PA

Decision Series

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Office of
Research and
Development

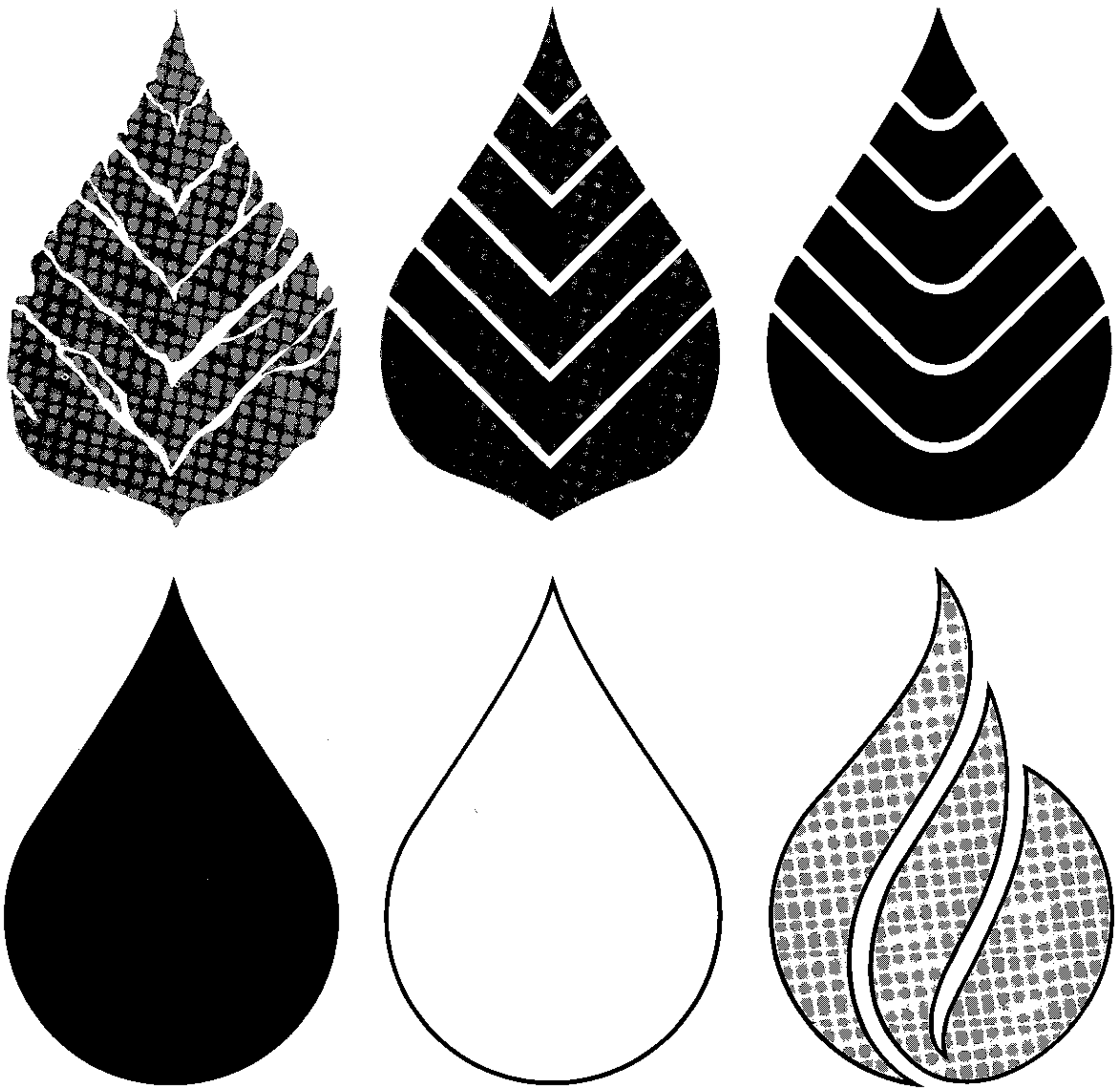
Energy,
Minerals and
Industry

EPA-600/9-77-013

June 1977

Advanced Fossil Fuels and the Environment

ADVANCED FOSSIL FUEL AND THE ENVIRONMENT: An Executive Report



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which $26 million was passed on by EPA to other federal agencies. This funding supports a number of ongoing, energy-related programs. These include characterization

With the concurrent development of the processes and the environmental control technologies, a balance is

CHEMICAL COAL CLEANING

Process

Chemical coal cleaning is used to remove sulfur and other pollutants from coal before it is burned. Sulfur is found in coal in two general forms: organic and pyritic. Organic sulfur is part of the molecular structure of coal, while pyritic sulfur, or iron sulfide, is part of the mineral portion of coal. The sulfur content of coal, both organic and pyritic, ranges from less than 1% to over 8%, depending on the coal type. Pyritic sulfur accounts for about half of the total sulfur in a given type of coal. When coal is burned, the pyritic sulfur, along with some of the organic sulfur, is transformed to sulfur dioxide and becomes a major source of air pollution. Chemical cleaning, which involves leaching to wash out pyritic sulfur and heating to break the bonds that bind the organic sulfur to coal, is potentially more effective in ridding coal of its pollutants than conventional physical cleaning methods.

