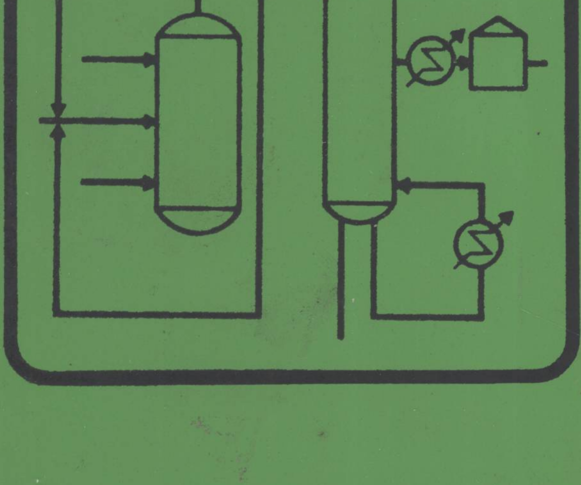
PROCESS TECHNOLOGY AND FLOWSHEETS: Volume II



CHEMICAL ENGINEERING Magazine

PROCESS TECHNOLOGY AND FLOWSHEETS VOLUME II

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and

the Staff of Chemical Engineering

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PROCESS TECHNOLOGY AND FLOWSHEETS
VOLUME II

CHEMICAL ENGINEERING BOOKS

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Calculator Programs for Chemical Engineers
Calculator Programs for Multicomponent Distillation
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Skills Vital to Successful Managers
Solids Handling
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BOOKS PUBLISHED BY CHEMICAL ENGINEERING

Fluid Mixing Technology: James Y. Oldshue
Industrial Heat Exchangers: G. Walker
Physical Properties: Carl L. Yaws
Pneumatic Conveying of Bulk Materials: Milton N. Kraus

Introduction

This book contains information on significant processes that have appeared in the pages of CHEMICAL ENGINEERING over the last four years. It is a continuation of *Process Technology and Flowsheets,* which was published in 1979. Volume II contains all new material. Together, these two books present the results of nine years of new techniques that have been developed to serve the chemical process industries.

We have attemped to follow the same format in dividing subjects into sections as was done in Volume I. As before, a section is devoted to winners of CHEMICAL ENGINEERING's biennial Kirkpatrick Chemical Engineering Award. This award is given to developers of those processes judged by a panel of prominent engineering educators to be the most significant additions to the body of chemical engineering technology.

Along with the first volume, this book details the search chemical engineers have been pursuing to meet environmental regulations, reduce energy costs, and cope with changing feedstock and product requirements. This is information that is at once both interesting and useful. *Process Technology and Flowsheets: Volume II* should help you in doing business today, and provide guidance for the future.

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Section I
Coal Processing and Conversion

Coal technology reigns at AIChE gathering

Two processes for solvent de-ashing of liquefied coal highlighted a continuing symposium on coal conversion, which attracted the biggest audience at the meeting. Other highly-rated sessions dwelt on automotive plastics, career planning, and feedstocks.

