



ENVIRONMENTAL REVIEW of SYNTHETIC FUELS

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INTRODUCTION

The *Environmental Review of Synthetic Fuels* is published by the Environmental Protection Agency's Industrial Environmental Research Laboratory in Research Triangle Park, NC (EPA/IERL-RTP). Previous issues of the *Review* have focused on aboveground coal gasification and coal liquefaction technologies; this and future issues will include information on four additional synthetic fuels technologies: *in-situ* gasification, oil shale, oil (tar) sands, and alcohol fuels. RD&D efforts in these four areas are directed by the Energy Pollution Control Division of EPA's Industrial Environmental Research Laboratory in Cincinnati, OH (EPA/IERL-CI).

The addition of these technologies will provide readers with a more in-depth, comprehensive range of information on synthetic fuels. The *Review* will describe synthetic fuels production processes, report environmental and health

effects associated with multimedia discharge streams, and identify pollution control technology needs.

This issue of the *Environmental Review of Synthetic Fuels* summarizes recent activities in EPA's synthetic fuels programs. The contractors involved in these programs, their EPA Project Officers, and the duration of each effort are tabulated on pages 8-9. Highlights of technology and commercial developments, major symposia, a calendar of upcoming events, and a list of publications provide up-to-date information on domestic and international developments in synthetic fuels technologies.

Comments or suggestions which will improve the content or format of the *Review* are welcome. Such comments should be directed to the EPA or Radian personnel identified on page 16 of this issue.

ENVIRONMENTAL DATA ACQUISITION

Laboratory-scale Gasification Tests Underway—The Research Triangle Institute (RTI) has reported the results of 38 laboratory-scale coal gasification tests. (EPA-600/7-79-200, see "Recent Major Papers and Publications.") These coal gasification screening tests were conducted as part of RTI's 5-year program, "Pollutants from Synthetic Fuels." A semi-batch fixed-bed gasifier was used to test the following coals: Montana Rosebud, Wyoming subbituminous, North Dakota Zap lignite, Pittsburgh No. 8, Illinois No. 6, Western Kentucky No. 9, and FMC char. North Carolina humus peat was also gasified.

Samples of the coals, particulate residues, tars, aqueous condensates, primary gas products, and volatile organic constituents were chemically analyzed. Compounds in gasifier effluents were selected for study if (1) they were suspected to possess moderately toxic to severe health hazard potentials, and (2) if their concentration in the effluents exceeded 5 mg/m³. Analyses indicated that sulfur species (H₂S, carbonyl sulfide) and phenolic compounds (phenol, cresols) were the predominant pollutants produced by the gasification process. Additionally, ammonia, benzene, toluene, naphthalene, anthracene, and phenanthrene were produced in substantial quantities. Table 1 shows selected results from gasifying five different coals, expressed as unit mass of compound produced per unit mass of carbon converted.

The total quantity (mass in grams) of tar produced per unit mass of carbon converted was greatest for two bituminous coals, Western Kentucky No. 9 and Illinois No. 6; North Dakota Zap lignite yielded the least amount of tar. Tar production in Wyoming subbituminous and Montana Rosebud coals was intermediate. The weight percents of the individual fractions composing the tar mass were obtained using crude tar partitioning. The polynuclear aromatic hydrocarbon (PNA) fraction was the predominant individual fraction in each case. North Dakota Zap lignite gasification yielded the least PNAs and organic base materials in the tar fraction; the greatest quantity of PNAs was produced by gasifying Western Kentucky No. 9 coal.

Analyses of bottom ash samples indicated that substantial carbon conversion (89 to 99.7 percent) was achieved in the screening tests. Higher rank coals had lower carbon conversion percentages, indicating lower reactivity. Sulfur conversion exceeded 80 percent in the gasification tests. Wyoming and Montana subbituminous coals and North Dakota Zap lignite had lower sulfur conversion percentages than the bituminous coals.

Results from earlier test runs of the RTI gasifier are reported in the *Environmental Review of Synthetic Fuels*, Vol. 3, No. 2.

TABLE 1. SELECTED POLLUTANT PRODUCTION IN A LABORATORY COAL GASIFICATION SYSTEM (μg compound produced/g carbon converted)^a

Compound	Illinois No. 6 Bituminous	Montana Rosebud Subbituminous	Wyoming Subbituminous	North Dakota Zap Lignite	Western Kentucky No. 9 Bituminous
Hydrogen sulfide	3.8E3	4.6E3	3.4E3	4.9E2	4.0E4
Carbonyl sulfide	4.0E2 ^b	1.5E2	2.0E2	3.7E2	8.5E2
Thiophene	1.8E3	5.2E1	1.6E1	1.1E3	4.0E2
Methylthiophene	3.2E2	1.1E1	1.8E2	2.9E1	4.9E2
Hydrogen cyanide	NA ^c	1.2E2	NA	1.4E2	NA
Ammonia	NA	8.7E3	NA	6.0E3	NA
Phenol	4.3E2	1.3E0	NA	1.4E3	1.2E3
Cresols	7.2E2	8.3E2	2.7E3	1.0E3	1.3E3
Xylenols	NA	1.0E3	8.9E2	1.1E3	2.9E2
Benzene	5.0E3	1.9E2	3.1E3	1.1E4	1.9E4
Toluene	3.5E4	1.0E3	3.3E3	3.1E3	3.0E3
Xylenes	8.9E1	8.9E2	8.1E2	8.3E2	4.1E2
Naphthalene	1.2E3	5.9E2	6.3E2	5.2E2	3.5E3
Anthracene	7.1E2	2.0E2	1.5E2	2.1E2	1.0E3
Phenanthrene	2.2E2	5.9E2	7.2E1	1.3E2	9.8E2

^aResults are expressed as "aEb" which should be interpreted as a $\times 10^b$.

^bIncludes sulfur dioxide.

^cNA = Not available.

Ft. Snelling Source Test and Evaluation Report Completed—Radian Corporation has conducted a Source Test and Evaluation (STE) Program at the Wellman-Galusha low-Btu gasification facility at the U.S. Bureau of Mines Twin Cities Metallurgy Research Center, Ft. Snelling, MN, site. Low-Btu gas produced at the Ft. Snelling facility is used as fuel in an iron-ore pelletizing operation. The STE report (EPA-600/7-80-097, see "Recent Major Papers and Publications") presents results obtained from samples collected during a test run firing North Dakota (Indianhead) lignite.

EPA's Source Analysis Model 1A (SAM/1A) and bioassay methods were used to characterize and evaluate samples from nine multimedia process and waste streams. Figures 1 and 2 summarize results from SAM/1A evaluation and bioassay analyses of selected process and waste streams.

Product gas samples contained benzopyrene and carbon monoxide, which are major contributors to overall health discharge severity. Polynuclear aromatic hydrocarbon (PNA)

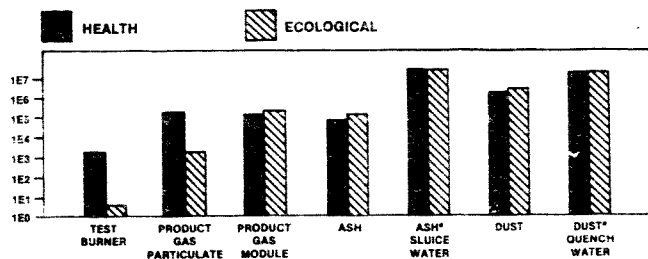
concentrations exceeded 3500 $\mu\text{g}/\text{scm}$ in the product gas samples analyzed. Arsenic and chromium were identified in samples of test burner flue gas.

Samples from two wastewater streams, gasifier ash sluice water and cyclone dust quench water, were compared to National Interim Primary Drinking Water Standards and Proposed National Secondary Drinking Water Regulations (Federal Register, 3/31/77). Gasifier ash sluice water exceeded national drinking water standards for selenium, iron, sulfate, and total dissolved solids (TDS); cyclone dust quench water exceeded national drinking water standards for fluoride, arsenic, lead, and iron.

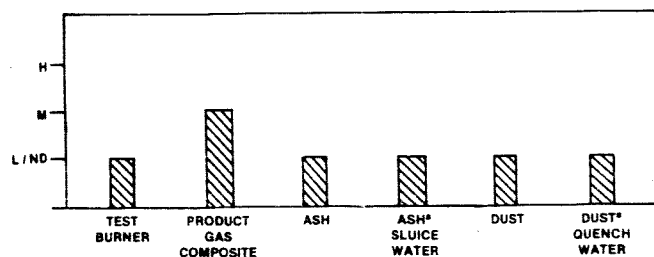
Two solid waste streams, gasifier ash and cyclone dust, were sampled and analyzed for trace element composition. Leachates of gasifier ash and cyclone dust qualified for non-hazardous classification under Resource Conservation and Recovery Act (12/18/78) guidelines for trace elements.

Bioassay results indicated low potential for adverse health and ecologic effects for all streams sampled except the product gas composite. The product gas composite exhibited moderate toxicity in the *in vitro* cytotoxicity test, rabbit alveolar macrophage (RAM). Ames mutagenicity tests were negative, but test cells exposed to product gas composite samples exhibited marked effects of toxicity. *In vivo* rodent acute toxicity (RAT) tests were negative for all streams tested. The product gas and gasifier ash sluice water exhibited moderate *in vitro* cytotoxicity for WI-38 human lung fibroblast cells.