Four chemical coal cleaning methods are currently being evaluated by EPA. These are:

- Meyers process
- Hydrothermal process
- Flash desulfurization process
- Microwave process.

Meyers Process — In the Meyers process, a heated liquid iron sulfate leaching solution is reacted with ground coal. This leaching action releases pyritic sulfur as well as iron, alkaline ash, and other impurities. Following the leaching, the coal is washed to remove these contaminants and the leaching solution is then processed for reuse. No organically bound sulfur is removed because the leaching solution does not penetrate the carbon-coal matrix. The Meyers process is 95% effective in removing pyritic sulfur in pilot plant tests (7 metric tons per day).

Hydrothermal Process — The hydrothermal process adds a leaching solution of sodium hydroxide, calcium hydroxide, or their combination, to a mixture of crushed coal and water at moderate temperatures. This heating/leaching transforms the solid sulfur compounds and ash to a solution, which can then be separated from the coal. This process removes up to 95% of the pyritic sulfur and 40% of the organic sulfur in pilot plant tests (¼ ton per day).

Flash Desulfurization Process — This process exposes coal to hydrogen at low pressure and high temperature. In this reaction, the sulfur in the coal is released into the gas stream where it is purified. Flash desulfurization removes over 90% of the total sulfur content of coal in laboratory tests.

Microwave Process — The microwave process heats coal to high temperatures so that the volatile parts of the pyritic sulfur are vaporized for separate recovery. This process is being evaluated to determine how much of the sulfur can be removed.

Rationale

The successful development of chemical coal cleaning and its adoption by the public and private sectors could potentially:

Assure removal of pyritic and organic sulfur from coal, while at the same time maintain a high level of energy content in the cleaned coal.
Physical coal cleaning methods in industrial use today remove some of the pyritic sulfur but do not remove organic sulfur. The amount of pyritic sulfur removed by physical methods ranges from 50% to 70%. In removing this pyritic sulfur, however, physical cleaning methods also significantly reduce the energy content of coal.

Offer a viable alternative to smaller users of coal for control of air pollution from combustion.
Some industrial users of coal may not be able to use flue gas desulfurization equipment because its size may be incompatible with installed combustion equipment, or the cost of adding stack gas scrubbers may preclude economical operation of the industrial plant.

Provide an economic advantage to coal users.
Initial cost/benefit analyses of cleaning coal using both chemical and physical methods plus flue gas desulfurization indicate a net cost saving to coal users compared with the use of flue gas scrubbers alone. Although some of the coal is inevitably lost in the cleaning process, thereby reducing the total

coal cleaned and its pyritic sulfur content. If the Meyers process proves to be efficient and economical, this could be an advantage to small industrial users of coal who may not be able to afford stack-gas contaminant removal technologies.

Program

The four chemical cleaning methods being sponsored by the EPA Interagency Program are currently undergoing careful evaluation:

Meyers Process — Development is at the pilot-plant stage and is receiving the major portion of current Interagency Program funds allocated to chemical coal cleaning because it appears to be the most promising of the four technologies under study. EPA is funding $4 million for a one-year demonstration of the process, scheduled to begin in the spring of 1977. The reactor test unit was designed by Procon, Inc., Los Angeles. Construction of the unit began in November 1976, at a site near Capistrano, California. TRW, Inc., Redondo Beach, California, will operate the pilot plant. The unit, which will treat about 7 metric tons of coal per day, performs only leaching and regeneration operations. Dewatering, drying, and sulfur removal will be done in the laboratory using coal samples from the test unit. Bench-scale support and applicability studies will be carried out concurrent with the test of the pilot plant.

The actual operation of this pilot plant is expected to demonstrate more effective coal cleaning processing and lower costs than previously indicated in laboratory and bench-scale tests. If these expectations are realized, EPA may recommend completion of the pilot plant to add dewatering, drying, and sulfur removal equipment. Further testing will then define process applicability, design, and cost data. Industrial and utility support will be sought during the test to help identify practical operating problems.