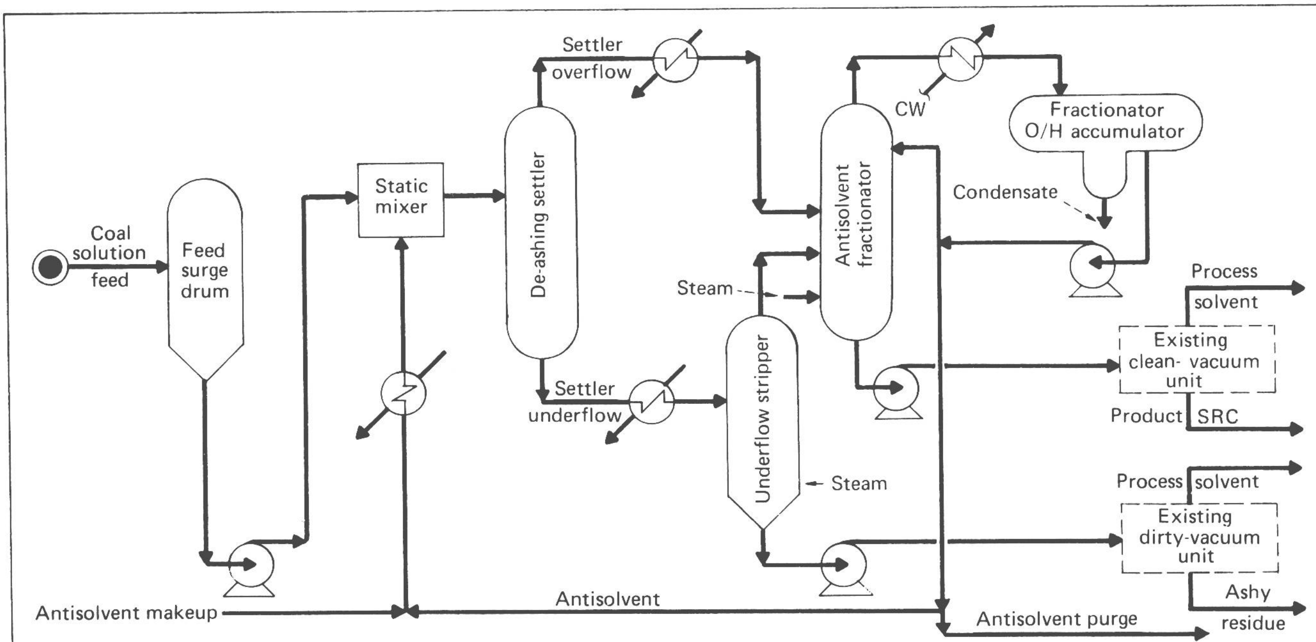
☐ Under sunny Miami Beach skies, chemical engineers attending AIChE's 71st annual meeting (Nov. 12-16) had their pick of interesting topics to choose from. Sessions on metrication (see previous article), automotive plastics, feedstocks outlook, career planning and education, and regulatory matters drew solid audiences. But a four-day session on the conversion of coal to synthetic fuel or feedstock was by far the most popular event.

DE-ASHING LURES VISITORS—Back-to-back papers dealing with competing concepts for solvent de-ashing of liquefied coal were presented. C-E Lummus (Bloomfield, N.J.) discussed its findings on "antisolvent" de-ashing. The company described a test unit installed last fall at the Ft. Lewis, Wash., pilot plant designed around the solvent-refined coal (SRC) process and operated by Pittsburg and Midway Coal Mining Co. under a U.S. Dept. of Energy (DOE) grant. Startup of Lummus' unit was to have begun in November, the same time as the paper was delivered. (A much larger Lummus unit is currently under construction at the 600-ton/d H-Coal pilot plant being built at Catlettsburg, Ky., scheduled to start up in 1980.)

The Lummus process employs an "antisolvent" that causes micron-sized ash particles to agglomerate, leaving behind a product containing less than 0.1% (by weight) ash (Fig. 1). (Such separation of solids from liquids is a major problem in the development of coal liquefaction routes.) Antisolvent is recycled, except for a small portion of purge material. The exact nature of this material is proprietary, as is the design of the de-ashing settler.

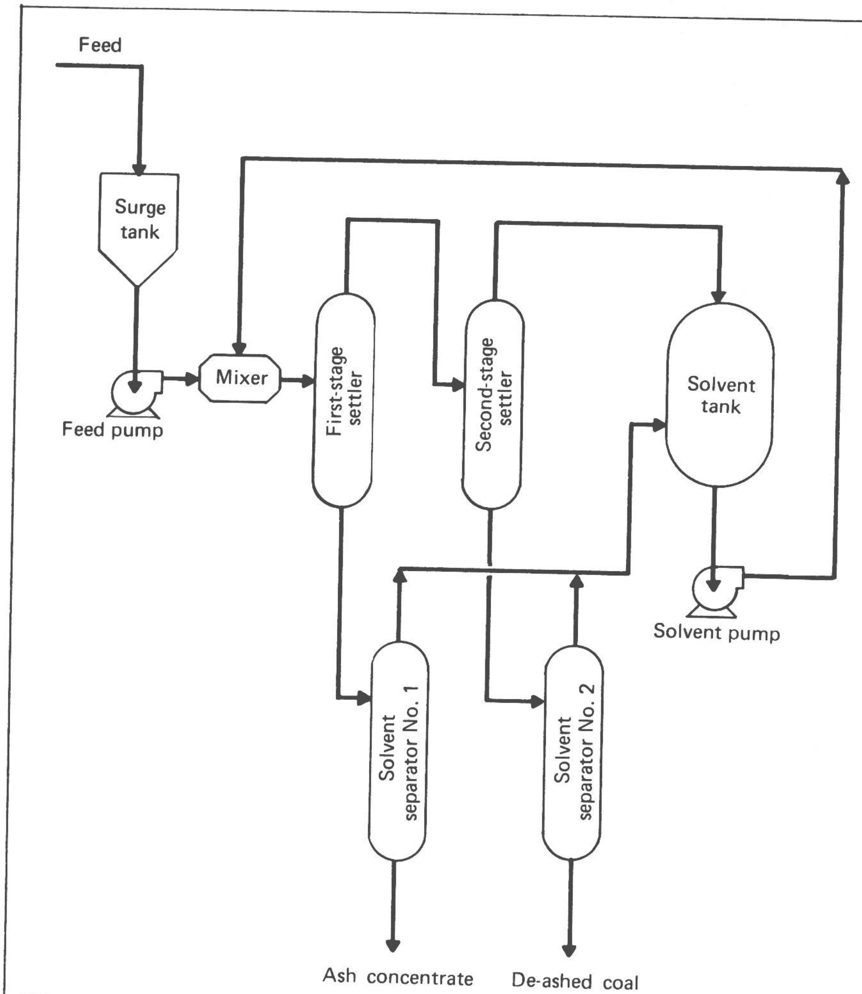
Kerr-McGee Corp. (Oklahoma City, Okla.) described its "critical solvent" de-ashing route (Fig. 2), which also achieves a claimed ash reduction to 0.1% by weight in the liquid product. In this process, the critical solvent works in two settling stages of different temperature levels. The first stage, at the lower temperature, results in a heavy phase of underflow that is stripped to recover entrained de-ashing solvent and yield a free-flowing ash concentrate. Light phase from the first settler is heated to decrease the critical solvent's density; coal values are rejected in the second stage.