The SAM/IA methodology and bioassay analyses used in STE programs are described and referenced in the *Environmental Review of Synthetic Fuels*, Vol 3, No. 1. In that issue, a report summary presents results from the STE report for Wellman-Galusha low-Btu gasification at the Glen-Gery Brick Co. in York, PA.



*Total sample organic loading expressed as single maximum worst case compound.
FIGURE 1. TOTAL STREAM DISCHARGE SEVERITIES FOR THE FT. SNELLING WELLMAN-GALUSHA PROCESS AND WASTE STREAMS SAMPLED



*Total sample organic loading expressed as single maximum worst case compound.
FIGURE 2. BIOASSAY TEST RESULTS FOR THE FT. SNELLING WELLMAN-GALUSHA PROCESS AND WASTE STREAMS SAMPLED

Kosovo Program Continued—An international environmental data acquisition program is continuing in the Kosovo Region of Yugoslavia. The Lurgi high-pressure, medium-Btu gasification system at Kosovo is being studied as a commercial-scale example of Lurgi-type technology. Radian Corporation, under EPA contract, is providing technical support to the Rudarski Institute of Yugoslavia and Kosovo Kombine, the operators of the gasifier. This cooperative agreement represents a unique opportunity to obtain environmental data on a technology proposed for commercialization in the U.S.

Phase I and II Objectives Met

Objectives of the first two phases of the Kosovo test program were: (1) to measure the emission levels of specific major and minor pollutants emitted from the plant, and (2) to characterize the emissions of minor and trace pollutants from the plant. Significant discharge streams were sampled. SAM/IA methodology was used to relate pollutants to health and ecologic effects. A Source Test and Evaluation Report (EPA-600/7-79-190, NTIS PB 80-183098) describing the Phase I environmental assessment was recently published. Specific

results of Phase I and II testing were also discussed in the *Environmental Review of Synthetic Fuels*, Vol. 2, Nos. 1 and 3.

Phase III Results Reported

Phase III testing involved ambient air sampling and analysis of atmospheric emissions from the plant. Fingerprinting techniques were used to link sources with pollutants.

Tests characterized pollutants in key discharge streams and determined levels of these pollutants in ambient air. Mass emission rates computed from analytical data indicate that significant quantities of CO, sulfur and nitrogen species, and phenols are discharged directly into the atmosphere from the plant.

Gas chromatographs equipped with flame ionization, Hall sulfur-mode, and Hall nitrogen-mode detectors were used to compare samples of ambient air with by-products of Lurgi gasification. The chemical profile obtained for by-product middle oil was very similar to that obtained for samples of organic matter collected from ambient air. Compound distributions ranged from benzene through polynuclear aromatic hydrocarbons (PNAs) such as benzo(a)pyrene.

Testing also considered the impacts of specific emissions on downwind ambient air quality. Sampling and analytical techniques were applied downwind of the facility to measure: total particles for organic analysis; total and fine particles for gravimetric, inorganic, and elemental analysis; size-fractionated particles for elemental analysis; and organic vapors.

Most of the increase in total mass downwind of the plant is due to the coarse particle fraction ($>2 \mu\text{m}$), indicating that fugitive dusts from coal handling processes may be a major source of pollution. A complex mixture of potentially hazardous organic compounds was detected in the ambient aerosol downwind from the plant. Compounds tentatively identified by GC/MS analysis include alkylated benzene and PNAs, linear and heterocyclic hydrocarbons, phenols, ketones, quinones, alkylated thiophenes, and dibenzofuran. Naphthalene was also identified at high ambient concentrations in the Kosovo aerosol.

A comprehensive summary of the Phase III study was presented in August 1980 at the 180th National Meeting of the American Chemical Society in San Francisco, CA.

Phase IV Sampling Completed

Radian and Yugoslavian engineers have completed the last of four phases of sampling scheduled at the Kosovo gasification facility. The objective of Phase IV testing was to characterize process fugitive emissions.

Process fugitive emissions were defined as inadvertent emissions from valves, flanges, pumps, compressors, drains, and relief valves. Sampling included the gasifiers, quench and cooling sections, Rectisol units, tar separation units, and Phenosan sections. The Kosovo gasification plant was estimated to have up to 5000 valves and 20,000 flanges. For this reason, a stratified random subset of the total population was sampled.

Two stages of testing were used to characterize fugitive emissions. First, leak detection or screening was conducted at each selected source point. A portable hydrocarbon detector was used to find leaks and to indicate the magnitude of hydrocarbon leakage. In the second stage of testing, enclosure sampling was applied to measure leakage rates from selected point sources. Samples were analyzed to measure emissions of hydrocarbons, CO, H₂S, SO₂, mercaptans, cyanides, and ammonia. Draeger selective adsorbent indicator tubes were used to screen and sample non-hydrocarbon emissions.

Analysis of the Phase IV samples will be completed in Fall 1980. Results will be published in subsequent issues of the *Environmental Review of Synthetic Fuels*.

CONTROL TECHNOLOGY ASSESSMENT

EPA's Alternate Fuels Group—The June 1980 issue of the *Environmental Review of Synthetic Fuels* announced the formation by EPA of the Alternate Fuels Group (AFG). This Group is co-chaired by Frank Princiotto, Director of the Energy Processes Division of the Office of Research and Development, and David Tundermann, Director of the Policy Planning Division of the Office of Planning and Management. The Group meets every 4 to 6 weeks. Its members include representation from the regulatory offices, regional offices, Office of Enforcement, and General Counsel. Its objectives are to develop EPA's regulatory strategy and the resource program to support this strategy for the developing synthetic

and alternate fuels industry. The Agency's overall purpose in this area is to ensure that the designs for these new energy technologies embody acceptable environmental safeguards so that they can be commercialized in a timely fashion.

To carry out its mandate, the AFG has established five Working Groups, one for each major technology area. These groups are chaired by senior staff from EPA's IERL-RTP, IERL-Ci, the Effluent Guidelines Division, and the Energy Processes Division. They are currently preparing Pollution Control Guidance Documents (PCGDs—see the previous issue of the *Environmental Review of Synthetic Fuels*) for the processes in Table 2.

TABLE 2. EPA WORKING GROUPS PREPARING PCGDs

Working Group	Process	Draft for Public Review	Chairman
Gasification & Indirect Liquefaction	Low-Btu Gasification (fixed bed, single-stage, atmospheric)	1/81	T. K. Janes IERL-RTP (MD-61) (919) 541-2852
	—Wellman-Galusha		
	—Wilputte Chapman		
	—Riley Morgan		
	Indirect Liquefaction	2/81	
	—Gasifiers		
	—Lurgi		
	—Koppers-Totzek		
	—Texaco		
	—Synthesis		
	—Fischer-Tropsch		
	—Coal to Methanol		
	—Mobile M (gasoline)		
	Medium-Btu Gasification		
	High-Btu Gasification	8/82	
Shale Oil	Surface Retort	3/81	I. A. Jefcoat IERL-Ci (513) 684-4417
	—Paraho		
	—Superior		
	—TOSCO II		
	—Union		
	Modified <i>In-situ</i>		
	—Occidental		
	—Rio Blanco		
Direct Liquefaction	Exxon Donor Solvent		D. A. Denny IERL-RTP (MD-61) (919) 541-2825
	H-Coal		
	SRC-I and -II		
Alcohol Fuel From Biomass	Gasohol		W. Tellard Effluent Guidelines Division (WH-552) (202) 426-4617
	—Commercial plants		
	—On-farm production		
Geothermal	Geothermal		D. Berg Energy Processes Division (RD-681) (202) 755-0205
	—Dry steam		
	—Wet steam		
	Geopressured Methane		

The PCGDs are a major output of the AFG and its Working Groups, and are intended to provide interim guidance, until technology-based standards are promulgated, on EPA's assessment of the best multimedia controls available for these processes to protect the environment adequately and at reasonable cost. This guidance is directed at both developers and permit writers in EPA's regional offices and state or local agencies. EPA believes that it can help developers protect the environment most cost-effectively by identifying environmental requirements early enough to permit their consideration in the process design. In addition, the Agency expects that it can contribute to speedier reviews of permit applications by providing guidance to permit reviewers.

The PCGDs will be published in three volumes:

Volume I -The Guidance. Control recommendations and summary of processes, pollutants, control technologies, and cost/energy/environmental impacts of controls.

Volume II -Processes, Environmental Problems, and Control/Containment Options. Detailed descriptions of processes, pollutant selection, and control system performance/cost energy consumption/secondary residuals (including advantages/disadvantages, applicability, and limitations of each control); discussion of approach to recommending selected control

strategies; and instructions/guidelines on the use of PCGDs.

Volume III-Appendices. Background data (test reports) mass and energy balances, detailed cost calculations, input data, etc.

Preliminary drafts of Vols. II and III of the indirect liquefaction PCGD were made available for technical review in May, and comments received are being considered during the preparation of Vol. I. The data that form the bases for the oil shale PCGD were also made available for technical review in May, culminating in an internal EPA workshop held June 24-27 to determine the guidance that could be developed from the data and to coordinate multimedia control approaches with the affected Program Offices. A preliminary draft Vol. I for low-Btu gasification was also reviewed internally and is being revised simultaneously with the preparation of Vols. II and III.

