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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). The *Review* describes synthetic fuels production processes, reports environmental and health effects associated with multimedia discharge streams, and identifies pollution control technology needs. Highlights of technology and commercial developments, major symposia, a calendar of upcoming events, and a list of publications provide information on domestic and international developments in synthetic fuels technologies.

This issue of the *Environmental Review of Synthetic*

Fuels summarizes recent activities in EPA's synthetic fuel programs. EPA/IERL-RTP coordinates research projects and environmental assessment programs for aboveground coal gasification and liquefaction technologies. EPA's Industrial Environmental Research Laboratory in Cincinnati, OH (EPA/IERL-Ci) directs RD & D efforts for four synthetic fuels technologies: *in-situ* gasification, oil shale, oil (tar) sands, and alcohol fuels.

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.

CURRENT PROCESS TECHNOLOGY BACKGROUND

EPA Research: Recent Findings in In-Situ

Gasification—Groundwater contamination, land subsidence, and air emissions have been identified as potential environmental impacts of *in-situ* coal and lignite gasification. EPA research to date has combined laboratory experiments and pilot field studies in an effort to identify environmental problems prior to commercial development. The information summarized in this article was taken from a paper entitled, "EPA Research: *In-Situ* Gasification Results to Date," by R. C. Thurnau and E. R. Bates. The paper was presented at the Sixth Underground Coal Conversion Symposium, which was held July 13-17, 1980, in Afton, OK.

Groundwater Contamination

A major environmental impact of *in-situ* gasification is potential groundwater pollution. Volatile organics vaporize, sweep through the gasification zone, and condense on coal, char, clay, and rock. Trace elements (e.g., Hg, Cd, Pb, and B) remain in ash or condense on surrounding materials. As groundwater levels are reestablished after gasification, these organics and trace elements can pollute groundwater.

A groundwater modeling study performed by the University of New Mexico identified absorption coefficients for trace elements such as Cd. This laboratory study determined that the distribution coefficient for Cd contamination is a function of the particle size of the overburden and underburden aquifers. In a similar modeling study of ion exchange rates for Cd, it was determined that Mg, Na, and K ion

systems remain relatively constant until the Cd concentration begins to exceed 100 mg/l. Since the concentration of Cd in groundwater rarely exceeds 100 mg/l, ion exchange was assumed to be constant in model development. A study is also being done on the use of coal as a natural filter for controlling the distribution of trace elements and organics from gasification; this research will be expanded from static to dynamic systems.

DOE's Morgantown Energy Technology Center (METC) has performed organic analysis of product and process waters from laboratory simulation of *in-situ* coal gasification. Actual product water from *in-situ* processing of Princetown I coal was also analyzed; concentrations measured were comparable to laboratory-predicted levels. Table 1 lists the concentrations of selected organic pollutants obtained in these analyses, and compares these concentrations with DMEG values. (DMEG values are defined in "Terminology for Environmental Impact Analysis," *Environmental Review of Synthetic Fuels*, Vol. 2, No. 4.)

Groundwater contamination studies performed by Lawrence Livermore Laboratories (LLL) in Wyoming at Hoe Creek I showed that the concentration of phenolic materials was substantially reduced in the burn cavity as a function of time. Phenolics concentrations were reduced to baseline conditions 15.2 m (50 ft) from the cavity. In later months, however, organic concentrations increased, probably as a result of the contaminant plume moving outward from the burn zone.

The University of Texas has performed organic analysis of groundwater samples from *in-situ* lignite gasification studies and found that more than 97 percent of the samples contained phenolic material. Analysis of samples taken 1 year later showed that phenol concentration had decreased by a factor of 5000 (100 ppm to 0.02 ppm). Concentrations of polynuclear hydrocarbons measured in these tests dropped by a factor of 10 (140 ppb to 14 ppb) after 1 year.

Land Subsidence

Subsidence from *in-situ* gasification can seriously impact groundwater resources and modify area topography. Fractures created in overlying strata can decrease groundwater quality and quantity via contamination and loss. Subsidence followed gasification by a few weeks at LLL's Hoe Creek III site, producing a crater 9.1 m (30 ft) wide and 3.0 m (10 ft) deep.

Rock fracturing and subsidence may be prevented by designing the size, shape, and spacing of cavities to provide

adequate natural support, or by providing additional support to cavities. Selective mineral abandonment is the most promising control option. In conventional coal mining, up to 50 percent of the resources must be left in place to ensure structural stability.

Air Emissions

Less data is available on air pollution from *in-situ* gasification than on water pollution and land subsidence. It has been assumed that control technology for cleaning gas streams from *in-situ* gasification processes will be directly transferable from aboveground gasification technology.

Environmental studies conducted at DOE's Hanna IV site indicated that hydrogen sulfide (H₂S) concentrations in gaseous emissions range from 1000 to 3000 ppm; mass emissions rates approached 900 kg/d for H₂S. Carbonyl sulfide concentrations in off-gases will influence control technology selection.

TABLE 1. CONCENTRATION OF SELECTED POLLUTANTS IN PRODUCT AND PROCESS WATERS FROM *IN-SITU* COAL GASIFICATION (μg/l)

Compound	METC Product Water	METC Process Water	Princeton I Process Water	DMEG (MATE) Value
Anthracene/ Phenanthrene	9.2E3 ^a	4.8E3	4.5E4	8.4E5 2.4E4
Chrysene/ Benz(a)anthracene	4.0E3	1.8E3	9.0E3	3.3E4 6.7E2
Benzopyrene (perylene) Benzo(a) pyrene Benzo(e) pyrene	1.2E3	1.0E3	3.7E3	3.0E-1 4.6E4
Dimethylbenzanthracenes 7-12 Dimethylbenzanthracenes	5.9E4	3.5E4	6.6E3	3.9E0

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

ENVIRONMENTAL DATA ACQUISITION

Source Test Evaluation Program Conducted at Koppers-Totzek Gasification Plant—Results of an initial limited Source Test Evaluation (STE) program indicate that, for the streams evaluated, the Koppers-Totzek (K-T) process should be environmentally acceptable for U.S. commercialization. The STE program was conducted at the K-T coal gasification

plant in Modderfontein, Republic of South Africa. Sampling and analysis were performed by TRW Systems, Redondo Beach, CA, and Krupp-Koppers (GmbH), Essen, Federal Republic of Germany. The Modderfontein plant converts bituminous coal to hydrogen synthesis gas for the production of 11.6 kg/sec (1000 tonnes/d) of ammonia.

TRW and Krupp-Koppers used EPA's Source Analysis Model (SAM/IA) evaluation method for environmental assessment and pollutant prioritization. The following multimedia wastestreams were sampled:

- Coal Dust Feed,
- Raw Product Gas,
- Tail Gas from H₂S Absorber,
- Tail Gas from CO₂ Absorber,
- Input Water (Purified Sewage Effluent),
- Input Water (Cooling Water),
- Settling Pond Effluent,
- Compressor Condensate Wastewater, and
- Diluted Rectisol Condensate Wastewater.

The SAM/IA methodology used in STE programs is described and referenced in the *Environmental Review of Synthetic Fuels*, Vol. 3, No. 1.

The feedstock at Modderfontein is bituminous high volatile B coal. It has very high ash content (20 percent) and low sulfur content (1.0 percent) compared to most U.S. coals. The coal dust feedstream was screened for trace element composition. Analytical data obtained via Spark Source Mass Spectrometry will be included in the final Modderfontein STE Report.

After it is water-washed for particulate removal, the raw product gas stream is primarily composed of H₂O, CO, H₂, and N₂. Data on hydrocarbons (HC) were not collected; low

concentrations of HC are expected due to the high temperature (2000°C or 2273 K) of the K-T gasification reaction.

A selective Rectisol unit was used to extract H₂S and CO₂ from the raw product gas. Analytical data on the composition of tail gases vented to the atmosphere from this unit were used to assess potential health and ecological impacts. Table 2 lists data on raw gas composition and compounds in the tail gases which are present at levels of potential concern.