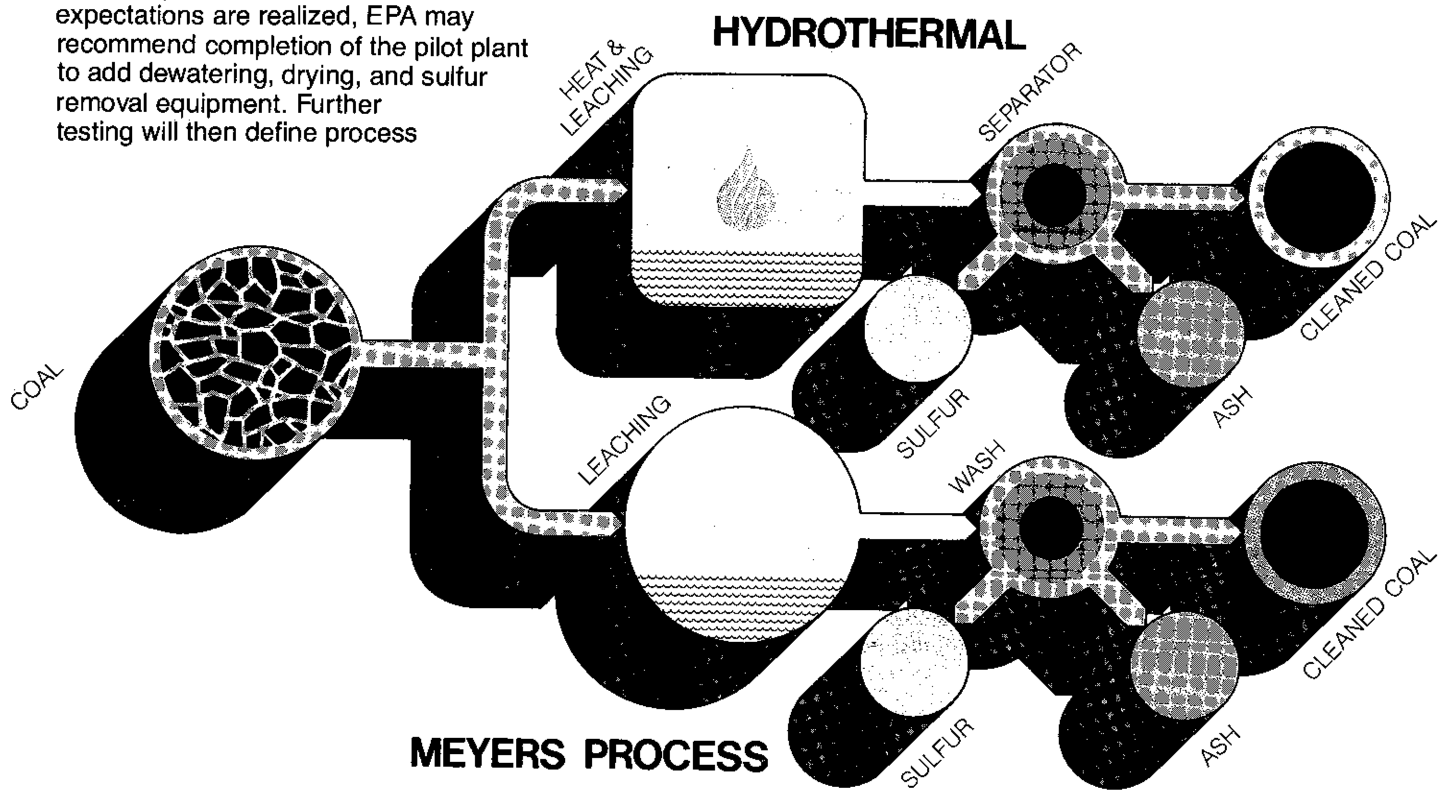
Flash desulfurization — Experiments are under way at the Institute of Gas Technology (IGT) in Chicago to establish the potential of this process. EPA is funding $370,000 for this 20-month project. Chemical reactions to remove nitrogen as well as sulfur are being evaluated as a part of this EPA-sponsored program.

Hydrothermal coal cleaning — This process was investigated by Battelle Laboratories in Columbus, Ohio. Although the process is technologically feasible, it does not appear to be cost competitive with other chemical coal cleaning methods.

Microwave treatment — Research performed at General Electric Company, Valley Forge, Pennsylvania, is currently being reviewed by EPA to determine the potential of microwave treatment to release both the pyritic and the organic sulfur in coal.

EPA also has a large ongoing program of environmental assessment of chemical coal cleaning processes. Process streams, compounds, and discharges that have adverse health and ecological effects are being analyzed. Results are used to establish permissible concentrations of potentially hazardous substances. Environmental guidelines for developers of coal cleaning processes will be based on the permissible concentrations determined in these studies.