The AFG is also preparing a comprehensive 5-year RD&D plan that will identify all federally funded research to collect process, emissions, and effects data and to demonstrate control technology needed to support the development of environmental standards for these emerging technologies. Individual plans are being prepared by each working group for submission to the AFG. The AFG staff will then synthesize these inputs into an overall 5-year RD&D plan for synthetic and related alternative fuels.

TECHNOLOGY AND COMMERCIAL DEVELOPMENT

New Law to Stimulate Production of Synthetic Fuels— President Carter has signed a \$20 billion synthetic fuels bill designed to stimulate synfuels production of 0.92 m³/s (500,000 bbl/d) by 1987 and 3.68 m³/s (2 million bbl/d) by 1992. Other measures included in the bill are (1) authorization of a \$1.45 billion alcohol fuel production program, (2) establishment of a solar energy bank, and (3) a requirement to resume filling the strategic petroleum reserve on October 1, 1980.

The bill establishes a seven-member U.S. Synthetic Fuels Corp. which will stimulate private investment through purchase guarantees, direct loans, and loan guarantees. The corporation is empowered to spend \$20 billion in the fiscal year starting October 1, 1980, and can allocate up to \$68 billion more in future years. As further incentive for private investment, the corporation is authorized to construct three plants that would be owned by the government and operated by contractors.

Since the new corporation may take years to become established, the legislation includes an interim program to encourage synthetic fuel production for defense needs. Up to \$3 billion can be spent in purchase agreements, loans, and loan guarantees.

The alcohol fuel production program authorizes DOE to lend 75 percent of the costs of building alcohol-from-garbage plants. It also requires that gasoline be used as fuel for federal vehicles, to the extent possible.

Petrochemical Feedstocks from Coal—Tests performed by Chevron Research Company indicate that at least two liquefaction methods can be used to produce high quality liquid chemical feedstocks from coal. Manufacturers of aromatic hydrocarbons are especially interested in coal as a primary raw material because of the high costs and limited supplies of petroleum.

The Chevron study, sponsored by DOE, tested liquids produced by Gulf Oil Company's Solvent Refined Coal-II (SRC-II) process and Hydrocarbon Research Inc.'s H-Coal process. Both methods produce a feedstock with high concentrations of aromatics and aromatic precursors. In addition, the liquefied coal feedstock can be readily refined with conventional technology.

Developers of the SRC-II process claim that up to 80 percent more benzene, toluene, and C₈ aromatics can be made from SRC-II naphtha, as compared to typical petroleum naphtha. The cost of SRC-II-derived BTX (benzene, toluene, and xylene) is \$229/m³ (\$0.87/gal.), substantially cheaper than the estimated \$321/m³ (\$1.22/gal.) required to produce BTX from petroleum naphtha.

Gulf is now planning an SRC-II demonstration plant to be built in Morgantown, WV. The Morgantown plant is scheduled for startup in 1981 and will process 63 kg/s (6,000 ton/d) of coal. Long range plans call for several commercial-scale SRC-II plants with individual capacities of 315 kg/s (30,000 ton/d).

The H-Coal process yields liquid products quite similar to those of SRC-II, but it should reach commercialization sooner. Ashland Oil Synthetic Fuels, Inc. presently operates an H-Coal pilot plant at Catlettsburg, KY. A \$1.5 billion commercial-scale plant, scheduled for startup in 1986, is planned by Ashland, Airco, Inc., and DOE. The output of this plant will include significant amounts of naphtha and LPG suitable for aromatic hydrocarbon feedstock.

Additional information on the SRC-II Morgantown plant and the H-Coal Catlettsburg project is available in the *Environmental Review of Synthetic Fuels*, Vol. 3, No. 1. For more timely information on the Morgantown and Catlettsburg projects, see the related summaries below.

Water Problems Beset Morgantown Liquefaction Plant—Water supplies in Morgantown, WV, may not be adequate to support the commercial-scale SRC-II plant planned by Gulf Oil Company. According to the U.S. Army Corps of Engineers, the Monongahela River can supply enough water for Gulf's 63 kg/s (6,000 ton/d) SRC-II demonstration plant, but not enough for the 315 kg/s (30,000 ton/d) plant scheduled for startup in 1989.

The Corps of Engineers is planning to construct a dam which would create sufficient water supplies for the larger SRC-II plant. However, the dam is being contested by landowners who would lose substantial acreage if it were built.

H-Coal Process Receives West German Support—Hydrocarbon Research, Inc. (HRI), Ruhrkohle AG, and the German

state of North Rhine-Westphalia have agreed to collaborate in the commercial development and application of HRI's H-Coal process. The agreement includes \$5 million from Ruhrkohle and North Rhine-Westphalia for the H-Coal pilot plant in Catlettsburg, KY. In return, Ruhrkohle, West Germany's largest coal company, will participate in the Catlettsburg project and share the coal liquefaction data.

The H-Coal pilot plant, now undergoing commissioning tests, is operated by Ashland Synthetic Fuels, Inc. with engineering support from HRI. The pilot plant is jointly funded by DOE and a consortium of Ashland, the Electric Power Research Institute, Standard Oil Company (Indiana), Conoco, Inc., Mobil Oil Corporation, and the state of Kentucky.

A \$1 million option under a separate agreement would allow Ruhrkohle to buy exclusive rights to H-Coal process technology for use and licensing in continental Europe and the U.S.S.R. The option would be exercisable during 1980 and would require initial payment of \$6.5 million plus additional sums as each H-Coal plant is licensed. At this time, however, the process cannot be licensed in the U.S.S.R. because of U.S. suspension of high technology exports to that country.

Retired Synfuels Plants May Be Reactivated to Test New Processes—DOE is examining the feasibility of reactivating several retired U.S. synfuels plants. New processes could be tested in the old plants, eliminating the substantial time (at least 2 years) required to build new test plants.

DOE is interested in reactivating a 0.26 kg/s (25 ton/d) test plant for operation as a coal liquefaction pilot plant or as a coal-fired commercial-scale plant for producing ethanol. Located near Rapid City, SD, the plant originally used the CO₂ acceptor process to gasify lignite and subbituminous coal. It was sponsored by DOE and the American Gas Association and operated from 1972 until completion of the test program in 1977. Most of the original equipment is still there, including the coal feed systems, conversion reactors, and the boiler.

A second candidate is a retired 0.13 kg/s (12 ton/d) liquefaction plant at Cresap, WV. The plant was operated in 1977 and 1978 by Fluor Engineers and Constructors. It was initially a coal-to-gasoline unit but was later converted to a multi-purpose test plant.

Several other retired plants are also eligible for reactivation, according to DOE. These include a synthane prototype pilot plant operated by the Lummus Company in South Park Township, PA; the Institute of Gas Technology's hydrogen-from-coal process unit in Chicago, IL, that operated from 1976 to 1978; and Battelle's 0.26 kg/s (25 ton/d) unit in Columbus, OH, that produced gas by agglomerating Rosebud coal with 90 percent ash capture.

DOE Encourages Two New Oil Shale Methods—Two new methods for recovering oil from shale have received DOE funding. One involves radio-frequency, *in-situ* recovery; the other uses a hydrogen retorting process to increase hydrocarbon yield. The Institute of Gas Technology (IGT) has received \$2.6 million to study the application of its Hytort hydrogen retorting process. In the Hytort process, retorting occurs in a hydrogen atmosphere which increases the yield of hydrocarbons from shale carbon. When applied to a low-grade Kentucky shale, the Hytort process produced up to 250 percent more oil than that recovered without the hydrogen addition.

The second DOE award was \$1.6 million to the IIT Research Institute (IITRI) to examine radio-frequency *in-situ* recovery. IITRI has applied this method to tar sands. Researchers hope that it may be used successfully to treat shale and eliminate the need for crushing the shale.

Exxon Plans Pilot Tests of Catalytic Gasification Process—Exxon Research and Engineering's catalytic coal gasification process will be evaluated at a 1.05 kg/s (100

ton/d) pilot plant scheduled for startup at Rotterdam Europort in mid-1985. The Exxon process uses a potassium catalyst and a single reactor to produce pipeline quality methane from a variety of coal feedstocks. Ground coal is sprayed with the catalyst solution, dried, and then injected into the gasifier where it is mixed with steam at relatively low temperatures. Exxon claims several advantages for this catalytic process, including the ability to operate efficiently at lower temperatures and the flexibility to handle several varieties of coal feedstocks. This latter capability will be tested by using a wide range of internationally traded coals in the Dutch pilot study.

The pilot plant will be built by Exxon's Dutch subsidiary, Esso Nederland. It is planned as part of an 8-year, \$500 million project designed to provide the data necessary for construction of a commercial-scale plant. Exxon is already testing the catalytic gasification process at a 10.5 g/s (1 ton/d) development plant in Baytown, TX (see the *Environmental Review of Synthetic Fuels*, Vol 3, No. 2).