Fifteen elements, including Fe and Mn, were chosen for priority pollutant metals screening of aqueous streams. It was determined that process waters (compressor condensate and Rectisol unit samples) exceeded the EPA levels of concern for Se, Zn, Cu, and Hg. The settling pond effluent was relatively clean compared to the process and input streams; an overall reduction was apparent in Sb, As, Zn, Pb, Ni, and Ca after wastewater treatment.

Results of organic priority pollutant analysis indicate that few of EPA's 116 organic priority pollutants are present in the aqueous samples tested. Those present are in low concentrations (<10 µg/l), with the exception of pyrene and chrysene in condensates from the Rectisol unit and bromomethane in the compressor condensates. Analysis of the Rectisol condensate samples for polynuclear aromatic material detected 11 distinct compounds. Five compounds were identified and quantified: fluoranthene; pyrene; 1, 2-benzofluorene; 1, 2-benzanthracene; and benzo(k)fluoranthene. The quantity of these five compounds measured in the Rectisol condensate did not exceed health- or ecology-based Discharge Multimedia Environmental Goal (DMEG) values.

TABLE 2. COMPOSITION OF GASEOUS EMISSIONS FROM KOPPERS-TOTZEK GASIFIER

	CO volume percent (dry)	NH ₃ mg/Nm ³ (dry)	HCN mg/Nm ³ (dry)	Health- based TDS ^a	Ecology- based TDS	Health- based WDS ^a	Ecology- based WDS
Raw Product Gas	59.1	57	76	NA ^b	NA	NA	NA
Tail Gas from H ₂ S Absorber	1.9 ^c	39 ^c	62 ^c	5.6E2 ^d	2.9E2	2.1E3	1.1E3
Tail Gas from CO ₂ Absorber	0.3 ^c	3 ^c	8	7.6E1	3.4E1	1.3E3	4.6E2

^aTDS = Total Discharge Severity and WDS = Weighted Discharge Severity. These terms are defined in the *Environmental Review of Synthetic Fuels*, Vol. 2, No. 4.

^bNA = Not Available.

^cCompounds present at levels of potential concern.

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

The wastewater treatment facility at Modderfontein consists of a clarifier and a settling pond. The settling pond effluent is the only wastewater stream discharged by the plant. Analyses of this effluent indicate that its chemical composition is very similar to that of the input waters used at the Modderfontein plant; the settling pond is effective in removing most aqueous pollutants formed during gasification. When compared to the input water, the effluent shows higher concentrations of trace elements such as Cs, Sr, Ba, Ga, and Mb, and lower concentrations of elements such as Al, Fe, and Mn.

Mn, Fe, and P concentrations in the aqueous input and discharge streams exceeded health-based DMEG values, and the P concentration also exceeded the ecology-based DMEG value. If the chemical form of P is phosphate, not elemental P, its priority for further consideration is greatly reduced. Ecology-based discharge severity values greater than 1 were also obtained for Cd, Cu, Mn, Ni, Pb, S, Zn, and phthalate esters in the input waters, and Cd, Mn, Ni, and S in the settling pond discharge stream. Discharge severity values determined for the discharged effluent were lower than those determined for input and process waters. This indicates that phthalate esters, P, Cu, Pb, Zn, and other constituents of the aqueous streams are transferred to the settling pond sludge.

The initial Modderfontein STE program was limited in scope; sampling and analyses have been completed for only 9 of 25 streams originally designated for analysis to meet comprehensive STE goals. All samples were collected during relatively steady state conditions when the plant was operating at near full-design capacity; these samples are expected to be representative of typical plant effluents. Wastewater characterization and controllability were emphasized. No bioassay tests were performed. The STE report, to be published in Winter 1980, will identify data gaps and will outline plans for possible future K-T source testing and evaluation.

Chapman STE Report Addendum Presents Results of Detailed Study—An addendum to the Source Test and Evaluation (STE) report for Chapman low-Btu gasification has identified (1) fused polycyclics (benzo(a)pyrene) in the coal feeder vent discharge and separator tar, and (2) phenols in the separator vent discharge and separator liquor as the organic compounds of greatest environmental concern. Under contract to EPA, Radian Corporation has completed detailed organic and inorganic characterization of emissions from Chapman gasification of Virginia bituminous coal. Preliminary chemical screening data identified six waste-streams for detailed organic analysis:

- Coal Feeder Vent Discharge,
- Separator Vent Discharge,
- Gasifier Ash,
- Cyclone Dust,
- Separator Liquor, and
- Separator Tar.

The addendum also includes results from trace element analysis performed on the feed coal, and it reports results from trace element and organic analyses of leachates produced from solid wastes (gasifier ash and cyclone dust).

Detailed organic analyses indicate that four waste-streams (coal feeder vent discharge, separator vent discharge, separator liquor, and separator tar) contained compounds with total discharge severities (TDSs) greater than 1. In general, TDS values reported after detailed organic analyses were from 2 to 4.5 orders of magnitude lower than values derived from preliminary data. The relative ranking of stream severity was similar in both preliminary and detailed analyses, indicating that TDS values derived from chemical screening data were valuable in ranking streams for health and ecological effects.

Detailed organic analysis identified benzo(a)pyrene as the principal contributing compound to the TDS health value for the coal feeder vent discharge and the separator tar. For the other four wastestreams studied, discharge severities originally assigned to organics in screening analysis were lowered by the detailed organic analysis. This increased the relative significance of inorganics.

Spark Source Mass Spectrometry (SSMS) identified 54 trace elements in the feed coal; Al, Ca, Fe, Mg, P, K, Se, Sr, S, and Ti had mass flows in excess of 0.03 g/sec. Quantitatively, most of the trace element mass which left the gasifier as solid waste was found in the gasifier ash. The 15 elements concentrated in ash samples were Al, Ba, Be, B, Ca, Co, Cu, Cd, Pb, Mg, Ni, Ru, Sc, Sn, and Ti.

Gasifier ash and cyclone dust were leached using the RCRA extraction procedure and extraction with deionized water without the addition of a pH buffer. The leachates had low potential for harmful health and ecological effects. Organic analysis indicated an absence of organics in the leachates. The leachability of trace elements from the solid wastes was very low; only As in the cyclone dust, and As, Fe, and S in the gasifier ash had leachabilities greater than 10 percent. All trace elements which had been assigned RCRA-specified limits had concentrations significantly below those limits.

Additional data needs for complete assessment of Chapman low-Btu gasification include long term process monitoring and gasification of a variety of coal types. Additional detailed analyses should include characterization of (1) combustion products of product gas, (2) gaseous emissions from the quench liquor forced evaporator, (3) phthalates in the gasifier ash, and (4) polycyclic hydrocarbon emissions. For more information on the Chapman STE report (EPA-600/7-78-202, NTIS PB 289940), see the *Environmental Review of Synthetic Fuels*, Vol. 1, No. 2.

Alcohol Plant Characterized—Results of a recent Source Test and Evaluation (STE) program indicate that alcohol plants have the potential to cause environmental problems if liquid effluents and air emissions are not properly treated and/or controlled. Under contract to EPA, Radian Corporation conducted the STE program at a commercial-scale alcohol synthesis plant in Atchison, KS. The plant produces 75,000 m³ (20 × 10⁶ gal.) anhydrous ethanol yearly from grain feedstocks; the anhydrous ethanol is used to produce gasohol. Characterizations of plant wastestreams after treatment and/or control indicate that the Atchison plant is in compliance with applicable environmental regulations.

Solid wastes and byproducts from the Atchison plant contain negligible concentrations of ammonia, benzene, and trace metals. Pesticides on grain feedstocks were apparently destroyed during feedstock preparation; no traces of pesticides were found in solid wastes or wastewaters from the plant. Solid wastes and byproducts such as distillers' dried grain (DDG), animal feed, and biosludge may be used or discharged without major environmental effects.

Untreated distillery wastewaters are high in biological oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids. Extended aeration and clarification reduce the high concentrations of suspended solids, BOD, COD, total organic carbon (TOC), and ammonia in wastewaters from distillation to acceptable discharge levels. The untreated wastewaters are also very acidic due to the addition of sulfuric acid during fermentation to retard bacterial growth. This acidity necessitates neutralization prior to discharge. A benzene dehydration unit is effective in reducing benzene concentrations to <60 ppb in the wastewaters.

