Kosovo Kombine) at Obilic, Yugoslavia. This environmental data acquisition program is being jointly sponsored by EPA and the government of Yugo-

slavia. Test efforts are being directed by Radian Corporation, the Rudarski Institute of Yugoslavia, and other technical organizations within Yugoslavia.

Because the Lurgi process is proposed for several U. S. plants, EPA wants to develop a sound basis for ensuring the environmental acceptability of these facilities. At Kosovo, EPA hopes to gather critical data needed to specify control priorities and to support reasonable performance standards for future U. S. Lurgi gasification facilities.

The Phase I test was a broad screening study of the process and waste streams at the Kosovo plant. In this phase, about 50 key streams were sampled and analyzed. Air emissions received primary attention, and the results give a reasonable definition of the scope and magnitude of the air emission problems to be addressed in U. S. Lurgi applications.

The Phase I testing identified nine major emission sources which must be examined further:

- Fleissner Lignite Drying Process.
- Coal Feeding System (Lock Hopper) Vents.
- Generator Start-up Gases.
- Gas Cooling/Tar Separation Section Flash Gases.
- Rectisol Process.
- Phenosolvan Condensate Strippers.
- By-Product Storage Tank Vents.
- Incinerator.
- Air/Oxygen-Rich Vents.

The Rectisol unit is one of the most significant air emission sources at Kosovo. This unit is a selective acid gas removal system which generates two emissions: a CO_2-rich stream containing minor amounts of H_2S and other sulfur species, and an H_2S-rich stream which should contain most of the other acid gases and sulfur species. The CO_2-rich stream is vented directly to the atmosphere at Kosovo. This same approach has been proposed in conceptual designs for several U. S. plants. Phase I data do not indicate that this vent stream would be a serious problem, except perhaps during upset conditions. Components other than CO_2 which were found in the CO_2-rich vent gas included primarily methane and other light hydrocarbons, with minor amounts of H_2S, HCN, and mercaptans.

The H_2S-rich gas stream generated by the Rectisol unit is a very significant waste stream. At Kosovo, this stream is flared. In the U. S., the use of a treatment process which produces a marketable by-product (e.g., Claus, Stretford) is the preferred approach. However, Phase I test results indicate potential problems with this option. First, the CO_2 content of this stream may be too high to permit the economical use of a Claus system. Also, the mercaptans and hydrocarbons in this stream could interfere with tail gas treatment and product purity.

EPA's Source Analysis Model (SAM) methodology was applied to the air emission streams and to individual stream components studied in Phase I. The SAM methodology is a rapid screening technique which determines the discharge severity associated with the pollutants and waste streams. The SAM methodology is thus a convenient method for assessing potential environmental problems associated with waste streams and pollutants.

SAM procedures were applied to Phase I test results for fixed gases, light hydrocarbons, and nitrogen species. CO is the most significant pollutant of the fixed gases. Of the light hydrocarbons examined, the most important pollutant is benzene. The analysis of sulfur species indicates that mercaptans are at least as significant a pollutant as H_2S. Finally, of the two nitrogen species analyzed, NH_3 appears to be more of a problem than HCN.

Phase I testing also yielded useful data concerning the liquid and solid waste streams at Kosovo. (For a summary of these data, see the *Environmental Review of Synthetic Fuels*, Volume 2, Number 1.) These streams will be characterized further during the Phase II tests. Major efforts will focus on:

- Quantification of trace and minor components, particularly leachable species, in solid waste streams and water soluble or highly volatile components in liquid wastes.
- Potential for hazardous emissions from the use of liquid hydrocarbon by-products as onsite fuels.

Future work at Kosovo will address some of the key questions raised by the Phase I test results. Key emission streams will be further characterized to determine levels of potentially hazardous components such as trace elements and trace organics. Control and treatment of the Rectisol acid gas streams will also be studied. Plans have also been made to characterize generator start-up gases and fugitive emissions.

A comprehensive summary of the Kosovo Program was presented in April at EPA's Symposium on Environmental Aspects of Fuel Conversion Technology (see "Recent Major Meetings" in this issue).

Sampling Effort to Aid in Environmental Assessment of Low-Btu Gasification Process — Union Carbide Corporation's Oak Ridge National Laboratory (ORNL) is conducting a DOE-sponsored test program at the University of Minnesota gasification facility. The facility includes a Foster-Wheeler Stoic two-stage gasifier, which provides a low-Btu fuel gas. The product gas is fired in conventional boilers to produce steam for campus heating. Tar and oil generated by the gasifier are combusted in an oil-fired boiler. Data gathered during this program will aid DOE and other federal agencies in evaluating the environmental acceptability of the low-Btu gasification process.