Suit May Delay Great Plains Gasification

Project—Opponents have challenged the Federal Energy Regulatory Commission's (FERC's) approval of the Great Plains gasification project. Ohio Consumers Council, General Motors, New York Public Service Authority, and the state of Michigan have all filed suit in federal court. The opponents claim that all taxpayers (not just the project consortium's customers) should pay for the plant, since the \$1.2 billion, commercial-scale plant will benefit the entire country.

American Natural Resources Company, leader of the project consortium, says that the suit could delay the project by 1 year and add more than \$100 million to project costs.

DOE Deputy General Counsel Eric J. Fygi has stated that if the FERC decision is reversed by the courts, DOE may issue loan guarantees for construction costs. In the meantime, DOE is providing financial assistance so American Natural Resources can proceed with project design.

The high-Btu gasification plant will be located in Mercer County near Beulah, ND. It will use Lurgi processing in conjunction with a methanation step to gasify lignite strip-mined at an adjacent site. Design capacity is 39.1 Nm³/s (125 × 10⁶ scf/d) of pipeline quality synthetic gas with a minimum heating value of 38 MJ/Nm³ (970 Btu/scf).

More information on the Great Plains gasification project is available in the *Environmental Review of Synthetic Fuels*, Vol. 3, Nos. 1 and 2.

Cellulose Pyrolysis Shows Promise for Biomass

Conversion—Recent efforts by several investigators indicate that cellulose pyrolysis may be a promising process for near-term, commercial-scale biomass conversion. SRI International, Battelle Northwest Laboratories, and the University of Pennsylvania are developing methods of cellulose pyrolysis that yield a variety of products, including methanol, oil, ammonia, and synthesis gas.

SRI International has developed four conceptual cellulose pyrolysis processes based on available technology. One SRI process produces oil and char from dried wood and has an estimated thermal efficiency of 74 percent. Total capital investment for the process is about \$9.92/kg (\$9,000/ton) of daily plant capacity. Operating costs would be approximately \$2.84 per GJ (\$3.00 per 10⁶ Btu) of oil and char. Wood feed represents the largest single cost item.

Other conceptual SRI processes produce methanol, oil by catalytic liquefaction, and ammonia. Estimated plant costs for these three SRI processes are about 50 percent more than for similar coal-based plants. The increased costs arise from the substantial pretreatment required for the raw wood, as well as the limited availability of feedstock over the life of the plant.

Both primary and secondary catalysts are used in Battelle Northwest Laboratories' steam pyrolysis process. Battelle operates a pilot plant designed to gasify wood particles. An alkali carbonate primary catalyst is used in the pyrolysis reaction to increase the yields of gas and char. Gas yields are further enhanced by secondary silica-alumina and nickel catalysts which crack and reform liquids from the pyrolysis step.

The University of Pennsylvania is studying low temperature, low pressure pyrolysis in an attempt to reduce the capital costs and energy requirements of biomass conversion processes. Several catalysts and additives have been studied, including γ -alumina and caustic solutions. To date, the yield of the desired liquid product has been too low (around 2 percent) to demonstrate commercial feasibility for the reactions. However, around 40 percent of the cellulose is converted to gases in all the reactions studied. The percentage of conversion shows promise for this approach to biomass conversion.

Methanol Slurry Process May Alleviate Water Storage Problems—A new process that combines coal conversion and coal transport could benefit western applications where water supplies are limited. The process, known as methacoal, is being developed by W. R. Grace and Company and Energy Transition Company. Methacoal involves two basic steps: (1) production of methanol and CO_2 from coal, and (2) pipeline transport of a coal/ CO_2 /methanol slurry to a power plant.

Because coal-derived methanol is used instead of water to transport coal, the methacoal process has minimal water requirements. Some, if not all, of the water needs can be supplied by the coal, depending on its moisture content. Water is recovered when the coal is dried by process heat from methanol production.

The methanol and CO_2 are produced during Koppers-Totzek gasification, with subsequent Vulcan synthesis. The two products are then combined with coal for pipeline transport. Slurry components are separated at the power plant and used in various ways: the coal to fire steam generators and the methanol to drive a gas turbine generator. The CO_2 can be sold and used in recovering heavy oil reserves.

ETCO and Grace have undertaken a \$1 million study of the methacoal concept. Grace is interested in the process as a method to develop its northwest Colorado coal reserves.

Production Underway at SASOL II—The South African Coal Oil and Gas Corp. (SASOL) has announced startup of its SASOL II plant in Secunda, South Africa. The \$3.05 billion plant is now producing unrefined oil from coal. Other products (including gasoline, diesel fuel, and chemicals) will soon be available. Production capacity is estimated at 0.092 m^3/s (50,000 bbl/d) of coal-derived liquids.

SASOL II and SASOL III, a sibling plant scheduled for completion in 1982, will eventually handle 787.5 kg/s (75,000 tons/d) of South African coal. The joint complex will consist of 72 Lurgi gasifiers and 14 liquefaction reactors. The reactors will convert the synthetic gas into 27 fuel and chemical products.

SASOL technology is now being marketed in the U.S. through an agreement by SASOL Ltd. and Fluor Engineers and Constructors, Inc., the managing contractor for the South African SASOL plants. SASOL and Fluor claim that a U.S. plant similar to SASOL II could be built at an approximate cost of \$3.6 billion. Such a plant would produce 0.107 m^3/s (58,000 bbl/d) of coal-derived liquids.

Memphis, Grace to Receive DOE Funding—DOE has decided to assist two gasification projects that have been competing for Department funding since 1977. Memphis Light, Gas, and Water Division will receive at least half of the construction costs for its \$700 million industrial fuel gas plant. In the second DOE allocation, up to \$16 million will go to W. R. Grace and Company for initial design of its commercial-scale coal-to-gasoline plant in Baskett, KY.

The Memphis project will use the U-Gas process to convert 32.6 kg/s (3100 tons/d) of Kentucky coal to 4.36 million m^3 (154 million scf) of medium-Btu industrial fuel gas. The U-Gas process was developed by the Institute of Gas Technology to eliminate caking problems with eastern coal. It uses a fluidized-bed gasifier to react coal with oxygen and steam.

A Texaco gasifier will be used at the Grace plant to convert 304.5 kg/s (29,000 tons/d) of caking, high-sulfur coal to synthesis gas. The synthesis gas will be in turn converted to methanol and then to 0.092 m^3/s (50,000 bbl/d) of high-octane gasoline. Total costs of the proposed plant are estimated at over \$3 billion.

Exxon Starts Up Pilot Liquefaction Plant—Exxon is now operating its new \$116 million coal liquefaction pilot plant in Baytown, TX. The 2.63 kg/s (250 ton/d) plant uses the Exxon Donor Solvent process to produce distilled low-sulfur petroleum from coal. Ash, sulfur, and ammonia are also generated by the conversion reaction.

The pilot plant, started in 1976, is being funded by several organizations, including DOE, Exxon, and the Electric Power Research Institute. Other participants are Japan Coal Liquefaction Development Company, Ltd., Phillips Petroleum, Atlantic Richfield, and Ruhrkohle.

Testing is scheduled to continue until 1984. Among the feedstock coals to be studied are Illinois No. 6, Wyoming subbituminous, and Wyoming (or Texas) lignite.

Westfield Slagging Lurgi Gasifier Shows Promise For Utility Application—The slagging Lurgi/British Gas Corp. gasifier has excellent potential for combined cycle, utility application, according to the Electric Power Research Institute (EPRI). EPRI and the British Gas Corp. have just completed a \$2.6 million research program at Westfield Development Centre in Scotland. The Westfield plant has a capacity of 3.68 kg/s (350 ton/d), making it the world's largest slagging Lurgi gasifier.

The goal of the test program was to characterize certain process capabilities essential for utility operation. These include (1) the ability of a unit to maintain efficiency at reduced output (load turn down), and (2) the rate at which a unit can progress from fractional to full capacity (load following). Such capabilities are important because utilities must constantly vary their output to meet changing demand.

During the testing, the Westfield unit maintained acceptable load following and efficiency at outputs as low as 30 percent of capacity. These results were obtained with two different coals: a high-sulfur, highly caking Pennsylvania coal, and a British coal, Rossington, similar to some Illinois coals.

The slagging Lurgi process uses a high temperature Lurgi gasifier in which the ash melts and is run off as liquid slag. It was developed during the 1950's to overcome some of the problems with the original Lurgi technology. These included low throughput rates, the inability to handle caking coals, and the need for excess steam to keep combustion temperature below the ash fusion (or slagging) point. The Westfield slagging Lurgi gasifier yields gas at higher rates (four or five times greater) than achieved in a conventional Lurgi unit.