Uncontrolled gaseous emissions from the byproduct DDG dryers are high in particulate loading, but cyclones on the dryers reduce particulate emissions to levels of com-

pliance. Condensers on the vent lines provide adequate hydrocarbon (HC) control. The Atchison plant uses natural gas for steam generation, so that SO₂ and NO_x emission levels are low. Combustion of coal or fuel oil would result in higher concentrations of SO₂, NO_x, and particulates in gaseous emissions from the plant.

Recommendations for future study include:

- Environmental characterization of other alcohol plants which use different feedstocks, processing equipment, fuel sources, and wastewater treatment methods;
- Gas chromatography/mass spectroscopy (GC/MS) analysis of pesticide concentrations in process streams to determine the fate of pesticides in alcohol synthesis;
- HC monitoring to ensure worker safety; and
- Analysis of byproducts for priority pollutant trace metals to determine whether these pollutants might build up in concentration if byproducts are landfarmed or landspread.

The STE report, with complete results from the environmental sampling and analysis program, will be published this winter. The STE report will also list requirements for STE programs at other alcohol production plants and will include a conceptual design of a grain-alcohol plant which uses a coal-fired boiler for steam generation. The design is projected to be representative of future plants which will be needed to support a gasohol industry.

Hittman Reports Preliminary Findings of SRC-II Source Test—Preliminary results of the Fort Lewis SRC-II pilot plant Level I-Level II source test conducted in March-April 1980 indicate that ammonia, sulfides, and phenols in process recycle water and some inorganic elements (metals) in vacuum bottoms may require further environmental consideration. Process sour water was selected as a sampling stream in the preliminary study, in addition to process recycle water and vacuum bottoms. Chemical components from these three process streams have been identified, screened, and prioritized for more detailed analysis.

Samples of recycle process water were characterized by extremely high alkalinity with very low hardness and low levels of alkali metals. Levels of ammonia, sulfide, and phenols in recycle water would have to be reduced before this wastestream could be discharged.

The Ft. Lewis SRC-II plant currently produces a vacuum bottom residue as a byproduct stream. This residue contains mineral matter and low-sulfur carbon. In a commercial facility, this material would be an internal stream fed directly to a gasifier for production of hydrogen or fuel gas.

The Fort Lewis pilot plant's wastewater treatment system averages a 20 to 93 percent reduction in the concentration of metals in process sour waters. The treatment process is also effective in decreasing levels of organics such as aliphatic hydrocarbons, benzene and substituted benzenes, and fused polycyclic hydrocarbons. Neither the plant influent nor effluent wastewater streams demonstrate toxicity in Ames or rodent bioassay tests.

Hittman will conduct further studies on the Fort Lewis SRC-II plant waste streams, results of which will be reported in future issues of the *Environmental Review of Synthetic Fuels*. For more information regarding the Fort Lewis plant, see the *Environmental Review of Synthetic Fuels*, Vol. 2, No. 3.

Gasifier Ash Leachates Characterized—Under contract to EPA, TRW and Radian Corporation have compared leachates of ashes from Lurgi, Wellman-Galusha, and Texaco gasifiers to National Interim Primary Drinking Water Stan-

dards (NIPDWS). None of the wastes are considered hazardous when compared to 100X the NIPDWS. The leachates were produced using the Resource Conservation and Recovery Act (RCRA) extraction procedure which simulates rainwater extraction of soluble materials from solid wastes. Trace element concentrations in the leachates were compared to NIPDWS for As, Ba, Cd, Cr, Pb, Hg, Se, and Ag. Se in the Texaco gasifier slag is the only element which approaches but does not exceed the 100X NIPDWS used to classify wastes as hazardous. Se may present a hazard if high-Se coals are gasified.

RCRA extraction procedures were used to test the following samples:

- Coarse slag from Texaco gasification of western sub-bituminous coal,
- Dewatered ash composite from Wellman-Galusha gasification of North Dakota lignite,
- Cyclone dust from Wellman-Galusha gasification of North Dakota lignite,
- Unquenched ash from Lurgi gasification of Rosebud coal,
- Unquenched ash from Lurgi gasification of Illinois No. 5 coal, and
- Unquenched ash from Lurgi gasification of Illinois No. 6 coal.

Leachates of these samples were compared to leachates of ashes from a lignite-fired steam boiler. Although the gasifiers and the boiler operate under different conditions, results showed that RCRA extract characteristics are generally quite similar for ashes from the two source types.

TRW and Radian are conducting further tests on ashes from Lurgi and Koppers-Totzek gasifiers in Yugoslavia and South Africa. Data on the leachate characteristics of these and other samples will be included in future issues of the *Environmental Review of Synthetic Fuels*.

Coal Conversion Wastewaters Compared—Under contract to EPA, Radian Corporation has reported strong similarities in both gross chemical parameters and concentrations of specific organic compounds between aqueous process condensates from an oxygen-blown, lignite-fired Lurgi gasifier and an air-blown, bituminous-fired Chapman gasifier. These aqueous gasifier condensates were also compared to aqueous condensate from a coke oven by-product recovery plant. Water quality parameters, phenolic compound concentrations, and concentrations of refractory organics in coke oven condensates were generally lower than those measured for the two gasification aqueous condensates.

The following analytical results were used to establish similarities between the three aqueous process condensates:

- **Water Quality Parameters**—Water quality parameters (e.g., BOD, COD, TOC, and concentrations of nitrogen species, phenolic compounds, and oil and grease) were very similar for the condensates from the Lurgi and Chapman gasifiers using lignite and bituminous coals; parameters for the coke oven process condensate were generally lower than those measured for the two gasifier condensates.
- **Extractions of Organics**—Extraction of the three condensates with diisopropyl ether (DIPE) resulted in 99+ percent removal of total phenols, 75 percent average removal of total organic carbon (TOC), and significant reductions in biological oxygen demand (BOD) and chemical oxygen demand (COD) values. The DIPE extraction procedure was designed to simulate the Phenosolvan process used by Lurgi to remove phenols from wastewaters. Oil and grease concentrations dropped below a detection level of 10 mg/l.

- **Concentrations of Phenols**—The same phenolic species were identified in all three process condensates. Phenolics concentrations were similar in the two gasification process condensates; coke oven phenolics were found at lower concentrations.
- **Concentrations of Nitrogen-Containing Organics**—All three process condensates contained the same nitrogen heterocyclic compounds; the relative concentrations of the compounds in each of the condensate DIPE extracts were similar.
- **Molecular Weight Distribution of Refractory Compounds**—The relative amounts of refractory (non-extractable) organics and their molecular weight distributions were found to be the same (within the limits of experimental error) for the Lurgi and Chapman process condensates. Levels of refractory organics in coke oven process condensate were lower than those measured for the two gasifier process condensates.

Results of this study led to a number of conclusions regarding the treatability of coal gasification wastewaters:

- Gasification process condensates may not be sufficiently similar to coke oven process condensates to justify the use of existing coke oven treatment methods for treatment of coal gasification wastewaters.
- Further treatment may be required to reduce the high residual TOC levels remaining in gasification process condensates after DIPE extraction and activated carbon adsorption.
- The Chapman aqueous condensate may be used as a model for treatment studies of Lurgi process waters.

Additional studies are needed to investigate the treatability of coal gasification wastewaters and the efficiency of various wastewater treatment processes. For more information on the present wastewater study, see the *Environmental Review of Synthetic Fuels*, Vol. 3, No. 2.

CONTROL TECHNOLOGY ASSESSMENT

Alternate Fuels Group—EPA's Alternate Fuels Group (AFG) has formed five working groups to prepare Pollution Control Guidance Documents (PCGDs) for major synthetic fuels technologies. The AFG is developing both EPA's environmental control guidance strategy for the synthetic fuels industry and the resource program to support that strategy. The PCGDs will provide guidance on available control technology for multimedia wastestreams. The guidance will address regulated and nonregulated potential pollutants in all media. When regulatory actions are finalized, they will supersede the guidance for that area.