As an adjunct to this chemical cleaning research, EPA and the U.S. Bureau of Mines plan to use computer modeling



SYNTHETIC FUELS

Process

The federal government is giving priority to the development of coal gasification and liquefaction processes. Such processes, it is hoped, will produce an adequate supply of synthetic gaseous and liquid fuels as sources of domestic petroleum are exhausted and petroleum imports become more expensive. The prime responsibility for the actual development of these coal conversion processes belongs to ERDA. The EPA responsibility is to ensure that these processes do not create adverse health and ecological effects. Major EPA concerns are the nature of pollutant by-products, the locations in the process stream where environmental control technologies should be integrated, and the development of effective environmental control techniques.

Synthetic fuel development research is concentrated on producing substitute natural gas (SNG) and liquid fuels, primarily for use as refinery feedstock and in electric power generation. However, gasification units are already being used by industry and more are scheduled to be installed. Thus, it is logical to assume that industry, rather than the electric utilities, will be the first to adopt advanced gasification techniques as they become ready for commercial use.

Coal gasification can produce low-, medium-, and high-Btu gas. The low-Btu gas has a heating value of 100 to 200 Btu per cubic foot and is used as a fuel feedstock or to generate power in combined gas-steam turbine power cycles. The medium-Btu gas has a heating value of 300 to 650 Btu per cubic foot and is usually used as a feedstock in the production of high-Btu gas. This high-Btu gas, with a heating value of 950 to 1,000 Btu per cubic foot, can be substituted for natural gas in industrial and residential consumption.

Coal liquefaction is used to produce an entire range of liquid products from coal. These products include fuel oil, gasoline, jet fuel, and diesel oil. Processes are being developed and improved to increase the supply of nonpolluting liquid fuels as well as to facilitate their transport and use. Current emphasis is being placed on the development of lower grade synthetic fuels suitable for firing industrial and electric utility boilers and gas turbines.

Coal Gasification Process

Coal is gasified by applying heat and pressure or a catalyst to break down the components of coal to form a synthesis gas containing mainly carbon monoxide, hydrogen, and some methane. The gas formed in this way may also contain carbon dioxide, nitrogen, water vapor, and contaminants such as hydrogen sulfide and ash.

In simple gasification, a synthetic gas is produced by reacting coal with steam or hydrogen and air or oxygen. If air is used, a low-Btu, nitrogen-rich gas is produced. The nitrogen limits the heating value of the synthesis gas and could cause release of environmentally hazardous nitrogen oxides (NO_x) if the gas were burned as fuel. The gas also will contain sulfur oxides and other pollutants that have to be removed.