PROJECT TITLES, CONTRACTORS, AND EPA PROJECT OFFICERS IN EPA'S SYNTHETIC FUEL ENVIRONMENTAL ASSESSMENT PROGRAMS

Project Title	Contractor	EPA Project Officer
Environmental Assessment of Low-Btu Gasification (March 1979-March 1982)	Radian Corporation 8500 Shoal Creek Blvd. Austin, TX 78766 (512)454-4797 (Gordon C. Page)	James D. Kilgroe IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919)541-2854
Environmental Assessment of High-Btu Gasification (April 1977-March 1981)	TRW, Inc. 1 Space Park Redondo Beach, CA 90278 (213)538-4105 (Chuck Murray)	William J. Rhodes IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919)541-2853
Environmental Evaluation of Coal Liquefaction (July 1978-July 1982)	Hittman Associates, Inc. 9190 Red Branch Road Columbia, MD 21043 (301)730-7800 (Jack Overman)	D. Bruce Henschel IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919)541-4112
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)541-2708
Water Treatment Bench Scale Unit (November 1976-October 1981) (Grant)	Univ. of North Carolina Chapel Hill, NC 27514 (919)986-1023 (Philip Singer)	N. Dean Smith 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, NC 27709 (919)541-8000 (Forest Mixon)	N. Dean Smith IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919)541-2708
Groundwater and Subsidence Effects of Underground Coal Gasification at Hos Creek, WY (January 1975-January 1981) (Interagency Agreement)	U.S. Dept. of Energy Washington, DC 20545 (301)353-5516 (Charles Grue)	Edward R. Bates IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513)684-4363
	Lawrence Livermore Laboratory Livermore, CA 94550 (415)422-6463 (S. W. Mead)	
Geotechnical Instrumentation for In-Situ Coal Gasification (July 1976-September 1980) (Interagency Agreement)	U.S. Dept. of Energy Washington, DC 20545 (301)353-5516 (Charles Grue)	Edward R. Bates IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513)684-4363
	Lawrence Livermore Laboratory Livermore, CA 94550 (415)422-6463 (S. W. Mead)	
Vegetative Stabilization of Spent Oil Shale (September 1976-July 1981) (Cooperative Agreement)	Colorado State University Fort Collins, CO 80523 (303)491-8358 (William Berg)	Edward R. Bates IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513)684-4363
Laboratory Leaching Study of Raw Mined Oil Shale (October 1976-August 1980) (Grant)	Colorado State University Fort Collins, CO 80523 (303)491-8358 (David McWhorter)	Edward R. Bates IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513)684-4363
Field Leaching Study of Raw Mined Oil Shale (April 1980-April 1983) (Cooperative Agreement)	Colorado State University Fort Collins, CO 80523 (303)491-8358 (David McWhorter)	Edward R. Bates IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513)684-4363
Water Quality Hydrology Affected by Oil Shale Development (June 1975-June 1980) (Cooperative Agreement)	Colorado State University Fort Collins, CO 80523 (303)491-8358 (David McWhorter)	Eugene F. Harris IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513)684-4363
Development of Monitoring Methodology for Modified In-Situ Oil Shale Development (May 1978-August 1981)	General Electric Center for Advanced Studies Santa Barbara, CA 93102 (805)965-0551	Leslie G. McMillion EMSL-LV Environmental Protection Agency Las Vegas, NV 89114 (702)796-2258
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**Environmental Review of Synthetic Fuels
September 1980**

Environmental Perspective on the
Emerging Oil Shale Industry
(August 1978-September 1980)

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Trace Elements in Naval Reserve
Oil Shale Cores
(June 1978-June 1980)
(Interagency Agreement)

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Assessment of SO_x and Hydrocarbon
Emissions from Old *In-Situ*
Oil Shale Sites
(November 1978-November 1980)
(Interagency Agreement)

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Pollution Control Guidance Document
for Oil Shale
(November 1979-September 1981)
(Cooperative Agreement)

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Laboratory Study on Spent Shale
from the Geokinetics Process
(April 1980-April 1982)
(Interagency Agreement)

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Assessment of Oil Shale Retort
Wastewater Treatment and Control
Technology
(May 1979-May 1982)

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Environmental Characterization of
Geokinetics *In-Situ* Oil Shale
Retorting Technology
(January 1979-June 1980)

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Air Pollution Investigations from
Oil Shale Retorting: *In-Situ* and
Surface
(April 1979-April 1982)

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Overview of the Environmental
Problems for Oil Shale Development
(May 1979-December 1980)

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Multimedia Sampling and
Analysis of Commercial
Alcohol Fuel Production
Facilities
(June 1979-September 1980)

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Environmental Assessment of
On-Farm Alcohol Fuel Production
Facilities
(December 1979-September 1980)

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Environmental Operations
Manual for On-Farm Alcohol
Production Units
(January 1980-September 1980)

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Analytical Methods Manual for
Oil Shale Effluents
(April 1979-April 1982)

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Distribution of Trace Elements
During Simulated *In-Situ* Oil
Shale Retorting
(October 1978-September 1981)

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REPORT SUMMARY
Technological Overview Reports
for Eight Shale Oil Recovery
Processes
(EPA-600/7-79-075)
(NTIS PB 295665)

by
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Although several hundred different processes for retorting oil shale have been proposed over the past 75 years, only a few are considered commercially viable. This report presents basic descriptions of eight major shale oil recovery processes with potential for commercial development. It includes overviews of six surface retorting processes: (1) Union Oil Retort B, (2) Paraho, (3) TOSCO II, (4) Lurgi-Ruhrgas, (5) Superior Oil, and (6) USBM Gas Combustion. In addition, it summarizes two *in-situ* retorting processes: (1) the Occidental Modified *in-situ* retort, and (2) true *in-situ* development programs of Laramie Energy Technology Center (DOE).

These technology overviews were prepared as part of EPA's project, Assessment of Environmental Impacts from Oil Shale Development. They are intended to aid in evaluating environmental impacts and pollution control technologies. Each overview includes general process description, shale preparation requirements, equipment types, operating conditions, and characteristics of products and by-products. Also summarized are energy and water requirements, process stream characteristics, disposal requirements for retorted shale, and site-specific aspects, where applicable.

The eight retorting processes were included in the study on the basis of several criteria:

- The process had been tested at sufficient pilot scale (1.1×10^{-4} to 5.5×10^{-4} m³/s or 0.6 to 3 bbl/day) to permit an evaluation of its operating characteristics and yields.
- The process was considered technically sound and suitable for further scale-up.
- Previous process operations had indicated no inherent adverse environmental emissions or effluents incapable of eventual control.
- The process had operated successfully on U.S. oil shales, especially those of the Western Green River Formation.
- Preliminary economics were sufficiently promising to warrant continued process development.
- Construction of a commercial module (0.0110 m³/s or 6000 bbl/day) would likely be underway before 1985.

- Process developers would cooperate in providing unpublished information, descriptions of new process changes, and other data.

The following paragraphs summarize some of the retorting processes included in the technology overview report. These technology descriptions represent state-of-the-art knowledge of shale oil process development at the time of report publication. It is anticipated that future research and commercialization efforts will result in some modification of these process technologies.

Union Oil Retort B

Union Oil Company's Retort B process involves moving crushed shale upward through a vertical kiln where it is contacted by a countercurrent stream of hot recycle gas. As the rising shale bed is heated by the recycle gas, shale oil vapor and make gas are produced. The mixture of shale oil vapor and make gas is forced downward by the recycle gas, and cooled by the cold incoming shale in the lower section of the retort cone.

The make gas is removed and routed to a venturi scrubber. One portion of the scrubbed make gas is then recycled to the retort; another portion is further processed and used as onsite plant fuel.

The rundown oil from the retort is treated sequentially for solids, arsenic, and light ends removal. The resulting partially upgraded shale oil can then be marketed as a low sulfur burner fuel or used as feedstock in refineries.

Principal pollution control devices include the Stretford process for removing hydrogen sulfide from the retort make gas. Other control mechanisms are oil/water separation and sour water stripping for wastewater treatment. Treated wastewater is used to cool and moisten retorted shale prior to disposal, thereby providing dust control and proper compaction.

The retorted shale is transported to a disposal area, where it is compacted in windrows proceeding up an embankment. The embankment has a leachate collection ditch, from which runoff is routed to the plant water supply pond.

Union Oil is studying revegetation for the retorted shale plots, including mulching, seeding, irrigation, and fertilization.

Paraho

The Paraho Oil Shale Process of Development Engineering, Inc. (DEI), uses a vertical kiln, operated in either a direct

or indirect mode. In both modes the crushed shale is fed by a rotary mechanism into the top of the Paraho retort and moves down by gravity through four zones: (1) a mist formation and preheating zone, (2) a retorting zone, (3) a combustion zone (direct mode) or heating zone (indirect mode), and (4) a residue cooking and gas preheating zone. The retorted shale is then discharged through a hydraulically operated grate which controls the desired downward velocity and maintains even flow through the retort. This grate, the rotary feed mechanism, and the multi-levels of heat input are among the unique features of Paraho technology.

The shale vapors produced in the retorting zone are cooled to a stable mist by the incoming shale (which is thereby preheated). The mist is cleaned and condensed, and the resulting shale oil is transported for storage. The oil can be converted to syncrude or low sulfur distillate oil using such processes as delayed coking, gas treating, and hydrogenation of naphtha and gas oil fractions. By-products of these conversion processes include ammonia, sulfur, and coke.

In the direct mode, heat for the Paraho process is supplied within the kiln: the carbonaceous residue on the retorted shale is burned in the combustion zone to provide the principal fuel. Low-Btu recycle gases are used to (1) cool the retorted shale in the residue cooling and gas preheating zone, and (2) dilute the air entering the retort for combustion.

In the indirect mode, heat for retorting is supplied by recycled retort gases heated in an outside furnace. No residual carbon on the retorted shale is burned in the kiln. Thus, the offgases have a higher heating value because they are not diluted by combustion products.