The dissolving power of the solvent changes roughly in direct proportion to its density, according to the Kerr-McGee paper. The firm has tested the route on a bench scale for over five years, and in a pilot-plant for one year. This spring, the pilot plant was moved to another SRC test facility, at Wilsonville, Ala., and operated there this past summer. SRC recovery rates in the 76-81% range were reported for



Use of proprietary antisolvent is critical in Lummus' de-ashing route **Fig. 1**

Originally published January 1, 1979



Kerr-McGee's critical solvent process features two settling stages **Fig. 2**

tests completed just this past October.

Another paper dealt not with the de-ashing of SRC, but with the liquefaction step itself. A group from the chemical engineering department of Auburn University, led by Diwakar Garg, discussed its examination of a "short residence" SRC route that produces a solid-fuel product. (Two versions of SRC have already been investigated in the pilot plant, SRC I and SRC II, producing solid and liquid fuels, respectively.)

The authors observed that a proposed tightening of sulfur-emission regulations could doom SRC I, because of its higher pollution potential. Their remedy is a two-stage process: In the first, residence time and hydrogen consumption are minimized "through the use of inexpensive mineral catalysts that have been treated to improve their selectivity for desulfurization over hydrogenation." The second stage employs hydrotreating with a cobalt-molybdenum catalyst.

OTHER ROUTES—A number of other papers detailed processes under development. A discussion of the H-Coal route, under construction at Catlettsburg, Ky., along with Lummus' de-ashing unit, was presented by Hydrocarbon Research, Inc., the process' developer. The study features a broad macroeconomic cost justification based on some assumed, legislated economic incentives.

Mobil Oil described its methanol-to-gasoline process piloted at its research and development facility at Paulsboro, N.J., while Exxon Research and Engineering Co. (Florham Park, N.J.) discussed the production of substitute natural gas from Illinois coal via catalytic gasification—a route that it recently revealed will get a 1-ton/d tryout under a contract with DOE (*Chem. Eng.*, Nov. 20, p. 82).

In addition, the Institute of Gas Technology (Chicago, Ill.) described the "Coal Conversion Systems Technical Data Book" now in preparation for DOE, and illustrated how the book (though still incomplete) could be used for process design.

CAREERS TOP METRICATION—Although AIChE's announcement about metrication (see previous article) created relatively little excitement, the session on career planning, which emphasized the importance of planning to both individuals and corporations, drew a sizable group. (Many of the approximately 300 ChE students attending the meeting undoubtedly sat through that session.)

Outgoing AIChE president William H. Corcoran (James Y. Oldshue takes over the helm from Corcoran this month, beginning his one-year term) opened the session with a paper advising engineers to set career goals marked by the decades of their working lives. During the first decade, he suggested, engineers should establish their fundamental career paths, as well as their new family lives. Then, during later decades, participation in professional societies and assistance to newcomers to the field should become more important. Though such plans can only be roughly sketched, Corcoran says, something of this sort is needed to achieve basic goals in life.