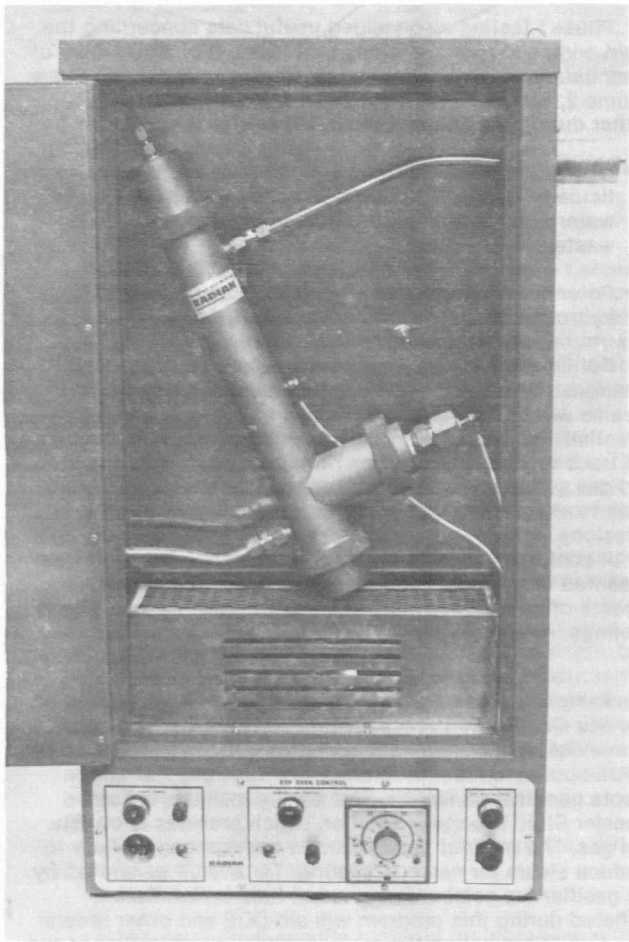
Under subcontract to ORNL, Radian Corporation is supplying all gas sampling equipment, operating manuals, and training of sampling personnel. Radian will also provide equipment for pretreating a side stream of the low-Btu product gas prior to analysis by on-line gas chromatographs.

To meet the objective of the ORNL program, product gas streams will be sampled for biological testing and also to determine stream velocity, particulates (including size distribution), liquid aerosols, and inorganic and organic chemical compositions. Two fuel gas particulate removal devices, a hot cyclone and an electrostatic precipitator (ESP), will be evaluated by upstream and downstream sampling.

To aid in the sampling efforts, Radian has developed a new adaptation of the electrostatic precipitator (ESP), as shown below. The adapted ESP can be used both to sample aerosol streams and to remove aerosol tars and oils in preparation for gas chromatography analysis. The aerosol tars and oils are a major problem in sampling and cannot be removed by standard filtering methods.

The ESP has a cylindrical design with a 0.3 m (1 ft)-long collection zone. The electron source, a fine wire mounted in the center of the cross-sectional area, runs the length of the collection chamber. The electric potential occurs between

this wire and the outer wall. The ESP has a high collection efficiency because ionization occurs over the full length of the collection zone. The ESP is enclosed in an oven for temperature control. Gas stream temperature can thus be maintained at process levels to control sample integrity, or at lower temperatures to cause condensation and tar/aerosol removal in the ESP.



ADAPTED ELECTROSTATIC PRECIPITATOR

The conditioning system which will supply gas samples to on-line chromatographs consists of two ESPs in parallel, each in a separate oven. When the ovens are maintained below process temperatures, the aerosols and tars in the incoming stream will condense in the ESP. This prevents fouling of the downstream instruments. The system is designed to switch the gas stream automatically from one ESP to the other when one becomes fouled by tars and oils. If both ESPs are fouled, gas flow to the process gas chromatographs stops automatically.

Arrangements for testing at Koppers-Totzek Gasification Facility — TRW is finalizing arrangements with Krupp-Koppers (KK), licensors for the Koppers-Totzek gasification process, for a program to acquire data from the Modderfontein gasification plant. This facility is operated by the African Explosives and Chemical Industries (AE & CI) of South Africa. KK is responsible for all sampling of the selected streams and will perform limited analyses in South Africa. Samples of liquids will be stabilized and shipped to the TRW laboratory for analysis. The sampling effort is scheduled for this fall.

Liquefaction

Testing at SRC-II Pilot Plant — Hittman Associates, Inc., is performing a sampling and analysis program at the SRC-II pilot plant in Ft. Lewis, Washington. The plant, operated by the Pittsburgh and Midway Coal Mining Company, can convert 0.52 kg/s (49 tons/day) of coal to SRC products. Hittman's sampling plan is based on the phased levels of sampling and analysis developed by EPA's IERL-RTP.

Level 1 studies, consisting of quantitative sampling and analysis, provided preliminary environmental assessment data on SRC products and on the wastewater treatment facility of the Ft. Lewis plant.

The wastewater treatment system significantly reduced levels of SRC-II pollutants. The bio-unit was especially effective in removing organics. TOC, oil and grease, and TCO material with boiling points between 100 and 300° C were decreased by over 99 percent; COD was reduced by 93 percent. The reduction efficiency for ammonia was relatively low because ammonia levels exceeded the nutrient requirements of the microorganisms in the bio-unit.

Very toxic chlorinated aromatic hydrocarbons were present in the clarifier influent and flottazur effluent streams. No quantitative data are available to verify their sources or the reduction of these substances in the wastewater treatment system.

The treatment process showed a removal efficiency of over 50 percent for all trace elements except calcium, lead, and sulfur.