Because the Paraho process is still under development, pollution control needs have not been fully determined. Several steps of the process can have adverse environmental effects requiring control.

A major environmental concern is disposal of the retorted shale. Disposal areas must be compacted, contoured, and revegetated.



Petroleum from oil shale. Photo compliments of U.S. Department of Energy

TOSCO II

TOSCO II, developed by The Oil Shale Corporation (TOSCO), is a retorting process based on solid-to-solid heat transfer between hot ceramic pellets and crushed oil shale. Crushed shale is preheated and fed to a horizontal rotating retort, together with roughly 1.5 times its weight in hot ceramic balls. The ceramic balls raise the shale to pyrolysis temperature and convert its contained organic matter to shale oil vapor. The shale vapors are withdrawn and fed to a fractionator for hydrocarbon recovery. The mixture of balls and spent shale is discharged and separated. The ceramic balls are cleaned, heated, and recirculated to the pyrolysis drum. The hot processed shale is cooled, moisturized, and transported to the disposal site.

The shale oil hydrocarbon vapors are routed to a fractionator where they are separated into water, gas, naphtha, gas oil, and bottom oil. The water is sent to a foul water stripper, and the other fractions are upgraded to synthetic crude oil and LPG. Upgrading also yields ammonia, sulfur, and coke as by-products. In addition, a treated fuel gas, a methane stream, fuel oil, and diesel oil are obtained for internal plant use.

Pollution control systems are used throughout the TOSCO II process. Wet scrubbers control gaseous and particulate emissions. Solid wastes include mainly processed shale (97 percent), dust, spent catalyst materials, sludges, and arsenic-laden solids. The wastes are transported to the disposal area and compacted. Contained salts are leached out of the surface layer prior to revegetation.

Lurgi-Ruhrgas

The Lurgi-Ruhrgas process was developed by Lurgi in collaboration with Ruhrgas AG in the 1950's to produce pipeline quality gas from the devolatilization of coal fines. Since then the process has been commercially applied for (1) the devolatilization of lignite fines, (2) the production of char fines from subbituminous coal for hot briquetting, and (3) the cracking of naphtha and crude oil to produce olefins. Lurgi has also proposed commercial application of the process for distillation of oil shale, based on several pilot studies.

In the Lurgi-Ruhrgas process, the crushed oil shale is fed to a double screw mixer where it mixes with six to eight times its volume of hot circulating shale residue. The fresh shale feed is heated rapidly, and gas, shale oil vapor, and water vapor are evolved. The circulating heat carrier and the partially retorted and fresh shale are then routed to a surge hopper where residual oil components are distilled off.

The mixture of heat carrier and retorted shale residue is passed to the lower section of a lift pipe where combustion air is introduced. The hot air raises the mixture pneumatically to a collecting bin and simultaneously burns residue carbon contained in the retorted shale.

The heat carrier is separated from the flue gases in a collecting bin; the combustion air supply to the lift pipe is preheated by countercurrent heat exchange with the flue gas stream. The flue gas is cleaned and cooled before discharge to the atmosphere.

The volatile gas product from oil shale retorting is cleaned in cyclones, scrubbed, and cooled. Heavy oil, gas naphtha, middle oil, and distillation gas (naphtha-free) are recovered.

The major atmospheric emission stream from the Lurgi-Ruhrgas process is the flue gas from the combustion of the shale residue. The flue gas contains a significant level of particulates and must be cleaned in a cyclone and electrostatic precipitator.

The major liquid waste stream is the gas liquor produced during distillation of the oil shale. The liquor contains minor amounts of ammonia, oil, and phenols, and is used to cool and moisten the spent shale. During this step, the minor contaminants are absorbed by the shale.

The heavy oil dust and the retorted shale represent the major solid waste streams from the Lurgi-Ruhrgas process. These streams can be combined, moistened, and disposed of together.

Superior Oil

The Superior Oil Shale Process is characterized by (1) its use of a circular grate retort, and (2) its ability to recover saline minerals from the shale. Superior Oil's shale holdings in Colorado's Piceance Creek Basin contain substantial quantities of the saline materials nahcolite (NaHCO_3) and dawsonite ($\text{NaAl}(\text{OH})_2\text{CO}_3$). These materials, together with the shale, are recovered, processed, and sold.

Most of the nahcolite is recovered during primary and secondary crushing of the raw shale. The remainder goes

through the retorting process where it is calcined to sodium carbonate (Na_2CO_3) and recovered in subsequent leaching operations.

The Superior Oil retort is doughnut-shaped and has five zones: loading, retorting, residual carbon recovery, cooling, and unloading. The raw shale is fed to a travelling circular grate and passes into the retorting zone, where it is contacted by a stream of hot gases. The gases pass down through the bed and heat the shale to retorting temperature. An oil-vapor-laden gas mixture leaves the bed and passes to a separator-condenser system where the product shale oil is removed. The oil-denuded and cooled recycle gases then pass through the cooling zone of the retort where they cool the shale. The recycle gases are then directed to the residual carbon recovery (or combustion) zone.

The retorted shale travels from the retorting zone to the combustion zone where it is contacted by steam, air, and recycled gases. The carbon residue is recovered, and a producer gas forms. The producer gas is used as on-site fuel. The retorted shale is cooled and unloaded.

During oil shale retorting, the dawsonite present is converted to alumina (Al_2CO_3) and sodium carbonate. These materials are recovered by alkaline leaching of the spent shale.

After leaching, the spent shale is washed and returned to the mine for disposal. Over 40 percent of the originally mined volume of shale is consumed to produce shale oil, alumina, sodium carbonate, and nahcolite. Because of this reduction in volume, all of the remaining processed shale can be returned underground. This eliminates surface disturbance and revegetation requirements.

Gaseous emissions from the Superior Oil process consist primarily of fugitive dust generated by handling the shale. Bag filters must be used to control these streams. The retort itself is gas-tight by virtue of water seals; as a result, no gases are released into the atmosphere.

Most of the water consumed by the process is recycled and eventually mixed with the spent shale for underground disposal.

Occidental Petroleum

Occidental Petroleum Company's modified *in-situ* process for shale oil recovery is being developed on its oil shale lease property in Piceance Creek, Colorado. The process involves vertical retorting of a column of broken shale which has formed by expansion into a previously mined, void volume.

In preparation for retorting, about 20 to 25 percent of the oil shale deposit is mined at the upper and/or lower level of the shale layer. Vertical longholes are drilled from the mined-out room into the shale layer. The longholes are loaded with an explosive which is detonated. After blasting, the broken (rubblized) shale fills both the volume of the room and the volume of the shale column.

Retorting is initiated by heating the top of the rubblized shale column with a flame formed from compressed air and an external heat source. After several hours, the external

heat source is removed, and the compressed air flow is maintained. At this point carbonaceous residue in the retorted fuel sustains air combustion. Hot gases from the combustion zone move down to pyrolyze the kerogen in the shale below. The pyrolysis yields gases, water vapor, and shale oil mist which condense in trenches at the bottom of the rubblized column. Oil production precedes the advancing combustion front by 9 to 12 m (30 to 40 ft). The crude shale oil and by-product water are pumped to storage. Part of the off-gas is recycled to control (1) the oxygen level in the pressurized incoming air, and (2) the retorting temperature. The rest of the offgas is routed to a Stretford unit for H_2S removal and then used for on-site power.

The crude shale oil product must be treated to remove by-product water and to stabilize the oil. The process also yields sulfur and substantial quantities of mined rock.

Several waste streams from the Occidental process are of environmental concern. These include the retort offgas, which must be treated in a Stretford unit to remove H_2S . The contaminated retort water may also require treatment. Another water problem is the potential contamination of naturally occurring groundwater in the oil shale zone. Proper disposal of the mined rock must also be considered.

LETSC/DOE Research Program

DOE's Laramie Energy Technology Center (LETSC/DOE) is conducting an intensive *in-situ* oil shale research program at several Wyoming sites. As part of this effort, LETSC/DOE has undertaken several studies of the environmental changes associated with *in-situ* oil shale processing. Underground fluids are being examined before, during, and after *in-situ* shale processing to identify any pollution. Water and brine samples from wells and coreholes are analyzed for significant organic and inorganic constituents. Another environmental study concerns the proper management of oil shale retort water. Potentially toxic constituents are identified, including any biological degradation mechanisms. Trace elements are also characterized.

In addition to the environmental studies, LETSC/DOE is investigating various shale fracturing techniques and different methods for *in-situ* oil recovery. The Center is sponsoring several vertical and horizontal retorting projects. *In-situ* processing variables being studied include:

- Effects of shale size, richness, and temperature on oil recovery yields.
- Gasification of oil shale with varied amounts of CO_2 , NO_2 , N_2 , and steam.
- Effects of retorting pressure on oil recovery yield.
- Pyrolysis of oil shale in the presence of CO and H_2O .

In addition to its LETSC R&D program, DOE is also conducting oil shale research at its Lawrence Livermore Laboratory and Sandia Laboratories.

RECENT MAJOR MEETINGS

Seventh Energy Technology Conference

"Expanding Energy Supplies" was the theme of the Seventh Energy Technology Conference (ET7), March 24-26, 1980, in Washington, D.C. More than 6,000 attendees heard 250 speakers address a broad range of energy-related topics, most of which centered around synthetic fuels and synfuels technology.