In the early stages of PCGD development, the EPA contractors and the developers of synthetic fuels technologies worked together to identify the environmental data base. The data bases for fixed-bed low-Btu gasification and for indirect coal liquefaction have been utilized by EPA to draft control options and preliminary guidance.

The indirect coal liquefaction PCGD has been divided into separate sections according to the gasification process used: Lurgi, Koppers-Totzek, and Texaco. Of the indirect liquefaction systems, the Lurgi-based PCGD is closest to completion.

Early identification of environmental guidance will (1) allow its utilization in technology process design, (2) provide Environmental Impact Statement (EIS) and permit reviewers with information to ensure that discharges will be reasonably controlled in a cost effective manner, and (3) expedite EIS and permit application review. These factors should speed commercialization of emerging synthetic fuels technologies while providing environmental protection for currently known environmental effects.

In November 1980, the PCGD for low-Btu gasification was submitted to the working group, and the PCGD for Lurgi-based indirect liquefaction was submitted to the AFG. The PCGD for shale oil will be submitted to the AFG this winter. The PCGDs for direct coal liquefaction, alcohol fuel from biomass, and geothermal systems are being prepared for EPA review. After approval by EPA, the PCGDs will undergo public review.

Oil Shale Retort Wastewaters Studied—Monsanto Research Corporation is conducting a 3-year, 5-phase study to: (1) summarize known information on oil shale retort

wastewater sources and characteristics, (2) identify control technologies for testing the identified wastewater streams, and (3) design, construct, and operate bench- and pilot-scale wastewater treatment units to evaluate identified control technologies. To date, oil shale retort processes have been reviewed, wastewater streams have been identified, and wastewater treatment and reuse options have been recommended.

Three wastewater streams from *in-situ* oil shale retorting were tested: (1) mine water pumped from the shale formation prior to ignition, (2) retort water condensed on cool rubblized shale located in front of the burn zone, and (3) gas condensates recovered when gases are cooled prior to purification. Three wastewater streams from surface retort processes were studied: (1) gas condensates, (2) product water separated from product oil after oil-gas separation, and (3) leachates from spent shale piles.

Mine Water

Mine water from *in-situ* retorting exhibits high levels of alkalinity, chemical oxygen demand (COD), Cl, F, S, B, H₂S, and Na. Trace metals in mine water are of special concern due to the likelihood that some mine water may be released to the environment. A number of treatment options have been recommended for mine waters:

- Aeration to remove dissolved gases;
- Chemical addition, flocculation, or sedimentation for clarification;
- Multimedia filtration to remove fine suspended solids;
- Reverse osmosis or ion exchange to remove total dissolved solids (TDS);
- Ion exchange to remove residual organics; and
- Chlorine addition for disinfection.

Mine water can serve as cooling water or boiler feed water after partial treatment, or it can be discharged after treatment for H₂S, volatile organics, F, B, and TDS.

Retort and Product Waters

Retort and product waters are quite similar in composition; they contain high levels of most pollutants identified in

wastewaters from oil shale processing. Product waters contain higher levels of organics than retort waters due to the presence of emulsified oils.

Treatment options recommended for retort and product waters include:

- Gravity separation, chemical addition, or ultrafiltration to separate emulsified oils;
- Stream stripping to remove dissolved gases;
- Aerobic biological treatment, wet air oxidation, or activated carbon adsorption to remove organics;
- Multimedia filtration to remove fine suspended solids;
- Chemical addition for scale control;
- Addition of granulated activated carbon or polymeric resins to remove trace organics; and
- Reverse osmosis or ion exchange to remove TDS and trace metals.

Extensive treatment is required prior to discharge of retort and product waters; a lesser degree of treatment is required if the retort and product waters are recycled as cooling waters. Treated water could also be used to generate steam (via a thermal sludge oxidizer) or to moisten spent shale.

Gas Condensates

Gas condensates from both *in-situ* and surface oil shale retorting are characterized by high ammonia, high alkalinity, and high organic composition. Trace metals and other inorganics are found in lower concentrations in gas condensates than in retort and product waters. Inorganics are present in low concentrations with the exception of ammonia and carbonate species. Treatability studies are being performed on gas condensates, as well as the other wastewaters. Treatment options recommended for use on gas condensates are the same as those recommended for use on retort and product waters, excluding chemical addition for scale control.

Leachates from Spent Shale Piles

Leachates from spent shale piles generated in surface retorting are high in organic composition, TDS, sulfates, and Na. No treatability studies on leachates are available, but it is likely that TDS and trace metals will require treatment prior to leachate disposal.

Future Study

Four potential sources of mine water, retort water, and/or gas condensates have been identified for bench scale testing. Conventional wastewater treatment methods will probably be used.

Data gaps identified in the oil shale wastewater data base include:

- Insufficient data on composition and flow rates of wastewaters due to inadequate analytical techniques and lack of information from tests at commercial-scale oil shale retorts;
- Insufficient data on water quality requirements for recycle applications; and
- Insufficient data on wastewater treatability.

Monsanto Research Corporation recommends additional bench-scale testing prior to design of a pilot-scale wastewater treatment system.

Stretford Sulfur Removal Process Recommended for Direct-Retort Application—A recent study of control technology for removing sulfur compounds from gases produced by direct-fired oil shale retorts identified the Stretford process as the most cost-effective in reducing sulfur emissions (see Recent Major Papers and Publications, "Control of Sulfur Emissions from Oil-Shale Retorts"). IT Enviroscience screened 31 commercial gas-sweetening processes based on the H₂S composition of gases produced by the Paraho direct-retort method (for a description of the Paraho method, see the *Environmental Review of Synthetic Fuels*, Vol. 3, No. 3).

Direct-fired oil shale retorts, reporting gaseous CO₂/H₂S ratios ranging from 75:1 to 165:1, require a sulfur removal process which selectively removes the smaller amounts of H₂S. The Stretford process, which directly oxidizes sulfur compounds to elemental sulfur, is most applicable at low concentrations of H₂S in the gaseous stream. The CO₂ content of the gas has little effect on the Stretford process.

Indirect sulfur recovery processes in which acid-gas components are removed from the fuel gas as a concentrated acid-gas stream are usually followed by the Claus sulfur removal process. The Claus process is commercially feasible when the H₂S concentration in the acid gas stream is 25 percent or higher. In this study, only the MDEA process with three stages of absorption produced an acid gas acceptable for a Claus sulfur recovery process.

Based on the State of Colorado's SO₂ emission limitation of 857 g/m³ (0.3 lb/bbl) of oil produced, the Stretford direct-recovery process would cost approximately \$3.45/m³ (\$0.55/bbl) of oil produced, about half that projected for the best indirect sulfur removal system.

Experimental Vapor/Liquid Equilibrium Data Compared to Model Predictions—Test results from an experimental equilibrium cell compare favorably with values predicted by a thermodynamic model.

Via a cooperative agreement with EPA, researchers at North Carolina State University (NCSU) are analyzing an acid gas removal system which uses physical absorption in refrigerated methanol to clean gases produced by coal gasification. A thermodynamic model is used to predict the equilibrium behavior of mixtures of methanol and three selected constituents of crude coal gas: CO₂, N₂, and H₂S. Values predicted for equilibrium pressures and vapor mole fractions are compared to data obtained in experiments conducted in an equilibrium cell equipped with sampling devices and a gas chromatograph.

Vapor/liquid equilibrium data are obtained for CO₂/H₂S/N₂/methanol mixtures at temperatures of 258.15 K and 273.15 K and pressures ranging from 0.6 to 4.1 MPa (6 to 40 atm). Experimental values for equilibrium pressures and vapor mole fractions of CO₂ and N₂ correlate strongly with predicted values. Correlation between experimental and predicted H₂S vapor mole fractions is not as strong due to reduced chromatographic sensitivity at low H₂S concentrations.

NCSU's thermodynamic model allows the prediction of equilibrium pressures and vapor compositions for mixtures of CO₂, H₂S, N₂, and methanol over a limited temperature range. Additional research is needed to adapt the model to bubblepoint, dewpoint, and flash calculations. Other key constituents of crude coal gas are scheduled for testing.