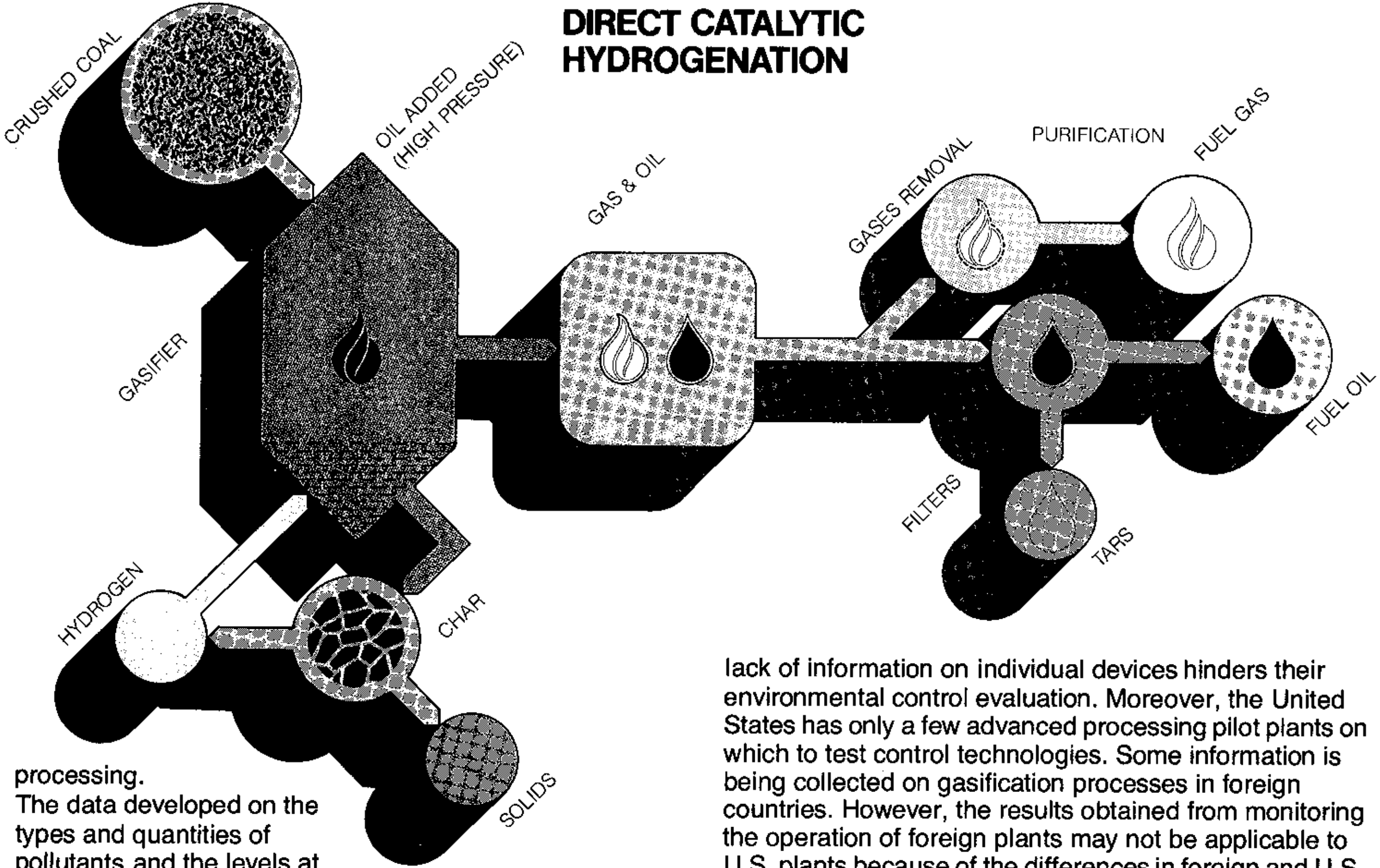
Alternatively, if oxygen is used, medium-Btu gas is produced. This product gas contains some sulfur oxides but no nitrogen. It is usually intermediate to the production of high-Btu gas.

Other gasification reactions use hydrogen instead of steam. This produces more methane directly in the synthesis gas than is produced in simple gasification. Consequently, the medium-Btu gas produced by hydrogasification requires less additional processing to be transformed to a high-Btu gas. Moreover, higher overall conversion efficiencies can be realized with hydrogasification than with simple gasification.

High-Btu gas is made from low- and medium-Btu gases by adjusting the ratio of hydrogen to carbon monoxide in these gases. This ratio adjustment is called the water-gas shift reaction. The gas is also purified by removing the acid gases produced in the reaction, chiefly hydrogen sulfide and carbon dioxide. The remaining hydrogen and carbon monoxide are then combined to form methane and water — a methanation reaction. The water is then removed leaving a methane-rich product with the essential characteristics of natural high-Btu gas.

Gasification is carried out in either a fixed bed reactor, fluidized bed reactor, or entrained bed reactor.

In the *fixed bed reactor* crushed coal is fed to the reactor to form a bed. Air or oxygen and steam are blown upward through the bed at a relatively low velocity to gasify the coal. The raw synthetic gas exits from the top of the reactor and is quenched to remove tars, oils, and particulates. The gas is then cooled for further processing.