Infrared analysis of solid wastes showed phenolic compounds in all streams. Polynuclear aromatic hydrocarbons (PNAs) were the major organic components in the flottazur skimmings and clarifier sediment. Of the trace elements studied, only iron in both the clarifier sediment and flottazur skimmings exceeded the health-based discharge multimedia environmental goal (DMEG) value. However, several trace elements did exceed the ecologically based DMEG value. The bio-unit sludge and clarifier sediment were quite toxic, largely because of the presence of phosphorous components. Since the chemical form of these components was not determined, the interpretation procedure requires that the worst case component, elemental phosphorous, be assumed.

Levels of non-volatile trace elements in product streams and residue seemed to correlate with trace element boiling points. Highest trace metal levels occurred in the residue. Lower amounts were found, in order of decreasing concentration, in the heavy distillate, middle distillate, and naphtha. PNAs were the main constituents of the heavy distillates; phenolic compounds were most abundant in the middle distillates. Aliphatics were the major components of the naphtha. The heavy distillate showed the greatest discharge severity, based on concentrations of pollutants and DMEG values.

Additional Phase I testing, started in February 1979, was designed to confirm the results of original Phase I data and to obtain additional data. Several streams were sampled and prioritized according to levels of potentially toxic materials. These streams are listed below, in decreasing order of priority:

- Recycle process water tank.
- Sulfur recovery area drain.
- Wastewater treatment plant inflow.
- Wastewater treatment plant effluent.
- Coal storage area drain.
- Drain from general surfaced area.
- Coal preparation area drain.
- Dissolver/separator area drain.

- Solvent fractionation area drain.
- Boiler blowdown.
- Sandvik belt water.
- Cooling water.

A significant result of the preliminary sample analysis is that large variations in the concentrations, and even the presence, of certain chemicals occur due to minor shifts in operating conditions. Thus, a single grab sample may not tell enough about the chemicals or concentrations that can exist in a waste stream from an SRC plant. Detailed information is required on operating temperature and pressure, changes in coal type and feed rate, and other physical parameters, to evaluate changes in wastewater constituents.

CONTROL TECHNOLOGY ASSESSMENT

General Topics

Biotreatability and Toxicity of Coal Conversion Wastewaters — The University of North Carolina (UNC) is studying the biotreatability and toxicity of wastewaters generated by coal conversion processes. This work is part of UNC's overall project to assess environmental impacts and alternate methods of controlling wastewater contaminants.

For the biotreatability studies, UNC developed a synthetic wastewater which includes 28 organic compounds in addition to nutrients and buffers. These constituents represent the major classes of organics and virtually all specific compounds found at high concentrations in real synthetic fuel wastewaters. The synthetic wastewater provides a medium for developing an acclimatized microbial community for use in biodegradation and treatability studies.

The studies are conducted in 25-liter reactor units which use activated sludge from a municipal wastewater treatment plant. The synthetic wastewater is fed to the reactors over a period of several days to permit acclimatization of the sludge to the wastewater.

High performance liquid chromatography analysis of the raw feed and effluent from one of the reactors showed a reduction in nonpolar compounds, including xylenols, pyridines, quinolines, indoles, naphthols, and trimethylphenol. UV absorbance and simultaneous fluorescence analyses indicated that, although much of the carbon in the feed is phenolic, few of the organics remaining after treatment are phenolic.

Toxicity studies using Chinese hamster lung cells demonstrated that substantial reductions in toxicity occur in the reactors. Only about 1 percent raw feed was required for a 50 percent reduction in cell plating efficiency; 90 percent reactor effluent was necessary to achieve the same reduction.

Ongoing work at UNC includes respiration rate studies to evaluate biodegradability and toxicity of wastewater constituents. Fresh sludge from the reactor is exposed to the individual wastewater constituents in order to determine the effects of the constituents on respiration rates over a period of several hours. A decrease in the respiration rate indicates inhibition of the sludge by the particular constituent in question.

Low/Medium-Btu Gasification

Pollution Control Guidance Report for Low-Btu Gasification Technology — Radian Corporation is preparing a Pollution Control Guidance Report (PCGR) for low-Btu coal gasification technology. The purpose of this work is to compile, in one document, a data base for applicable multimedia pollution controls. The PCGR will be useful to both private industry and those regulatory agencies responsible for permitting or licensing low-Btu gasification facilities.

The PCGR will provide information about:

- The uncontrolled discharge streams of potential environmental concern.
- Applicable control methods for these streams.
- The effectiveness and associated costs of these control methods.

In addition to data on specific pollution control technologies, the PCGR will provide EPA with information that can be used in standards setting activities. The PCGR will identify suggested discharge limits and long term monitoring needs for various pollutants in the absence of standards or other criteria. It will also discuss EPA's approach to developing emission standards for low-Btu gasification technology.

Preparation of the PCGR will continue into the winter of 1979. The final report should be available in early 1980.

TECHNOLOGY AND/OR COMMERCIAL DEVELOPMENT

Joint Rupture Most Probable Cause of BIGAS Fire — Investigations are underway at DOE's BIGAS coal gasification pilot plant in Homer City, Pa., to determine the cause of a February 1978 explosion. Preliminary analyses indicate that corrosion cracking caused a stainless steel expansion joint to rupture. The expansion joint was part of a tube which served to recycle coal char, in addition to natural gas and steam, back to the gasifier. The fire probably started when hot fuel gas from the high-pressure gasifier flowed back through the rupture and contacted oxygen in the air.