Many ET7 attendees were optimistic about the status of U.S. synfuels projects. Two major oil companies are considering shale oil plants. A large chemical manufacturer is constructing an acetic anhydride plant which will use coal-derived synthesis gas as feedstock. Private groups, in collaboration with DOE, are considering two solvent-refined coal

demonstration plants. DOE itself expects to spend more than \$4 billion this fiscal year in developing fossil, nuclear, and renewable resources.

Paul Rudolph, director of coal technology for Lurgi Kohle und Mineraloeltechnik, told conference attendees that the Lurgi gasifier is ready for use in large plants. In describing the gasifier's performance at the SASOL plant in South Africa, he indicated that the Lurgi gasifier performs well on a number of coals. Rudolph noted that demonstration of the British Gas/Lurgi slagging gasifier has been so successful that it, too, may be ready for commercialization. The gasifier, which operates with liquid-slag removal, is ideal for treating coals with low ash melting points and low reactivity.

According to A. L. Kohl, program manager in Rockwell International's Energy Systems Group, the Rockwell slagging gasifier has been successfully demonstrated. The Rockwell gasifier employs a sodium sulfide catalyst formed in a reaction between sulfur in the coal and molten sodium carbonate added to the melt. The resulting low temperature (982°C or 1800°F) process produces small quantities of ammonia, nitrogen oxides, heavy hydrocarbons, and tar.

The Texaco gasification process, an oxygen-blown, slurry-fed, entrained-bed process, also results in low tar formation, according to Thomas O'Shea of the Electric Power Research Institute (EPRI). O'Shea, project manager of a 10.2 kg/s (1,000 ton/day) Texaco gasifier being installed at Southern California Edison's (SCE's) Cool Water generating station, told conference attendees that the SCE gasifier's efficiency, capital, and operating costs will be competitive with a direct-fired coal power plant equipped with flue gas desulfurization.

Copies of ET7's proceedings are available from: Government Institutes, Inc., P. O. Box 5918, Washington, D.C. 20014, (301) 656-1090.

Waste-To-Energy Technology Update 1980

The EPA-sponsored conference, Waste-to-Energy Technology Update 1980, was held in Cincinnati, OH, April 15-16, 1980. Papers were presented on the potential of waste feedstocks to provide energy alternatives. Feedstocks discussed included municipal solid waste, refuse-derived fuel, industrial/sewage sludge, scrap tires, and biomass such as agricultural wastes and waste cellulose. These feedstocks may be pyrolyzed, hydrolyzed, combusted, and/or co-fired with coal for use as alternative fuels. Products of waste-to-

energy technologies described include low-Btu gas, residual oil, ethanol, and gasoline.

Presentations described fuel production, fuel conversion, emission assessment, and control device applications. Results were reported from bench-scale studies, pilot plant operations, and industrial-scale applications of waste-to-energy technologies.

Abstracts of the presentations and more information on the EPA conference may be obtained by contacting Ruth Ann Gibson, Battelle Columbus Laboratories, 505 King Avenue, Columbus, OH, 43201, (614) 424-5532.

Sixth Underground Coal Conversion Symposium

Sixty-three papers describing underground coal gasification technology, environmental effects, and economics were presented at the Sixth Underground Coal Conversion Symposium. The meeting, held July 13-17, 1980, in Afton, OK, was sponsored by the U.S. Department of Energy (DOE) and cohosted by the Laramie Energy Technology Center (LETC) and Williams Brothers Engineering Company.

Topics discussed at the Symposium included:

- Reports on DOE field testing at four underground coal gasification (UCG) sites: Pricetown 1, Hoe Creek 3, Hanna IV, and Rawlins Steeply Dipping Bed.
- Status of private sector development of UCG.
- Comparison of the economics of UCG and surface coal gasification processes.
- Results of European linking studies.
- Methods and results of environmental monitoring.

One day's session was devoted to special topics. In this session, speakers discussed drilling holes in coal with water jets, selection of gasification processes, water treatment at UCG sites, UCG site characterization, and interpretation of environmental data from UCG test runs.

Proceedings of the Symposium will be published. Information regarding the proceedings may be obtained from: R. A. Mason, Williams Brothers Engineering Company, Resource Sciences Center, 6600 S. Yale Avenue, Tulsa, OK 74177, (918) 496-5020.

MEETING CALENDAR

1st SERI International Workshop on Biotechnology for the Production of Chemicals and Fuels from Biomass, Oct. 1-3, 1980, Vail, CO. Contact: Donna Post, Solar Energy Research Institute (SERI), 1617 Cole Blvd., Golden, CO 80401; telephone (303) 231-1861.

4th International Symposium on Alcohols (and other biomass fuels), Oct. 5-8, 1980, Guarujá, São Paulo, Brazil. Contact: N. E. DeEston, Caixa Postal 7141, 0100, São Paulo, Brazil.

5th Annual Conference on Materials for Coal Conversion and Utilization, Oct. 7-9, 1980, Gaithersburg, MD. Contact: S. J. Schneider or S. J. Dapkunas, NBS, Materials Bldg. B-348, Washington, DC 20234; telephone (301) 921-2893.

24th ORNL Conference on Analytical Chemistry in Energy Technology, Oct. 7-9, 1980, Riverside Motor Lodge, Gatlinburg, TN. Contact: A. L. Harrod, Analytical Chemistry Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830.

Synthetic Fuels: Status and Directions, Oct. 13-16, 1980, San Francisco, CA. Contact: Kathy Davis or S. B. Alpert, Electric Power Research Institute, P. O. Box 10412, Palo Alto, CA 94303; telephone (415) 855-2512.

3rd World Energy Engineering Congress, Oct. 13-16, 1980, Atlanta, GA. Contact: Albert Thumann, AEE, 4025 Pleasantdale Road, Suite 340, Atlanta, GA 30340; telephone (404) 477-5083.

1st International Energy Symposium-World's Fair Energy Expo 82, Oct. 14-17, 1980, Knoxville, TN. Contact: Sheila McCullough, Energy Opportunities Consortium, P. O. Box 2229, Knoxville, TN 37901; telephone (615) 637-4554.

International Symposium on Environmental Pollution, Oct. 16-17, 1980, Sheraton Biltmore, Atlanta, GA. Contact: V. M. Bhatnagar, Alena Enterprises of Canada, P. O. Box 1779, Cornwall, ONT. K6H 5V7, Canada.

Energy Conservation Expo 1980, Oct. 17-19, 1980, El Cajon (San Diego), CA. Contact: Harold Tucker, Energy Conservation Assoc. of S.D., P. O. Box 1241, La Mesa, CA 92041; telephone (714) 464-4509.

DOE/EPA Conference on European Waste to Energy Systems, Oct. 29-31, 1980, Washington, DC. Contact: Caroline Brooks, ANL, EES, 9700 S. Cass Avenue, Argonne, IL 60439; telephone (312) 972-3720.

Synfuels Industry Development, Nov. 6-7, 1980, Washington, DC. Contact: Martin Heavner, Gov. Inst., P. O. Box 5918, Washington, DC 20014; telephone (301) 656-1090.

1980 Annual Meeting of American Petroleum Institute, Nov. 10-11, 1980, San Francisco, CA. Contact: American Petroleum Institute, 2101 L Street N.W., Washington, DC 20037.

AIChE 73rd Annual Meeting, Nov. 16-20, 1980, Palmer House, Chicago, IL. Contact: American Institute of Chemical Engineers, 345 E. 47th Street, New York, NY 10017.

ENERGI 80, Dec. 2-5, 1980, Copenhagen, Denmark. Contact: Boersen's Exhibition Service, A/S Forlaget Boersen, Monergade 19, DK-1014 Copenhagen K, Denmark; telephone (451) 15-72-50.

National Conference on Renewable Energy Technologies, Dec. 8-11, 1980, Honolulu, HI. Contact: Donni S. Hopkins, Hawaii Natural Energy Institute, University of Hawaii at Manoa, 1540 Dole Street, Holmes Hall 246, Honolulu, HI 96822; telephone (808) 948-6379.

3rd Miami International Conference on Alternative Energy Sources, Dec. 15-18, 1980, Miami Beach, FL. Contact: T. Nejat Veziroglu, Dir., Clean Energy Research Inst., Univ. of Miami, P. O. Box 248294, Coral Gables, FL 33124; telephone (305) 284-4666.

European Conference on Environmental Pollution, Dec. 18-19, 1980, Frankfurt Plaza Hotel, Frankfurt, West Germany. Contact: V. M. Bhatnagar, Alena Enterprises of Canada, P. O. Box 1779, Cornwall, ONT. K6H 5V7, Canada.

Energy-Sources Technology Conference and Exhibition, Jan. 18-21, 1981, Houston, TX. Contact: Frank D. Demarest, ETCE, P. O. Box 59489, Dallas, TX 75229; telephone (214) 247-1747.

8th Energy Technology Conference and Exposition (ET8), March 9-11, 1981, Washington, DC. Contact: Martin Heavner, Gov. Inst., P. O. Box 5918, Washington, DC 20014; telephone (301) 656-1090.