DIRECT CATALYTIC HYDROGENATION

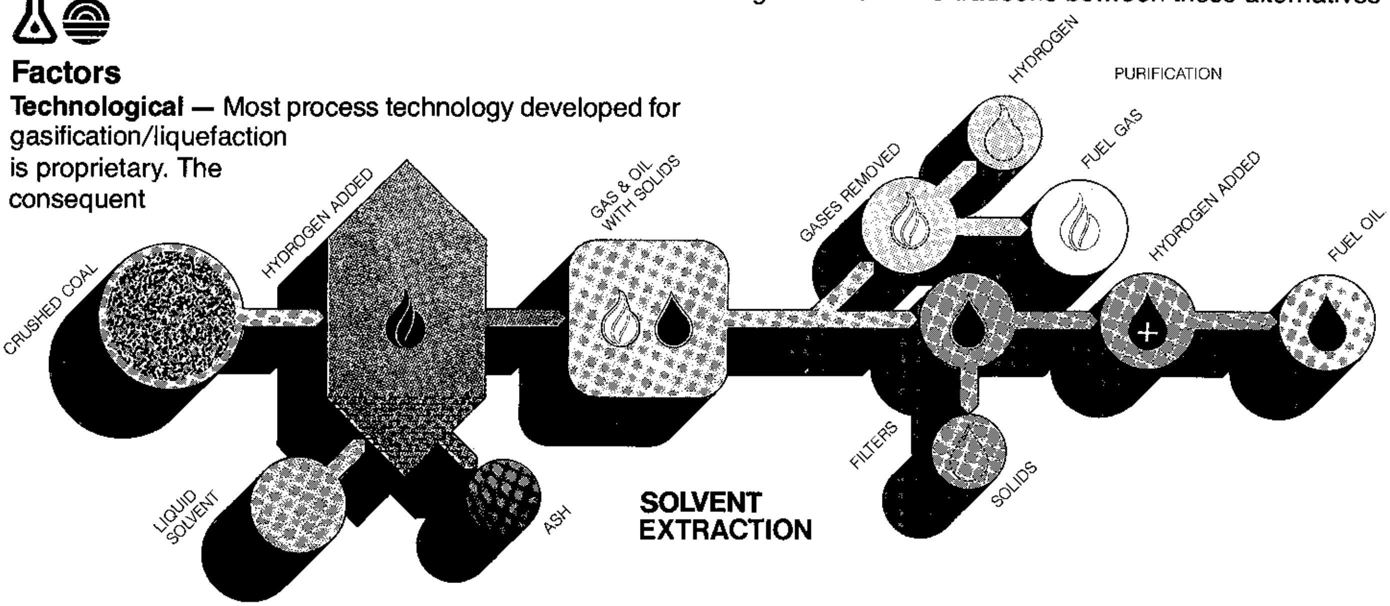
processing.
The data developed on the types and quantities of pollutants and the levels at which they become toxic are used to develop criteria for controlling such pollution.

A synthetic fuel industry will grow rapidly when production processes are proven technically and economically viable. Environmental control technologies developed concurrent with the processes themselves will avoid costly delays which would be necessitated by attempts to add environmental controls after processes are perfected. Environmental controls integrated into processing systems are also likely to be more efficient than add-on methods.

Factors

Technological — Most process technology developed for gasification/liquefaction is proprietary. The consequent lack of information on individual devices hinders their environmental control evaluation. Moreover, the United States has only a few advanced processing pilot plants on which to test control technologies. Some information is being collected on gasification processes in foreign countries. However, the results obtained from monitoring the operation of foreign plants may not be applicable to U.S. plants because of the differences in foreign and U.S. coal and the consequent variations in effluents.

Other technical problems involve the removal of individual pollutants, such as solid waste in the form of particulates, at the high temperatures and high pressures in some of the gasification processes. Large particulates, over a few microns in size, can cause erosion of power plant turbine blades, while the smaller particulates are environmentally undesirable. It is not clear at what stage in the fuel conversion stream these particulates can be most effectively and economically removed. Their effective removal, in any event, will be a benefit both to process technology and to environmental control technology. The current alternatives for removal are during or after gasification. The tradeoffs between these alternatives



SOLVENT EXTRACTION

will produce 90,000 cubic meters per hour (cu M/H) of raw generated gas and 60,000 cu M/H of clean gas. It also produces appreciable amounts of tar; heavy, medium-heavy, and light oil; raw phenol; and ammonia water. The Kosovo plant is equipped with only minimal environmental controls. It does not have a sulfur recovery unit or an operational waste water treatment facility.

The Lurgi process is to be used in three industry-sponsored commercial U.S. coal gasification plants. The three are sponsored by the Western Gasification Company (WESCO), the El Paso Natural Gas Company, and the Michigan-Wisconsin Pipeline Company. The results of research at the Kosovo plant will provide a basis for establishing environmental control technologies to be incorporated into the design of U.S. plants, an economically and operationally superior alternative to retrofit controls. Recommendations for municipal regulations on disposal of solid waste from coal gasification plants also will be made on the basis of the study.

The Kosovo project was approved by the U.S. and Yugoslavian governments in June 1976. EPA has allocated $290,000 for the three-year program. Yugoslavia is providing matching funding.

Gas and water treatment — A gas treatment test facility is being constructed at North Carolina State University to treat raw gas that contains large amounts of acids. The facility is being designed and installed by the Aerotherm Division of Acurex Corporation, Mountain View, California. Research on treating waste water is being performed by the University of North Carolina under a grant from EPA.

High temperature/high pressure particulate removal — To develop the technology necessary to remove solid waste particles from fluidized bed reactors used in gasification, HTP particulate removal programs, mainly at the bench-scale level, have been funded. Additionally, some demonstration tests of electrostatic precipitators have also received agency support. An HTP electrostatic precipitator (1700°F) is being developed by Research-Cottrell, Inc., Bound Brook, New Jersey, under a $130,000 contract from EPA. Standard electrostatic precipitators operate at 600° to 800°F.