Additional studies of companion char burner expansion joints are being conducted to confirm the diagnosis. The problem may be avoided in the future by using metal alloys other than stainless steel for the expansion joints.

Brazilian Oil Company to Use Koppers-Totzek Process — Petrobras, Brazil's state oil company, has awarded Krupp-Koppers, West Germany, a $245-million contract to design and build a coal gasification plant in Rio Grande de Sul in southern Brazil. The plant will use the Koppers-Totzek process to produce gas to feed a 6.3 kg/s (600 tons/day) ammonia plant. Start-up is planned for 1983. The project is intended eventually to provide municipal gas that will replace imported LNG.

Slurried Coal to be Gasified in Fluid-Wall Reactor — Southern California Edison (SCE) and Thagard Technology Co. have recently started a test program to gasify slurried coal in a high-temperature, fluid-wall reactor. The slurried coal is exposed to intense infrared radiation at temperatures up to 3,315°C (6,000°F) in a reactor developed by Thagard.

SCE's Mohave plant is currently the only facility in the U. S. supplied by a coal-slurry pipeline. SCE will conduct tests to determine equipment reliability and energy efficiencies for gasifying (without previous dewatering) coal

slurries similar to the 50/50 water-and-coal mix that it now receives. Small-scale gasification tests have been successful, yielding at least a 70 percent carbon conversion in a single 0.3-second pass through the reactor. The level of contaminants in the product gas is very low, and the process produces a dry, granular, free-flowing slag.

According to Thagard, capital costs of such a system would be almost 10 percent less than those for current coal gasification technology. This decrease in costs results from the elimination of an oxygen plant, feed-preparation, and gas purification equipment. Operating costs would also be reduced, since SCE could avoid using costly low-sulfur oil.

Hydrogasification Process to be Tested — Rockwell International's Energy Systems Group (Canoga Park, Ca.,) will design, build, and operate a 1.1 kg/s (100 tons/day) hydrogasification reactor. The $18-million test program, a joint effort of DOE and the Gas Research Institute, is planned for fall, 1980.

The hydrogasification process may be one of the most efficient methods of producing pipeline quality gas from coal. The unique reaction chamber employs a fuel injector system similar to rocket engine designs. The reactor mixes pulverized coal directly with hot 1093°C (2000°F) hydrogen to produce gas with a heating value of 35-37 mJ/Nm³ (900-950 Btu/scf). The rapid mixing (2-3 seconds) prevents bituminous coals from caking and plugging the gasifier. Also, the direct reaction produces pipeline quality gas, eliminating a major part of the purification equipment needed by other processes. Current findings indicate the process has potential for a 20 percent increase in coal conversion/utilization efficiency compared to other processes under development.

Kilngas Demonstration Plant Planned — A $100-million demonstration plant using Allis-Chalmers Corporation's (Milwaukee, Wis.) Kilngas process will be constructed near Wood River, Illinois. Illinois Power is examining the process as a way of using high-sulfur, high-caking Illinois coal to produce low-Btu gas for their power plant. The Kilngas project will use about 6.3 kg/s (600 tons/day) to produce 57 kW/s (700 × 10^6 Btu/hr) of product gas.

Recently, the state's Energy Resources Commission voted to allocate $18 million to the project, bringing current funding commitments to about half the total needed. Illinois Power, along with twelve other utilities and EPRI, will make a complete assessment of the project by the end of the year. Depending on the assessment, construction could begin in the first quarter of 1980.

NCB Plans Two Liquefaction Plants — Britain's National Coal Board (NCB) has started engineering and design studies for two coal liquefaction plants. Each plant will use 0.26 kg/s (25 tons/day) of feed coal. One will use a liquid-solvent extraction process to produce 0.14 kg/s (13 tons/day) of fuel. In this process, crushed coal is slurried with anthracene oil and pumped to a dissolver where up to 85 percent of the coal dissolves at temperatures of 370-450°C (698-842°F). The resultant liquid is filtered, stripped of solvent, and then hydrogenated over a cobalt-molybdenum catalyst.

NCB's supercritical-gas solvent extraction (SGSE) process will be used at the second plant to produce 0.08 kg/s (8 tons/day) of such aromatics as benzene, toluene, and xylene. In this process, one of the aromatic products is used as a supercritical fluid at pressures of 20-27 MPa (200-270 atm) and temperatures of 573-673° (1063-1243°F). The fluid enters an extraction vessel where it contacts a heated bed of coal. Coal constituents dissolve into the fluid and are precipitated from the extract in a separator operating at atmospheric pressure.

Construction of both plants is scheduled to begin in mid-1980. Construction costs of around $60 million are predicted.

High-Sulfur Coal Beneficial for Liquefaction — Pennsylvania State University researchers are studying coal samples to predict which coals can most successfully and economically be converted to clean fuel oil. The University has established a coal sample data base containing information on over 1,000 coals from across the country. The data base has been extensively characterized and analyzed in a series of experiments on 104 types of coals. Fourteen coal properties were analyzed to determine which properties have a significant effect on the liquefaction process.