A report describing the NCSU study is available (EPA-600/7-80-116 (NTIS PB 80-212236), "Solubilities of Acid Gases and Nitrogen in Methanol"). The study is underway at NCSU's coal gasification gas cleaning pilot plant in Raleigh, NC. For more information on the NCSU pilot plant, see the *Environmental Review of Synthetic Fuels*, Vol. 3, No. 1.

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 78768 (512) 454-4797 (Gordon C. Page)	William J. Rhodes IERL-RTP Environmental Protection Agency Research Triangle Park, NC 27711 (919) 541-2853
Environmental Assessment of High-Btu Gasification (April 1977-March 1981)	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) 541-2853
Environmental Evaluation of Coal Liquefaction (July 1979-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 University 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)	University 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) 541-6000 (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 Hoe Creek, WY (January 1975-January 1981) (Interagency Agreement)	U.S. Dept. of Energy Washington, DC 20545 (301) 353-5516 (Charles Grusa) Lawrence Livermore Laboratory Livermore, CA 94550 (415) 422-6463 (S.W. Mead)	Edward R. Bates IERL-CI Environmental Protection Agency Cincinnati, OH 45268 (513) 684-4353
Geotechnical Instrumentation for In-Situ Coal Gasification (July 1976-February 1981) (Interagency Agreement)	U.S. Dept. of Energy Washington, DC 20545 (301) 353-5516 (Charles Grusa) Lawrence Livermore Laboratory Livermore, CA 94550 (415) 422-6463 (S.W. Mead)	Edward R. Bates IERL-CI Environmental Protection Agency Cincinnati, OH 45268 (513) 684-4353
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) 684-4353
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) 684-4353

**Environmental Review of Synthetic Fuels
December 1980**

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) 793-2258	Edward R. Bates IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513) 684-4353
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Environmental Perspective on the
Emerging Oil Shale Industry
(August 1978-January 1981)

EPA Oil Shale Research Group
Office of Research and
Development

Edward R. Bates IERL-Ci Environmental Protection Agency Cincinnati, OH 45268 (513) 684-4353	Terry L. Thoen Region VIII Environmental Protection Agency Denver, CO 80295 (303) 837-5914
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Trace Elements in Naval Reserve
Oil Shale Cores
(June 1978-December 1980)
(Interagency Agreement)

Laramie Energy Technology Center
Laramie, WY 82071
(307) 721-2011
(Richard Poulson)

Edward R. Bates
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

Assessment of SO₂ and Hydrocarbon
Emissions from Old *In-Situ*
Oil Shale Sites
(November 1978-December 1980)
(Interagency Agreement)

Laramie Energy Technology Center
Laramie, WY 82071
(307) 721-2011
(Richard Poulson)

Edward R. Bates
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

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

Denver Research Institute
Denver, CO 80208
(303) 753-2912
(Andrew Jovanovich)

Edward R. Bates
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

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

Laramie Energy Technology Center
Laramie, WY 82071
(307) 721-2011
(G.F. Dana)

Edward R. Bates
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

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

Monsanto Research Corporation
P.O. Box 8, Station B
Dayton, OH 45407
(513) 268-3411
(Gary Rawlings)

Walter Liberick
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

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

Monsanto Research Corporation
P.O. Box 8, Station B
Dayton, OH 45407
(513) 268-3411
(Gary Rawlings)

Robert Thurnau
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

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

Denver Research Institute
2390 So. York Street
University of Denver
Denver, CO 80210
(303) 753-2911
(Andrew Jovanovich)

Robert Thurnau
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

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

Denver Research Institute
University of Denver
Denver, CO 80210
(303) 753-2911
(Andrew Jovanovich)

Robert Thurnau
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

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

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
(415) 451-6698
(Phyllis Fox)

Robert Thurnau
IERL-Ci
Environmental Protection Agency
Cincinnati, OH 45268
(513) 684-4353

TECHNOLOGY AND/OR COMMERCIAL DEVELOPMENT

DOE Will Distribute First Synthetic Fuels Corporation Funds—Congress has authorized the U.S. Department of Energy (DOE) to spend or commit \$5 billion on synthetic fuels commercialization projects. The money is part of the \$20 billion appropriated for the U.S. Synthetic Fuels Corporation (SFC) for the fiscal year starting October 1, 1980. DOE Assistant Secretary for Resource Applications Ruth Davis will oversee the synfuels subsidy program until members of the SFC are confirmed.

The SFC will help plan and fund commercial projects to produce fuels from coal, oil shale, and tar sands. The SFC does not have jurisdiction over projects involving wood, biomass, and renewable resources. However, DOE and the U.S. Department of Agriculture will spend \$1.2 billion to aid new industries producing fuels from crops, wood, and urban waste.

In September 1980, DOE committed \$450 million of the SFC funds. A \$250 million loan guarantee will aid the Great Plains Gasification Associates to construct the Beulah, ND, coal gasification plant. DOE reviewed 971 proposals and selected 110 projects for awards totaling over \$200 million. Half of this money will be used to sponsor 99 selected feasibility studies; the remaining \$100 million will be spent for 11 cooperative agreements with industries ready to start work on commercial energy projects.

Synthetic fuels projects in 46 states were selected for funding. The greatest number of awards were for small-scale, commercial alcohol plants. These alcohol plants would have a combined potential production capacity of 0.12 m³/sec (1.0 × 10⁶ gal./yr) and will receive awards totaling \$56 million. A total of \$100 million will be used for coal gasification and liquefaction projects.

DOE will consider proposals and select projects for an additional \$300 million recently appropriated by Congress. DOE will also solicit bids for the \$5 billion provided by Congress for loan guarantees, price guarantees, and purchase agreements. For more information on the SFC, see the *Environmental Review of Synthetic Fuels*, Vol. 3, No. 3.

Synthetic Fuels Storage Stability Studies—A study of the storage stability of nine synthetic gasolines and jet fuels reported that high levels of gum deposits were found in most of the synthetic fuels after 32 weeks of storage. Petroleum-derived fuels studied for comparison showed good storage stability.

Higher gum formation in synthetic fuels was attributed to higher total heteroatom concentrations in fuels refined from coal liquids, shale oil, and tar sands bitumen. The gums formed during storage resulted primarily from oxidation reactions. Some polymerization reactions may also have occurred; high-molecular weight species (170 to 5000) were present in the gums. In addition, nitrogen and sulfur compounds tended to concentrate in gums formed during storage.

High performance liquid chromatography and gas chromatography were used to analyze samples before and after the 32-week storage period to detect changes in fuel composition. Both analytical techniques indicated that approximately 25 percent of the lighter gasoline components were lost during the 32-week test. This loss increased the percent of aromatics in the gasolines. The less volatile jet fuels showed no loss of fuel and little compositional change.

The synthetic fuels studies included SASOL coal-derived gasoline, tar sands-derived naphtha, Paraho shale oil-derived

JP-5 jet fuel, Athabasca tar sands-derived JP-5 jet fuel, coal syncrude (COED process)-derived JP-5 jet fuel, and Paraho shale oil-derived Jet A fuel. For comparison, petroleum-derived JP-5 jet fuel, and commercial unleaded and leaded, regular-grade gasolines were also studied.

Endangered-Species Fish Affect Dam Construction—Fish of a species protected by the federal government's Endangered Species Act have delayed permitting required for construction of a dam on Utah's White River. The dam is considered essential to synthetic fuels development in north-eastern Utah, an area with extensive deposits of tar sands, oil shale, and coal. U.S. Fish and Wildlife officials fear the dam would interfere with the Colorado squawfish's spawning and migration patterns by decreasing water temperatures and depleting water flow in the White River. Additional studies of the squawfish's migration and reproductive patterns are proposed.

Shell Announces New Process Developments, Plans for Two Gasification Plants—Shell Internationale Petroleum Maatschappij has developed a high-pressure slagging gasification process to be tested at two 11.5 kg/sec (1100 ton/d)-prototype coal gasification plants in Europe. The first plant is to be built at Moerdijk in the Netherlands and is scheduled for operation in 1984. The second, in West Germany, is to start operation in 1985. Larger units, with capacities up to 28.9 kg/sec (2750 ton/d), are scheduled to come on-line in the late 1980's.