Filter concepts for HTP control are under study by several contractors. A contract for assessment of granular bed filtering is currently being negotiated. Westinghouse is evaluating the use of ceramics and other materials as filters. Aerotherm is comparing the collection performance of metallic, ceramic, and fabric filters against the performance of electrostatic precipitators.

Air Pollution Technology Corporation, San Diego, has a contract to develop a bench-scale dry scrubber for HTP particulate removal.

Economically viable techniques to remove large and small particulate matter at gasifier exit temperatures are being sought. The cost tradeoffs between high-temperature and low-temperature particulate removal are also being studied.

Pollutant sampling and emission standards — Additional research on identifying pollutants from synthetic fuels processing is expected to begin by early 1977.

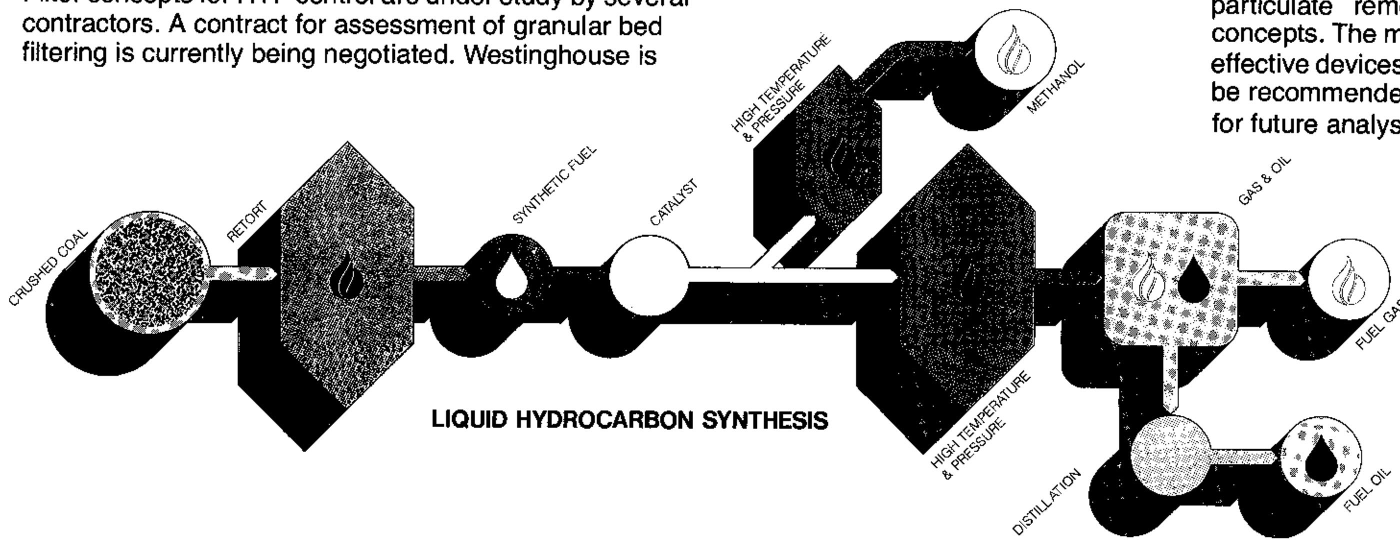
EPA is reviewing preliminary new source performance standards for atmospheric emission of sulfur and hydrocarbons from coal gasification plants. These standards will be published in 1977. But no new standards on water pollution are planned because the demands of environmental control technologies on plant water use are not yet known.

Agency Interaction

EPA, under the auspices of the Interagency Program, is working closely with ERDA to collect data on environmental effects of coal gasification/liquefaction in a number of projects.

EPA is evaluating data on process effluents from ERDA gasification and liquefaction pilot plants — HYGAS in Chicago, Solvent Refined Coal (SRC) in Tacoma, Washington. Joint agency environmental testing is planned. SRC is the liquefaction process that is closest to commercialization. In addition, EPA has entered into an agreement with ERDA to characterize effluents and to provide guidance for ERDA's comprehensive industrial gasification program including the startup and operation of pilot plant gasifiers at Morgantown, West Virginia, and Grand Forks, North Dakota.

EPA and ERDA are coordinating work on particulate removal concepts. The most effective devices will be recommended for future analysis.



LIQUID HYDROCARBON SYNTHESIS

CHEMICALLY ACTIVE FLUID BED

Process

The chemically active fluid bed (CAFB) process is designed to convert heavy, high-sulfur residual oil to clean, low-sulfur gas. The process also may be applicable to making clean gas from high-sulfur coal.