An unexpected result is that coals with higher sulfur levels or certain macerals (organic materials derived from different plant organs) are more readily liquefied. Researchers do not know why sulfur content is important but speculate that during liquefaction the sulfur is converted into pyrrhotite, a mineral with catalytic properties.

Cresap Liquefaction Test Facility in Full Operation — DOE's liquefaction test facility at Cresap, W. V., has been brought on-line for sustained integrated operation. The facility integrates two separate steps: the first is extract and solvent production and extract storage, and the second is the hydrogenation process. The hydrogenation unit has been tested on a continual basis for more than 400 hours. Mechanical difficulties encountered with the high-pressure heat pumps used in the hydrogenation process are considered solvable. The Cresap facility represents the largest scale at which hydrogenation technology has been operated. Conoco Coal Development Company's de-ashing process is also being used on an unprecedented scale at Cresap. So far, this process has proven mechanically reliable.

New Process for High-Ash Coals Tested in West Germany — A new coal gasification process is being tested at a $9-million 0.38 kg/s (1.5 tons/hr) plant at Hueckelhoven, West Germany. The process, especially suitable for gasifying high-ash coal, was developed by Projektierung Chemischer Verfahrenstechnik, a subsidiary of the Flick Group.

The new process can treat coal with an ash content of up to 40 percent. Since high temperature coke is the only feedstock used, the raw product gas contains easily removable impurities, such as carbon dioxide and hydrogen sulfide.

Air rather than oxygen is fed directly to the gasifier, eliminating the need for an oxygen plant. However, this practice does yield a product gas with significant nitrogen levels, which reduces the heating value and makes the process most suitable for low- or medium-Btu fuel needs.

Study to Examine Health Effects of Liquefaction Processes — DOE's Energy Technology and Environment Divisions are planning a five-year study of the health effects of coal liquids. In the first phase of the study, Battelle Pacific Northwest Laboratories will assess DOE's solvent refined coal (SRC) pilot plant at Fort Lewis, Washington. Subsequent phases, to be carried out by Oak Ridge National Laboratory and others, will examine the H-coal and the Exxon donor solvent processes.

Earlier studies have shown that coal liquids, particularly the heavier fractions, contain carcinogenic materials. The DOE study will take samples from several stages of the production process and examine them for toxicity, carcinogenicity, mutagenicity, and other properties. The goal is to identify those stages of the process with the potential for exposing workers to harmful substances, so that protective measures can be developed.

PROJECT TITLES, CONTRACTORS, AND EPA PROJECT OFFICERS IN EPA'S IERL-RTP FUEL PROCESS BRANCH ENVIRONMENTAL ASSESSMENT PROGRAM*

Project Title	Contractor	EPA Project Officer
Environmental Assessment of Low/Medium-Btu Gasification (March 1976-November 1979)	Radian Corporation 8500 Shoal Creek Blvd. Austin, TX 78766 (512) 454-4797 (Gordon 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-October 1979)	Hittman Associates, Inc. 9190 Red Branch Road Columbia, MD 21043 (301) 730-7800 (Wayne Morris)	William J. Rhodes IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
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 (James Ferrell)	N. Dean Smith IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
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) 966-1023 (Phillip Singer)	N. Dean Smith IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851
Pollutant Identification From a Bench Scale Unit (November 1976-October 1981) (Grant)	Research Triangle Institute P. O. Box 12194 Research Triangle Park, NC 27709 (919) 541-6000 (Forest Mixon)	N. Dean Smith IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2851

*Three control technology projects previously listed here have been terminated due to the lack of available funds.

REPORT SUMMARIES

Environmental Assessment Data Base for Coal Liquefaction Technology Volume I — Systems for Fourteen Liquefaction Processes

by

C. Koralek and S. S. Patel
Hittman Associates, Inc.

Volume I of this report (EPA-600/7-78-184a) is part of EPA's current data base for the environmental assessment of coal liquefaction technology. It is an assessment of 14 coal liquefaction systems now under development. In general, these liquefaction operations begin with pretreatment of the coal. Coal feed must be reduced to the required particle size and either dried or slurried by mixing with a process-derived slurry. In the liquefaction operation,

hydrogen is added and the components in the coal dissociate. These components are then separated from the coal residues through a variety of operations. The resulting products and by-products are purified, upgraded, and refined.

The study data for the fourteen systems examined in Volume I include process descriptions, flow diagrams, and lists of the materials entering and leaving each system. The processes required to produce clean, liquid fuels from coal are divided into discrete operations. Each of these operations is then further divided into discrete modules, with each module having a defined function, identifiable raw materials, products, and discharge streams. A general discussion of potential, applicable control techniques is presented, along with the current status and development plans for the fourteen coal liquefaction systems.

The fourteen processes addressed in Volume I are:

- Solvent Refined Coal (SRC)
- H-Coal
- Exxon Donor Solvent
- Consol Synthetic Fuel
- Clean Coke
- Supercritical Gas Extraction
- Fischer-Tropsch
- Methanol
- Co-Steam
- Synthoil
- COED
- Liqui-Coal
- Toscoal

These processes are grouped into the general technology categories of hydrogenation, pyrolysis and hydrocarbonization, and extraction and gasification followed by catalytic synthesis.