Shell began operating a 0.06 kg/sec (6 ton/d) pilot plant in 1976 in Amsterdam. This successful pilot operation led to construction of a 1.7 kg/sec (165 ton/d) plant by Krupp-Koppers in 1978. The Shell-Koppers process developed at these two plants will be tested at the two commercial-scale plants.

The Shell-Koppers process can be used for gasifying most types of coals and petroleum coke; it can accommodate ash contents up to 40 percent and sulfur contents up to 8 percent. Shell has also developed a method to gasify vacuum residues of direct liquefaction processes so that liquids containing unconverted coal can be gasified without removal of ash or coal solids.

In the Shell-Koppers process, ground coal feed enters the reactor through two opposed burners in a high-pressure shell, protected from hot gases by a tube wall. In the tube wall, saturated steam is generated at 5.0 MPa (725 psi). Slag exits through a hole in the bottom of the reactor. It is quenched with water, crushed in a submerged mill, and then passed through a pressure lock to atmospheric conditions. Gases leave the reactor at 1773 K (1500°C) and 3.0 MPa (435 psi). They are quenched with cool recycle synthesis gas at 373 K (100°C), reducing the net temperature to below 1173 K (900°C), at which temperature any entrained slag is solidified. Next, the gases pass through a waste heat boiler where the temperature drops below 593 K (320°C). Remaining solids are separated from the gases by a cyclone and/or a water scrubber, while the gas cools to 313 K (40°C). High reactor temperatures result in product gas which is primarily composed of carbon monoxide and hydrogen (93 to 96 percent by volume).

The medium-Btu product gas may be used as feedstock for combined-cycle power generation. It has potential use in iron ore direct reduction or may be catalytically converted to methane.

Environmental impacts of the Shell-Koppers process are reported to be negligible. Solid waste products include elemental sulfur and ash in the form of inert slag. Little or no wastewater is discharged. Thermal efficiencies are high (79 to 82 percent) and depend on coal feedstock and quenching medium. The raw product gas has a heat content of about 11.8 MJ/Nm³ (300 Btu/scf).

Dow Coal Liquefaction Process Conceptualized—Dow Chemical has designed a commercial coal liquefaction process which includes cryogenic separation for hydrogen recovery. The conceptual design proposes a mine-mouth, 105 kg/sec (10,000 ton/d) coal liquefaction plant to produce high-Btu (33.2 MJ/Nm³ or 845 Btu/scf) gas, liquefied petroleum gas, and naphtha. An economic study of design feasibility estimates that the products will cost approximately \$132 to \$180 per m³ (\$20.90 to \$28.50 per bbl).

In the Dow liquefaction process, crushed dried coal is slurried with process oils and an emulsified ammonium molybdate catalyst. The preheated slurry is mixed with hydrogen and flashed in two stages in the reactor. Gases and light liquids are collected and separated to produce recycle hydrogen, high-Btu gas, and light naphtha. Cryogenic hydrogen recovery is reported to be 76 percent efficient. The nonvolatile byproducts of two-stage flashing include ash, unreacted coal asphaltene, and heavy oils. Ash is removed in the underflow of a hydroclone and subsequently deasphalted; the overflow is recycled as slurry oil.

Research and pilot plant studies were performed using Pittsburgh No. 8 seam coal containing 4 percent sulfur.

Lummus Process May Cut Direct Coal Liquefaction Costs—At its New Brunswick, NJ, test plant, C-E Lummus is testing a new two-stage direct liquefaction process which researchers believe will greatly enhance the efficiency of hydrogen use in the direct coal liquefaction process. Department of Energy studies show that up to one-third of the capital cost of a direct liquefaction plant results from hydrogen requirements. The two-stage direct liquefaction process could reduce hydrogen plant size, thus decreasing the cost of direct coal liquefaction.

The Lummus two-stage direct liquefaction process combines two concepts developed by Air Products and Chemicals and by Mobil Oil Co. At the bench-scale level, Air Products and Chemicals has demonstrated that a blend of up to 50 percent (by weight) of dissolved solvent-refined coal (SRC) can be catalytically hydrocracked. Mobil Oil has shown in laboratory studies that a two-stage process can cut hydrogen requirements. Integrating these ideas, Lummus has modified the SRC I process and has been testing its version since April.

In the conventional SRC I process, coal is preheated in a reactor, and then sent to a separate dissolver where it loses hydrogen. The Lummus-modified process eliminates the dissolver and uses only the preheater coil. The modified process liquefies over 90 percent of the coal, and uses only 0.8-1.6 percent hydrogen, rather than the 2.5 percent hydrogen required in the one-step process.

After the primary hydrogenation step, the product still contains sulfur, ash, and some unreacted coal. In the second, or deashing, stage, an antisolvent (a paraffin) is added to the liquid coal extract, causing solids to drop out. The extract is then hydrocracked in the Lummus LC Finer, producing a liquid fuel.

Approximately 536 kg (1,180 lb) of distillate in the C₅, 728 K (850 °F) boiling range is produced from every ton of dry ash-free coal that enters the process. Some of the heavier byproducts are returned to the first hydroliquefaction stage to provide reactor solvent. The remainder is cycled to a partial-oxidation unit for hydrogen generation.

The two-stage direct liquefaction process has several advantages over one-stage processes. The higher temperatures used to ensure direct liquefaction in a one-step process produce excessive amounts of hydrogen-consuming C₁-C₄ gases. These high temperatures also result in more coking, which decreases catalyst life. The two-step process, however, permits moderate reaction conditions, thus consuming less hydrogen, producing fewer C₁-C₄ gases, and causing fewer coking problems.

The primary disadvantages of the Lummus two-stage direct liquefaction process are that the reactor product is more difficult to deash than that from the one-step version, and that the extract is more difficult to hydrocrack than typical petroleum liquids.

Utah Oil Shale Commercial Feasibility Study Receives Industry Support—Ten industrial sponsors have joined the Paraho Development Corp. to study the feasibility of the commercial-scale Paraho oil shale module design and demonstration project in Vernal, UT. The companies are Chevron Research Co., Phillips Petroleum Co., Conoco, Inc., Davy McKee Corp., Mobil Research and Development Corp., Mono Power Co., Sohio Shale Oil Co., Sunoco Energy Development Co., Texas Eastern Synfuels, Inc., and Cleveland-Cliffs Iron Co.

The \$9 million, 18-month feasibility study was funded by DOE earlier this year. The proposed plant is expected to cost \$200 million, and could be operational by 1984.

Paraho and Superior Oil Company designed the project for DOE. The plans call for a single, aboveground oil shale retort, a mine, and support facilities. The design under study would process 189 kg/sec (1.8 × 10⁴ tons/d) of oil shale to produce over 0.018 m³/sec (1.0 × 10⁴ bbl/d) of crude shale oil and a product gas to be used to generate electricity.

Paraho Development Corp. has successfully produced over 17,480 m³ (4.6 × 10⁶ gal.) of crude oil from oil shale at its Anvil Points plant near Rifle, CO.

Riley Stoker Demonstrates Commercial-Scale Atmospheric Fixed-Bed Coal Gasifier—Using a full range of U.S. coals, Riley Stoker Corp. (Worcester, MA) has demonstrated that an atmospheric, fixed-bed, commercial-scale coal gasifier can produce low-Btu gas at cold gas efficiencies of 71 to 78 percent and hot gas efficiencies of 87 percent or more. In its commercial 3.15 m (10 ft 6 in.) I.D. unit and a smaller development unit, Riley Stoker studied fuels ranging from sized anthracites to sized and run-of-mine coals with swelling indices up to 8.5. Depending on the type of coal used, net heat output was in excess of 14.6 MJ/sec (5.0 × 10⁷ Btu/hr).

The Riley Stoker gasifier is designed for simple, on-site coal gasification, and features a thin-bed, variable-heat process in which the fuel bed slowly rotates. The bed, up to 1.40 m (55 in.) in height, permits variation in the particle heating rate, which is an essential element in managing swelling coals. The rotation of the bed ensures even fuel distribution, which allows different coal sizes to be used. The bed is agitated to prevent large particles and channels from forming inside.