In applying the process to residual oil, the oil is first heated and then fed to a reactor that contains a fluidized bed of fine particles of limestone. The oil is vaporized in the reactor through a series of catalytic cracking and oxidation reactions. Hydrogen sulfide and some organic sulfur are released from the vaporized oil to be absorbed by the lime in the "boiling" limestone. The remaining hot, low-sulfur fuel gas produced in the process can be piped directly to steam boilers or gas turbines for combustion.

The CAFB reactor contains two sections, one for gasification of the oil and one for regeneration of the sulfur-absorbing lime. In the regeneration step, air reacts with the limestone, freeing it from the sulfur, which is released into the air stream as sulfur dioxide. The sulfur dioxide is removed from the regeneration gas and may be converted to a nonpolluting solid. The cleansed limestone is then recycled through the reactor continuously until it loses its efficiency as an absorbent.

Rationale

Many utilities are required to burn only low-sulfur fuel in order to meet federal and state emissions regulations. This means that large supplies of heavy residual oils remain untapped as sources of fuel for power plants. In the face of the growing shortage of domestic oil supplies, it is important that maximum use be made of all grades of petroleum. By efficiently converting high-sulfur residual oil to clean gaseous fuel, the CAFB process offers an environmentally sound means of freeing this resource for the production of energy.

The process has particular importance as a retrofit mechanism for the numerous gas-fired power plant boilers in the southwest. These boilers cannot be readily converted to the use of high-sulfur heavy oil or coal. Most of the existing gas-fired boilers in Texas, for instance, have a remaining life of 20 to 30 years, but the sources of natural gas to fuel them are expected to be unavailable in just a few years. These boilers are in power plants that currently produce approximately 120,000 megawatts of power. Use of the CAFB process could permit this level of energy production to be maintained throughout the useful life of these boilers.

In addition, the CAFB process offers a technological advantage over other methods of contaminant removal by avoiding the necessity of cooling and scrubbing the gas. These methods lower the heating value of the product gas and the efficiency of the gasification process.

Factors

Technological — Individual power plants may present engineering problems in retrofitting the CAFB process. The age and condition of boilers and the size of burners will have to be considered in designing retrofit equipment. The adequacy of existing pipelines to handle liquid fuels will be another design consideration. But these problems are expected to be readily solved on a case-by-case basis using good engineering practice.

Environmental — The release of large amounts of sulfur in the gasification step of the CAFB process is a basic environmental concern. The efficiency of the fluidized bed of limestone will determine how much of this sulfur, in the form of highly toxic hydrogen sulfide gas, reaches the atmosphere. Efficient removal of the sulfur dioxide gas released from the limestone in the regeneration step is also necessary to maintain air quality.

Another environmental concern is the release of contaminant metals such as vanadium, nickel, sodium, and some alkali metals during gasification. These metals pose a health hazard because of their high toxicity. There is concern that these toxic metallic substances, which may have been present only in trace amounts in the original fuel, will be concentrated as a result of the fuel conversion process in amounts that intensify their pollution potential.

Approximately $1.3 million is allocated for studies of the process in FY77.

Outlook

Preliminary calculations indicate that the CAFB process can be as much as three times more efficient in pollutant removal than initial estimates suggested. However, demonstration tests under a range of operating conditions and grades of fuel are necessary to confirm these indications. The full capability of the process also has yet to be determined. To confidently predict the efficiency of the process over years of operation, it will be important to determine early in the demonstration tests how effectively contaminants are removed.

With the capabilities of the process determined, standards of practice and recommendations for control technologies can be formulated to meet environmental requirements. For these purposes, long-term monitoring of emissions and waste streams will be necessary.

The economics of the process in terms of retrofit, operation, maintenance, and costs added to the fuel product will have to be determined. How well the process competes with the cost of alternative technologies such as flue gas desulfurization also will require analysis.

Work on the CAFB concept to date suggests that it has significant potential as a means of producing clean fuel. The next step in the development of the process is the demonstration at La Palma Station to determine the technical, environmental, and economic realities of plant operation.

Chemically Active Fluid Bed Facts

Process: Heating high-sulfur coal or residual oil in the presence of a fluidized bed of limestone to convert the coal or oil to gas and transfer sulfur and other contaminants to the limestone.

Purpose: Make high-sulfur oil and coal available as a boiler fuel.

Problems: Retrofit of boilers to use the CAFB process. Transport of liquid fuels to the boilers. Hydrogen sulfide and sulfur dioxide emissions. Heavy metals release from spent limestone. Inadequate information on installation and operating costs.

Potential: CAFB may be more efficient than expected. Fuels produced by CAFB will be clean and air pollution will be reduced. Techniques to handle CAFB solid wastes already exist.

yet on the feasibility of the concept.

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