The hydrogenation processes are the most advanced. Two SRC pilot plants are successfully operating. A full scale test of the combustion characteristics of solvent refined coal (SRC-I) was conducted in the spring of 1977. Construction of an H-Coal process pilot plant is nearing completion. When operational, this facility will be the largest liquefaction plant in the United States. A pilot demonstration of the Exxon Donor Solvent (EDS) process is also planned. A 227-metric ton (250-ton) per day pilot plant will be built at Baytown, Texas, as a joint government-industry project. Plans are for operation to begin in FY 80 in this major development effort.

Pyrolysis and hydrocarbonization projects include two primary efforts: the Char-Oil-Energy-Development (COED) and Coalcon processes. COED has progressed successfully through the pilot plant stage, and work on this process has been terminated — however, the developers are pursuing related efforts. The Coalcon process developers, faced with escalating costs as well as technical problems, have terminated plans for constructing a pilot plant. All processes in this category will have the disadvantage of comparatively low thermal efficiency.

The Supercritical Gas Extraction process has not been developed beyond the laboratory stage. In systems using gasification followed by catalytic synthesis, carbon monoxide and hydrogen (produced in the gasifier) react in the presence of a Fischer-Tropsch catalyst to produce a wide variety of liquid products.

The multimedia waste streams produced by these processes must be characterized to supply the information necessary for environmental assessment. Hittman is now formulating test plans and contacting system developers to fill these data gaps.

Environmental Assessment Data Base for Coal Liquefaction Technology: Volume II — Synthoil, H-Coal, and Exxon Donor Solvent Processes

by

C. L. Parker and D. I. Dykstra, Editors
Hittman Associates, Inc.

Four coal liquefaction processes are generally considered the most technologically advanced at this point in time: Solvent Refined Coal (SRC), H-Coal, Exxon Donor Solvent (EDS), and Synthoil. This study (EPA-600/7-78-184b) is an environmental characterization of three of these processes (H-Coal, EDS, and Synthoil). It includes an integrated multimedia assessment of the discharges to the environment from conceptualized 0.09 m^3/s (50,000 bbl/day) systems. The fourth process mentioned above, SRC, is specifically addressed in the *Standards of Practice Manual for the Solvent Refined Coal Process* (EPA-600/7-78-091, see the *Environmental Review of Synthetic Fuels*, Volume 2, Number 2).

Events since initiation of this study indicate that the Synthoil process will not be developed to a larger scale. However, since work was already completed on this process, the information was included in the report.

The H-Coal, EDS, and Synthoil liquefaction processes have similar products and wastes. The amounts and compositions of these materials are functions of several variables:

- Composition of the feed coal.
- Treatment and control technology.
- Operating conditions.
- Operations and auxiliary processes such as coal preparation; generation of hydrogen, oxygen, steam, and electricity; and by-product recovery.

Generally these variables have a greater influence on the environmental discharges, impacts, and needed safeguards than the specific liquefaction process itself.

For the purposes of this report, components of the three coal liquefaction processes were compared and grouped into two categories: (1) general operations common to all three systems, and (2) operations specific to each system.

General operations, processes, and facilities include coal preparation; heat and power generation; cooling water provision; hydrogen and oxygen generation; storage for raw materials; waste treatment and control installation; and personnel and process-related buildings, storage, and transportation facilities. Environmental discharges, with the possible exception of hydrogen generation, can be estimated directly from similar installations in other industries.

Operations and processes specific for each system include hydrogenation, phase separations, and acid gas treatment. Other operations and processes will be present for specific system variations. The product and waste stream discharges from this portion of the system were not estimated from a similar facility, since there is none. Instead, product and waste stream discharges for this portion of the system have been estimated from information available as of September 1977 for bench-scale, PDU, and pilot plant units.

Waste Characterizations

Substantial effort in this study was devoted to characterizing emissions. Tables 1, 2, and 3 illustrate the results for gaseous, solid, and aqueous discharges generated by conceptualized systems using the three processes.

Environmental Effects

In line with earlier research on available technology to remove or control wastes such as hydrogen sulfide, sulfur dioxide, ammonia, and phenols, the most critical concerns over potential environmental effects are with the lesser-volume waste and product components, such as trace elements and biologically active organics. This is true partially because, while some attention is being addressed to the high-volume pollutants, neither the presence nor the effects of these lesser-volume substances have been quantified at this time. A detailed discussion of current

TABLE 1. GASEOUS DISCHARGES FROM COAL LIQUEFACTION PROCESSES[1]

STREAM	PROCESS[2]		
	H-COAL	EDS	SYNTHOIL
Acid Gas From Product Purification			
Total	659	553	1,169
H_2S	2-10 ppm	2-10 ppm	2-10 ppm
NH_3	0.5	7.5	5.7
CO_2	493	540	988
Hydrocarbons	20	3.9	42
H_2O	145	—	133
Acid Gas From Hydrogen Purification			
Total	8,789	6,146	8,395
H_2S	2-10 ppm	2-10 ppm	2-10 ppm
NH_3	0.9	0.6	0.9
CO_2	8,738	6,110	8,346
SO_2	—	—	—
HCN	Trace	Trace	Trace
N_2	50.8	35.4	48
NO_x	Trace	Trace	Trace
Flue Gas From Heat and Power Generation			
Total	—	—	—
SO_2	—	—	18.7
NO_x	—	—	—

[1]Facility is a conceptual 0.09 m^3/s (50,000 bbl/day) plant.