In addition to the design features, the following factors were cited as important to the successful operation of a fixed-bed gasifier: (1) maintaining a smooth, vertical temperature transition between zones; (2) achieving a level fuel bed at startup; and (3) controlling temperature and particle heat rate to avoid caking.

HRI Refines Shale Oil for Use as Jet Fuel—Hydrocarbon Research, Inc. (HRI) has successfully refined shale oil into jet fuel. At its Research and Development Center in Trenton, NJ, HRI produced 42.9 m³ (11,300 gal.) of synthetic JP-4 aviation fuel which met or exceeded all JP-4 military specifications. The shale oil was refined as part of a U.S. Air Force Systems Command program.

Connecticut Plant Turns Garbage into Energy—Eco-fuel II, a low-sulfur, powdered, refuse-derived fuel, is produced at the Connecticut Resource Recovery Authority's Bridgeport recycling plant. The Authority claims that Eco-fuel II is the most highly processed garbage-derived fuel in the U.S. It also maintains that Eco-fuel II could replace up to 1.1×10^5 m³ (7.0×10^5 bbl) of imported oil per year at 70 percent of the cost of the oil. Use of garbage for fuel could also alleviate landfill and other disposal problems.

Connecticut's Department of Environmental Protection adopted a 120-day emergency regulation in May to allow Eco-fuel II to be burned. The garbage-based fuel currently contains more sulfur than the state usually allows. The plant operators, Combustion Equipment Associates of New York, maintain that the sulfur content will decrease when more garbage is processed. A conversion rate of 0.91 Gg (1,000 tons) of garbage per day was set for October 1980.

Various delays have put the project 2 years behind schedule. The Bridgeport plant is to eventually convert 1.6 Gg (1,800 tons) of garbage per day from nine nearby towns. Total cost of the plant was originally set at \$53 million; recent cost estimates exceeded \$100 million.

The Bridgeport plant is a larger version of a plant at East Bridgewater, MA, that has been converting 0.45 to 0.54 Gg (500 to 600 tons) of garbage per day for 2 years.

The Authority is also planning to construct a major plant at Hartford and one at New Haven, as well as two or three smaller plants at other locations, within the next 5 years. Eleven plants were originally planned.

The major plant at Hartford will generate steam for a utility company. It is modeled after a Saugus, MA, steam-generating plant operated by Refuse Energy Systems Co.

(RESCO), a Wheelabrator-Frye subsidiary. The Saugus plant has generated the steam equivalent of more than 2.0×10^5 m³ (1.3×10^6 bbl) of oil since 1975.

Three New Ethanol Plants Proposed—Plans have been announced for three ethanol plants using corn and other agricultural crops as feedstock. Texaco, Inc. and CPC International will convert CPC's corn wet-milling plant in Pekin, IL, to produce up to 0.0072 m³/sec (6.0×10^7 gal./yr) of ethanol from corn. Oregon plans a \$60 million agricultural/industrial energy complex at Boardman, OR. Sunrise Farms, Inc. is the developer of the Oregon energy complex, which centers around an ethanol plant capable of producing 0.0024 m³/sec (2.0×10^7 gal./yr) of ethanol from corn and other crops. A newly formed corporation in Delaware, the U.S. Ethanol Corp., will construct a \$150 million plant at a site on the Mississippi River to derive ethanol from corn. The product, 0.012 m³/sec (1.0×10^8 gal./yr) of ethanol, will be used in automotive fuels.

The Texaco-CPC and Boardman plants will supply their own power for producing ethanol. The Texaco-CPC plant already has a coal co-generation plant providing both electric power and steam; the Boardman, OR, complex will include a wood- or coal-fired power plant.

Engineering and design studies for the Texaco-CPC plant have been in progress for several months; construction is expected to be completed late in 1981. Construction of the Oregon complex, including an alcohol fuel plant, a power plant, and crop processing, storage, and shipping facilities, is scheduled to begin this fall, with completion expected in Summer 1982. The U.S. Ethanol project is planned to go onstream late in 1982.

MEETING CALENDAR

Science and Technology: Bridging the Frontiers, Jan. 3-8, 1981, Toronto, Canada. Contact: American Association for the Advancement of Science, Dept. R, 1515 Massachusetts Ave. NW, Washington, DC 20005.

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.

5th Annual Symposium on Energy from Biomass and Wastes, Jan. 26-30, 1981, Lake Buena Vista, FL. Contact: Kathy Fisher, IGT, 3424 S. State St., Chicago, IL 60616; telephone (312) 567-3650.

3rd International Conference on Future Energy Concepts, Jan. 27-29, 1981, London, England. Contact: Conference Dept., Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, England.

Workshop on Instrumentation and Control for Fossil Energy Processes, Feb. 2-3, 1981, Houston, TX. Contact: Diane Weitzel, Jet Propulsion Laboratory, MS 125-138, 4800 Oak Grove Drive, Pasadena, CA 91103; telephone (213) 354-3303, FTS 792-3303.

84th National Western Mining Conference and Exhibition, Feb. 4-6, 1981, Denver, CO. Contact: D. R. Cole, Colorado Mining Assoc., 330 Denver Hilton Office Building, 1515 Cleveland Place, Denver, CO 80202.

8th Energy Technology Conference and Exposition (ET8), Mar. 9-11, 1981, Washington, DC. Contact: Martin Heavner,

Gov. Inst., P. O. Box 5918, Washington, DC 20014; telephone (301) 656-1090.

6th International Technical Conference on Slurry Transportation, Mar. 23-26, 1981, Las Vegas, NV. Contact: Donald N. Beck, Slurry Transport Association, 490 L'Enfant Plaza East SW, Suite 3210, Washington, DC 20024; telephone (202) 554-4700.

18th ACS National Meeting, Mar. 29-Apr. 3, 1981, Atlanta, GA. Contact: ACS, 1155 16th Street NW, Washington, DC 20036; telephone (202) 872-4600.

3rd International Symposium on Coal-Oil Mixtures Combustion, Apr. 1-3, 1981, Orlando, FL. Contact: Daniel Bienstock, Science Applications, Inc., St. Clair Building, 1725 Washington Road, Pittsburgh, PA 15241; telephone (412) 831-3535.

Energy and the Third World, Apr. 6-8, 1981, Oslo, Norway. Contact: Charles F. O'Connor, Council for Energy Studies, P. O. Box 3122, Tulsa, OK 74101; telephone (918) 585-5152.

14th Annual Oil Shale Symposium, Apr. 22-24, 1981, Golden, CO. Contact: Dr. Harry W. Emrick, Colorado School of Mines, Golden, CO 80401; telephone (303) 279-0300.

3rd Annual Industrial Coal Utilization Symposium, May 14-15, 1981, Nashville, TN. Contact: Daniel Bienstock, Science Applications, Inc., St. Clair Building, 1725 Washington Road, Pittsburgh, PA 15241; telephone (412) 831-3535.

1981 Symposium on Instrumentation and Control for Fossil Energy Processes, Jun. 8-10, 1981, San Francisco, CA. Contact: M. L. Holden, ANL, Building 362-H309, 9700 S. Cass Avenue, Argonne, IL 60439; telephone (312) 972-5585, FTS 972-5585.

1981 Lignite Symposium, Jun. 14-17, 1981, San Antonio, Texas. Contact: Gordon H. Gronhøvd, GFETC, Box 8213, University Station, Grand Forks, ND 58202; telephone (701) 795-8131.

2nd International Energy Symposium—World Fair Energy Expo 81, Jun. 16-19, 1981, Knoxville, TN. Contact: Sheila McCullough, Energy Opportunities Consortium, P. O. Box 2229, Knoxville, TN 37901; telephone (615) 637-4554.

Coal Conference and Expo IV: Dollar-Saving Strategies for the Coal Industry, Oct. 27-29, 1981, Louisville, KY. Contact: McGraw-Hill Conference and Exposition Center, 1221 Avenue of the Americas, Suite 3677, New York, NY 10020; telephone (212) 997-3610.