1981 Symposium on Instrumentation and Control for Fossil-Energy Processes, June 8-10, 1981, San Francisco, CA. Contact: Miriam L. Holden, ANL, Bldg. 233, 9700 S. Cass Avenue, Argonne, IL 60439; telephone (312) 972-5585.

2nd International Energy Symposium-World's Fair Energy Expo 82, June 16-19, 1981, Knoxville, TN. Contact: Sheila McCullough, Energy Opportunities Consortium, P. O. Box 2229, Knoxville, TN 37901; telephone (615) 637-4554.

RECENT MAJOR PAPERS AND PUBLICATIONS

Coal Gasification and Indirect Liquefaction

Anastasi, J. L., **SASOL: South Africa's Oil From Coal Story: Background for Environmental Assessment**. EPA-600/8-80-002 (NTIS PB 80-148752). Redondo Beach, CA, TRW, Inc., January 1980.

Balfour, W. D., et al., **Collection and Characterization of Ambient Aerosols Downwind from a Commercial Lurgi Coal Gasification Facility**. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Bombaugh, K. J., et al., **Characterization of Emissions from a Lurgi Coal Gasification System at Kosovo**. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Cleland, J. G., et al., **Pollutants From Synthetic Fuels Production: Coal Gasification Screening Test Results**. EPA-600/7-79-200 (NTIS PB 80-182769). Research Triangle Park, NC, Research Triangle Institute, August 1979.

Ferrell, J. K., et al., **Coal Gasification/Gas Cleanup Test Facility, Volume I: Description and Operation**. EPA-600/7-80-046a (NTIS PB 80-188378). Raleigh, NC, North Carolina State University, March 1980.

Griest, W. H., et al., **Characterization of Ambient Vapor and Particulate Phase Organics Collected Near the Kosovo Coal Gasifier**. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Huntzicker, J. J., R. L. Johnson, and J. J. Shah, **Carbonaceous Aerosol in the Vicinity of a Lurgi Gasifier**. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Kapor, S., B. Januzl, and D. Petkovic, **GC-MS Data from Air Sampling Tests of the Coal Gasification Complex at Kosovo, Yugoslavia**. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Kilpatrick, M. P., R. A. Magee, and T. E. Emmel, **Environmental Assessment: Source Test and Evaluation Report: Wellman-Galusha (Ft. Snelling) Low-Btu Gasification**. EPA-600/7-80-097. Austin, TX, Radian Corporation, May 1980.

Lee, K. W., et al., **A Comparison of the Organics Collected from the Ambient Air with the By-Products of a Lurgi Coal Gasification Plant**. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Murin, P., T. Sipes, and G. C. Page, **Environmental Assessment Report: Wellman-Galusha Low-Btu Gasification Systems**. EPA-600/7-80-093 (NTIS PB 80-190796). Austin, TX, Radian Corporation, May 1980.

Thurnau, R. C. and E. R. Bates, **EPA Research: In Situ Coal Gasification Results to Date**. Presented at the Sixth Underground Coal Conversion Symposium, Afton, OK, July 13-17, 1980.

Williams, C. H., Jr., et al., *GC-MS Characterization of Trace Organic Compounds in the Ambient Aerosol Associated with the Coal Gasification Plant at Kosovo*. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Wolff, T., et al., *Latent Mutagenicity and Cytotoxicity in a Complex Mixture: Bioassay of Coal Gasifier Crude Tars*. Presented at the 11th Annual Meeting of the Environmental Mutagen Society, Nashville, TN, March 1980.

Zweidinger, R. A., and J. McDaniels, *Evaluation of the Performance of the Sorbents, Tenax GC and Amberlite XAD-2, for Sampling and Analysis of Coal Gasification Process Streams*. Presented at the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, March 1980.

Liquefaction

Carson, T. C., et al., *Two-Step Coal Liquefaction is a Hydrogen Efficient Route to Distillate Fuels*. CONF-790961-1. Tulsa, OK, Cities Service Co., 1979.

Chillingworth, R. S., et al., *LC-Fining of SRC: A Logical Second Stage in Two-Step Coal Liquefaction*. CONF-790822-13. Tulsa, OK, Cities Service Co., August 1979.

Epperty, W. R., *EDS Coal Liquefaction Process Development. Phase IV*. FE-2893-42. Florham Park, NJ, Exxon Research and Engineering Co., April 1979.

Skowionski, R. P., and L. A. Heredy, *Molten Alkali Metal Hydroxide Catalyzed Coal Liquefaction. Quarterly Technical Progress Report, Jan-Mar 1979*. FE-3048-2. Canoga Park, CA, Rockwell International Corp., April 1979.

Wiser, W. H., *Applied Research and Evaluation of Process Concepts for Liquefaction and Gasification of Western Coals*. FE-2006-14. Salt Lake City, UT, Utah Univ., March 1979.

Oil Shale

Barkley, W., D. Warshawsky, and M. Radike, *Toxicology and Carcinogenicity of Oil Shale Products*. In: Proceedings of the Symposium on Assessing the Industrial Hygiene Monitoring Needs for the Coal Conversion and Oil Shale Industries. Brookhaven National Laboratory, Upton, NY, Nov. 6-7, 1978. pp. 79-95.

Chappell, W. R., *Trace Element Release and Transport Associated with Shale Oil Production*. In: Oil Shale Symposium Proceedings. Golden, CO, April 18-20, 1979. pp. 156-165.

Cotter, J. E., and D. J. Powell, *Fugitive Dust at the Paraho Oil Shale Demonstration Retort and Mine*. EPA-600/7-79-208 (NTIS PB 80-122591). Redondo Beach, CA, TRW, Inc., October 1979.

Fox, J. P., K. K. Mason, and J. J. Duvall, *Partitioning of Major, Minor, and Trace Elements During Simulated In Situ Oil Shale Retorting in a Controlled-Retort*. In: Oil Shale Symposium Proceedings. Golden, CO, April 18-20, 1979. pp. 58-71.

Franklin, R. E., *Environmental Impacts of Oil Shale Technologies*. In: Proceedings of the 25th Annual Technical Meeting of the Institute of Environmental Sciences. Seattle, WA, April 30-May 2, 1979. pp. 294-297.

Hepler, D. I., et al., *Toxicological Evaluation of an In Situ Oil Shale Process Water*. In: Oil Shale Symposium Proceedings. Golden, CO, April 18-20, 1979. pp. 139-148.

Kuo, M.C.T., et al., *Inorganic Leaching of Spent Shale from Modified In Situ Processing*. In: Oil Shale Symposium Proceedings. Golden, CO, April 18-20, 1979. pp. 81-93.

Skinner, Q. D., et al., *Phototoxicity and Plant Responses to Aqueous Effluents Derived from an In Situ Oil Shale Process Water*. In: Oil Shale Symposium Proceedings. Golden, CO, April 18-20, 1979. pp. 122-138.

Thoen, T., et al., *Status of EPA Regulatory and Research Activities Affecting Oil Shale Development*. Presented at the 13th Oil Shale Symposium, Colorado School of Mines, Golden, CO, August 16-18, 1980.

Alcohol Fuels

Environmental Evaluation of Gasohol Production and Health Effects: Seminar Proceedings, EPA-907/9-79-005 (NTIS PB 80-146756). U.S. Environmental Protection Agency, Region VII, Kansas City, MO, June 27, 1979.

Harper, J. P., A. A. Antonopoulos, and A. A. Sobek, *Environmental and Economic Evaluations of Energy Recovery from Agricultural and Forestry Residues*. ANL/EES-TM-58. Argonne, IL, Argonne National Lab., August 1979.

NEUS, Inc., *Biosciences Digest: A Journal on Biomass Utilization. Vol. 1, No. 1 and No. 4*. (NTIS PB 80-140973 and PB 80-140981). Santa Monica, CA, January 1979 and October 1979.

"Processes Promising for Cellulose Pyrolysis," Chem. & Eng. News, 58(9): 26-28, 1980.

Sitton, O. C., et al., "Ethanol From Agricultural Residues," Chem. Eng. Prog., 75(12):52-57, 1979.

Other

Burchfield, T. E., and L. G. Hepler, "Some Chemical and Physical Properties of Produced Water from an *In Situ* Oil Sands Plant," *In Situ* Oil Coal Shale Miner, 3(4):383-390, 1979.

Frick, W. G., *Environmental Restrictions on Synfuels Development*. Presented at Synfuels Industry Development Seminar, Washington, D.C., 1980.

Harmsworth, R. V., and C. G. Musgrove, *Environmental Issues*. Presented at Synfuels Industry Development Seminar, Washington, D.C., 1980.

Hersman, L. E., and D. A. Klein, "Retorted Oil Shale Effects on Soil Microbiological Characteristics," J. Env. Quality, 8(4):520-524, 1979.

Supple, M. A., and K. Rashid, "Reduction of Flue Gas Particulates in a Tar Sand Plant," Energy Process Can., 72(1):62-68, 1979.

Surles, T., et al., *Environmental Constraints to Increased Coal Use: A National Assessment*. Presented at the American Chemical Society Meeting, Division of Environmental Chemistry, San Francisco, CA, August 24-29, 1980.

Watson, T., *The Fast-Track Legislation*. Presented at Synfuels Industry Development Seminar, Washington, D.C., 1980.

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