[2]Units are in metric tons per day except where indicated otherwise.

knowledge regarding their possible presence, known behavior, and potential for environmental impact is included in this study. On the basis of very limited information, it appears that the environmental effects of discharges from coal liquefaction complexes will lie between those from petroleum refineries and those from coal tar facilities.

To supplement this environmental or health characterization study, it is recommended that the following investigative priority be established:

(1) Quantify process wastewater streams and their composition, using the control assay procedure approach of IERL-RTP methodologies. Laboratory experiments should first be run for oil separation, suspended solids removal, soluble organics, phenol extraction, and carbon adsorption. Analyses should then be made for the oil, water, and solid phase compositions, particularly for trace elements and biologically active organics.

(2) Similarly quantify gas stream compositions both before and after treatment. Special attention should be given to trace components.

(3) Determine product, solid waste, and residue compositions. Analyses should be primarily aimed at known toxic and hazardous chemicals.

(4) Assemble all known information to form a data base and model for determining plant discharges to the environment.

(5) Supplement information present in Multimedia Environmental Goals (MEGs) with other known information on the toxicological properties of identified product and waste constituents.

(6) Perform environmental assessment of coal liquefaction processes.

TABLE 2. RESIDUE AND SOLID WASTE DISCHARGES FROM COAL LIQUEFACTION PROCESSES[1]

STREAM	PROCESS[2]		
	H-COAL	EDS	SYNTHOIL
Process Residues[3]			
Total	1,444	2,106	206
Organic	722	1,445	98
Ash	722	661	108
Hydrogen Generation Discharges			
Total Wet Ash	1,889	2,600	3,526
Ash	1,116	1,051	2,115
Water	773	1,548	1,411
Discharges from Heat and Power Generation			
Boiler Ash	—	—	557
SO_2 Scrubber Sludge	—	—	4,744
Coal Preparation Discharges			
Total	1,007[4]	7,175[5]	1,279[4]
Dry Refuse	998	1,451	1,270
Wet Refuse and Tailings	—	5,715	—
Dust Particulates	9	9	9

[1]Facility is a conceptual 0.09 m^3/s (50,000 bbl/day) plant.

[2]Units are in metric tons per day except where indicated otherwise.

[3]Based on excess of that required for hydrogen generation. Does not include spent catalyst and other miscellaneous solid wates.

[4]Dry coal preparation techniques used.

[5]Wet coal preparation techniques used.

TABLE 3. AQUEOUS DISCHARGES FROM COAL LIQUEFACTION PROCESSES[1]

STREAM	PROCESS[2]		
	H-COAL	EDS	SYNTHOIL
Process Sour Water			
Total	4,154	1,776	3,411
H_2S	0.15 ppm	0.15 ppm	0.15 ppm
Oil	—	—	—
Phenols	0.1 ppm	0.1 ppm	0.1 ppm
NH_3	10 ppm	10 ppm	10 ppm
Hydrogen Generation Discharges[3]			
Clarifier Overflow	419	—	—
Other	1,204	—	—
Cooling Tower Blowdown			
Total	563	—	621
Coal Preparation Discharges			
Total	—	—	—
Water	—	—	—
Tailings	—	—	—
Coal Pile Runoff	63.5	63.5	63.5

[1]Facility is a conceptual 0.09 m^3/s (50,000 bbl/day) plant.

[2]*Units are in metric tons per day except where indicated otherwise.*

[3]Koppers-Totzek Process

MEETING CALENDAR

1979 Intersociety Energy Conversion Engineering Conference, August 5-10, 1979, Boston, MA. Contact: Barbara Hodsdon, Manager of Meetings and Expositions, 1155 16th St., NW., Washington, DC 20036.

AIChE 87th National Meeting, August 19-22, 1979, Boston MA. Contact: Ralph A. Buonopane, Department of Chemical Engineering. Northeastern University, 360 Huntington Ave., Boston MA 02115.

1979 Symposium on Instrumentation and Control for Fossil Energy Processes, August 20-22, 1979, Denver, CO. Contact: Mrs. Miriam L. Holden, Director, Conference Planning and Management, Argonne National Laboratory, Building 223, 9700 South Cass Avenue, Argonne, IL 60439; telephone (312) 972-5585.

10th World Petroleum Congress, September 1979 (dates not known), Bucharest, Romania. Contact: William F. O'Keefe, American Petroleum Institute, 2101 L St., NW, Washington, DC 20037.

178th National Meeting of the American Chemical Society, September 9-14, 1979. Contact: A.T. Winstead, ACS, 1155 16th St. NW, Washington, DC 20036.

National Energy Economics III, September 16-19, 1979. Houston, TX. Contact: Charles F. O'Connor, Council for Energy Studies P. O. Box 7374, Tulsa, OK 74105; telephone (918) 582-1582.