RECENT MAJOR MEETINGS

Second Chemical Congress of the North American Continent

The Congress was held on August 24-29, 1980, in Las Vegas, NV. Its sponsors were the American Chemical Society (ACS), Asociación Farmaceutica Mexicana, the Chemical Institute of Canada, Instituto Mexicano de Ingenieros Químicos, and Sociedad Química de Mexico. More than 4000 papers were presented in about 550 technical sessions. Environmental issues were included in several symposia. Presentation topics included organic pollutants in wastewaters, residual fuels characterization, oil shale, tar sands, and performance and modeling of fluidized-bed reactors.

Three divisions of the ACS and the American Institute of Chemical Engineers (AIChE) sponsored symposia on synthetic fuels sources. In the Fuels-from-Biomass sessions, papers were presented on chemical processes for production of fuel, alcohol production, organisms for biomass conversion, and environmental effects of biomass-to-energy conversion. A four-session symposium was held on refining, stability, pyrolysis, and retorting of oil shale and upgrading of tar sands.

The symposium on alternative feedstocks for petrochemicals focused on the uses of synthesis gas from coal and catalytic hydroprocessing of syncrudes. The emphasis in several sessions was on distillates and feedstocks obtained from biomass, oil shale, and tar sands. The role of the federal government—including academic research funding, production of transport fuels from coal, and future funding of coal research—was also included in this symposium.

Coal gasification and liquefaction research was emphasized in a symposium on the thermodynamics of coal conversion processes, sponsored by the ACS Division of Industrial and Engineering Chemistry and the Division of Petroleum Chemistry. The thermodynamic aspects discussed in presentations included vapor pressure estimations for high-boiling components in liquid fossil fuels, vapor/liquid equilibria of light oil, and properties of materials from coal liquefaction and gasification. The performance and modeling of fluidized bed reactors were subjects of several presentations in another symposium jointly sponsored by the ACS Division of Industrial and Engineering Chemistry and the AIChE.

The ACS Division of Environmental Chemistry sponsored symposia on energy and environmental chemistry, specifically dealing with oil shale, tar sands, coal gasification, and the identification of organic pollutants in water. Chromatographic techniques and extraction of pollutants for analysis were described in several presentations. One group

of papers dealt with analyses of organic pollutants by gas chromatography/mass spectroscopy (GC/MS). The energy and environmental chemistry symposium, jointly sponsored with the ACS Committee on Environmental Improvement, reported on the impacts of oil shale and tar sands development on the environment. The factors potentially affecting the environment were polynuclear aromatic hydrocarbons, alkylpyridines, and trace elements in oil shale. Air emissions from coal gasification plants, such as the Kosovo, Yugoslavia, Lurgi gasification complex, were discussed. Two presentations were concerned with the impact of tar sands development on the aquatic environment and on archaeological resources.

Methods and techniques used in environmental sampling were subjects of papers in other symposia. The ACS Division of Analytical Chemistry held a symposium on gas chromatography in which a quantitative study of coal tar compounds was presented. In other general analytical chemistry symposia, the effect of organic ligands on trace element mobility in oil shale wastes and the loss of components during evaporation/reconstitution of organic environmental samples were examined. The use of synthetic adsorbents in air and water sampling was also described in two papers.

The Analytical Chemistry Division also sponsored a symposium on techniques for characterization of residual fuels. The aspects of the techniques presented in papers were comparison of porphyrins, separation and characterization of alkylphenols, and characterization of acids in shale oil residues and distillates.

More information on the Congress can be obtained by contacting: A. T. Winstead, American Chemical Society, 1155 16th Street NW, Washington, DC 20036; telephone (202) 872-4600.

Symposium on Environmental Aspects of Fuel Conversion Technology V

The Environmental Protection Agency's Industrial Environmental Research Laboratory at Research Triangle Park, NC (IERL-RTP), sponsored the Fifth Symposium on Environmental Aspects of Fuel Conversion Technology. The meeting was held in St. Louis, MO, September 16-19, 1980. The General Chairman was William J. Rhodes, IERL-RTP Synthetic Fuels Technical Coordinator, Gasification and Indirect Liquefaction Branch. The Technical Chairman was N. Dean Smith, also of IERL-RTP, Gasification and Indirect Liquefaction Branch.

Stated objectives of the symposium were: (1) to provide a colloquium for discussion of environmentally related information on coal gasification and liquefaction; (2) to discuss the development and status of EPA's Pollution Control Guidance Documents (PCGD's) for coal indirect liquefaction, for direct liquefaction, and for low-Btu gasification; and (3) to present results from environmental assessment source tests, laboratory and pilot-scale studies on pollutant formation and control, and fuel conversion projects sponsored by other agencies and organizations.

Speakers reported on the IERL-RTP research programs in gasification, direct and indirect liquefaction, synfuel product use, and EPA's environmental assessment methodology. Permitting, control options, and the status of the TVA and Great Plains projects were discussed. A session on environmental assessment of direct liquefaction included reports on Ft. Lewis SRC-II test results, chemical and biological characterization of SRC-II products and byproducts, and combustion techniques for controlling environmental impacts of synfuels.

Several papers reported results from environmental assessment studies of commercial gasification plants in Yugoslavia and South Africa, and laboratory- and pilot-scale gasifiers in America. Sulfur-containing chemical species in fluidized bed gasification and COS/H₂S relationships in low-to-medium Btu gas from coal were discussed. Two other presentations focused on characterization and comparison of coal conversion wastewaters and coal gasification ash leachates.

Environmental control was the theme of the final group of presentations. Reports on the development of PCGD's for low-Btu coal gasification and direct and indirect coal liquefaction were presented. Pollutants from gasification were ranked, the treatability of coal conversion wastewaters was discussed, and methods for sulfur removal from gaseous emissions were described in other papers in this session.

Synthetic Fuels: Status and Directions

The Electric Power Research Institute (EPRI) and the Federal Republic of Germany's Ministry of Energy (KFA) jointly sponsored the conference, "Synthetic Fuels: Status and Directions," held October 13-16, 1980, in San Francisco,

CA. The conference was attended by representatives of the electric power industry, developers of synthetic fuels technologies, and administrators of energy policy.

The introductory session of the conference included presentations on the role of synthetic fuels in the Federal Republic of Germany's and DOE's energy programs, the effect of synthetic fuels on Middle East oil supplies and price dynamics, and the use of alternative fuels by oil-burning utilities. Other speakers emphasized clean liquid and solid fuels, clean gaseous fuels, and power generation.

Status reports and updates on various conversion processes were presented in three sessions on clean liquid and solid fuels. Papers described the status of several coal conversion processes: the Exxon Donor Solvent Coal Liquefaction process, the H-Coal process, the two Solvent Refined Coal (SRC-I and SRC-II) processes, the Mobil Methanol-to-Gasoline process, and the Dow coal liquefaction process. Representatives of Union Oil Corp. and Occidental Petroleum Corp. reported on shale oil demonstration plants and the commercialization of modified *in-situ* shale oil recovery processes. A Chevron Research Co. paper presented results of studies on the upgrading of synthetic crude oils to distillate fuels. Speakers from Germany reported on the coal hydrogenation plant in Bottrop, coal liquefaction in Saarburg, and the liquefaction of brown coal in Rheinbraun.

In the session dealing with power generation, speakers discussed gas turbines for future coal-based power generation systems, coal gasification-combined cycle power generation, and the VEW coal conversion plant in the Federal Republic of Germany.

Coal gasification was the main topic in the three sessions on the production of clean gaseous fuels. German gasification was the topic of several papers on Lurgi coal gasification, the Rheinbraun High-Temperature Winkler process, the Saarburg/Otto gasifier, and the use of the Shell-Koppers process in power generation. Papers were presented on coal gasification programs coordinated by Texaco, Southern California Edison, Westinghouse, and the British Gas Corp. Other papers described commercial applications of the KILNGAS process and the Combustion Engineering coal gasification process.

More information on the conference can be obtained by contacting: S. B. Alpert, Advanced Power Systems Division, Electric Power Research Institute, 3412 Hillview Avenue, P. O. Box 10412, Palo Alto, CA 94303, (415) 855-2000.

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