4th Annual Conference on Materials for Coal Conversion and Utilization, October 9-11, 1979, Gaithersburg, MD. Contact: W. T. Bakker, DOE, Fossil Energy Program, DSE, Germantown Office C-156, Washington, DC 20545.

2nd International Coal Utilization Conference, November 6-8, 1979, Houston, TX. Contact: David I. Johnson, Coal Technology '79, 6006 Bellaire Boulevard, Suite 101, Houston, TX 77081; telephone (713) 665-5188.

7th International Conference and Exhibition on LNG and LPG-Gastech 79, November 13-16, 1979, Houston, TX. Contact: Gastech Ltd., 2 Station Rd., Richmansworth, Herts. WD3-1QP, U.K.

72nd AIChE Annual Meeting, November 25-29, 1979, San Francisco, CA. Contact: C. Judson King, Department of Chemical Engineering, University of California, Berkeley, CA 94720.

RECENT MAJOR MEETINGS

Fourth Symposium on Environmental Aspects of Fuel Conversion Technology

EPA's Fourth Symposium on "Environmental Aspects of Fuel Conversion Technology" gave participants an opportunity to discuss the environmental aspects of coal gasification and liquefaction. Presentations emphasized the environmental assessment methodology as well as results obtained from research and field studies. The Symposium was held April 17-20 in Hollywood, Florida. Over 300 representatives from process developers, process users, environmental groups, and research scientists attended the meeting. General Chairman was William J. Rhodes, EPA Program Manager, Synthetic Fuels.

Session I provided a general overview of environmental assessment, including methodology as well as specific assessment programs. Several key elements of IERL-RTP's methodology were explained, such as Multimedia Environmental Goals (MEGs) and Source Assessment Models (SAMs). Other presentations concerned various environmental assessment and health programs sponsored by EPA, the Department of Energy, the National Institute of Occupational Safety and Health, the Electric Power Research Institute, and the Bureau of Mines

The major emphasis of Session II was on data and conclusions from ongoing research and field studies. Several gasification and liquefaction applications were summarized, including the gasifier in Kosovo, Yugoslavia and the Solvent Refined Coal pilot plant in Fort Lewis, Washington. Also discussed in Section II were some major pollutants generated by coal conversion processes, such as phenols and trace constituents.

Session III featured the evaluations of environmental control technology. Topics included control assay screening procedures, wastewater treatability, and control technology for particulate and tar emissions from coal converters. Other presentations described a gas cleaning pilot plant and chemical analysis and leaching of solid wastes. Water requirements for synthetic fuel plants were also discussed in Session III, as was the applicability of petroleum refinery and coke oven control technologies to coal conversion.

Session III also included summaries of EPA's regulatory activities by representatives from EPA Program Offices. D. Friedman of the Office of Solid Waste explained EPA's definition and regulation of hazardous waste materials. J. W. Lum of EPA's Effluent Guidelines Division described the development of effluent limitations guidelines.

A comprehensive list of Symposium presentations is included in the "Recent Major Paper and Publications" section of this issue. For ordering information, contact the Symposium Coordinator, Franklin A. Ayer, Research Triangle Institute, P. O. Box 12194, Research Triangle Park, North Carolina 27709, (919) 541-6260.

Ammonia From Coal Symposium

The Tennessee Valley Authority's (TVA's) Ammonia From Coal Symposium provided a wide range of technical and economic information on substituting coal for natural gas as a feedstock in ammonia production. Approximately 300 participants from the U. S. and abroad attended the meetings, held May 8-10, 1979, at TVA's National Fertilizer Development Center in Muscle Shoals, Alabama.

Papers were presented on a variety of topics, including the overall processes and the individual unit operations involved in producing ammonia from coal. Other papers summarized the role of coal in the U. S. fertilizer industry, the status of coal gasification today, and applicable environmental regulations. Also featured were descriptions of TVA's major project to demonstrate efficient technology for using coal to make ammonia.

The Coal Gasification Processes Session included summaries of several major processes:

- Lurgi Pressure.
- Winkler.
- U-Gas.
- Koppers-Totzek.
- Texaco.

Papers presented during the Auxiliary Systems Session described air separation plant technology, treatment of wastewater effluents, ammonia production, carbon monoxide shift catalysts, and carbonyl sulfide hydrolysis catalysts.

Acid gas removal and sulfur recovery systems were featured in a separate session, which also included summaries of operating experience at plants in India, South Africa, and West Germany.

The final session on Future Plans and Projections focused on the economic prospects for future ammonia production and also on TVA's project to produce ammonia from coal. TVA's demonstration plant now under construction in Muscle Shoals, Alabama, will use the Texaco gasification process to produce 1.4 kg/s (135 tons/day) ammonia from a coal feed of 1.8 kg/s (7 tons/hr). The facility is scheduled for completion in 1980.

Copies of the Symposium Proceedings (TVA Bulletin No. Y-143) may be obtained by sending a written request to the Technical Library, Tennessee Valley Authority, Muscle Shoals, Alabama 35660. (See also "Recent Major Papers and Publications" in this issue for a comprehensive list of papers presented.)

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