Arnold A. Bondi, of Shell Development Co. (Houston), remarked that risk-taking can pay off in the long run. Risk-taking, he explained, could involve learning about new processes and other matters at the expense of knowing about things of current commercial importance. Over the course of a lifetime, risk-takers generally earn higher salaries, Bondi has observed, on the basis of his own statistical studies.

Others emphasized the company viewpoint, stressing the need for free flow in information between employee and employer regarding career paths and performance evaluations.

AUTOMOTIVE PLASTICS—Today, the average automobile contains 185 lb of plastic materials, most of which goes for trim and decorative applications, noted Ford Motor Co.'s Seymour Newman. In describing future uses—ones that will raise the amount of plastics in the average car to 350 lb by 1985—Newman mentioned a number of large structural components, including doors, roof and floor panels, firewalls, and even some chassis parts, such as wheels, springs, suspension-control arms and radiator supports. He emphasized, however, that high-volume low-cost production techniques must be developed before these goals can materialize. He also stressed the need for rapid online quality control for the monitoring of materials consistency and the nature and location of materials defects.

John A. Svera, of General Motors, assured attendees that plastics, in addition to saving weight, will ease manufacturing difficulties, particularly by increasing opportunities to integrate several components into larger parts. He sees especially big opportunities for fiberglass-reinforced plastics.

Nevertheless, substituting plastics for metals presents some problems, says Svera. For example, certain properties of plastics—e.g., fatigue strength, resistance to impact—do not measure up to those of currently-used metals. Also, the surface quality of sheet-molded plastic materials needs to be improved. And, Svera noted, the tricky assembly techniques required with plastics might result in slower production rates, at least until auto manufacturers become more familiar with the materials.

Svera pointed out that current development work to solve these problems is underway. Graphite-fiber reinforcement, for instance, is being used to improve resistance to fatigue.

FEEDSTOCKS—Du Pont's Kenneth N. McKelvey reported on a study written by an AIChE ad hoc taskforce for the U.S. Office of Technology Assessment, discussing the outlook for chemical feedstocks. Basically, it reiterated a now familiar line that there will be a gradual shift away from natural gas and distillate fuel oil, toward coal, and ultimately, biomass. McKelvey emphasized that synthesis gas and ethylene, which are the predominant feedstocks of today, will remain as such, though the raw materials for generating them will change. Production of synthesis gas from coal will result in the construction of large, coal-based synthesis-gas complexes (*Chem. Eng.*, Nov. 6, pp. 73-75).—**John C. Davis; Vincent Cavaseno; Richard W. Greene.**

Synthetic gas and chemicals from coal: economic appraisals

Conventional economic analyses cast doubt on the commercial potential of producing synthetic gas from coal. However, making chemicals via coal gasification appears more hopeful.

Joseph P. Leonard, *Chem Systems Inc.*

☐ Early economic evaluations of coal-based synthetic fuels and chemicals were made before and during the worst period of plant construction hyperinflation in the history of the U.S. Equipment and material costs were escalating rapidly.

The impact on plant construction

For a long period, fabricators were refusing to offer firm price quotations. Final costs were geared to date of delivery rather than date of purchase.

During the worst period, it was not uncommon for prices to increase from 1 to 2% per month between date of purchase order and date of delivery. Material shortages also plagued the construction industry. In many instances, certainty of supply became more important than price.

This situation radically changed the engineering construction business for refinery, chemical, petrochemical and fledgling coal-gasification plants. Engineering contractors were no longer willing to bid on a lump-sum basis. Even on a cost-plus basis, clients were told to include large contingencies in their budget figures because of continually escalating material costs.

Against this backdrop, it was not surprising that capital cost estimates filed with the Federal Power Commission (FPC) by the first gas companies to consider commercial coal-gasification projects soon became economically outdated. Similarly, technical brochures put out by promoters of new and existing coal-based technologies for producing synthetic fuels or chemicals understated plant investment and, therefore, product costs.

The experience of the first natural-gas company to announce plans for a commercial-scale coal-gasification plant is dramatic but not unique. The cost of El Paso Natural Gas Co.'s projected Four Corners Plant was estimated in early 1973 by the National Petroleum Council to be $209 million. Later that year, however, FPC revised the figure to $437 million; in mid-1974, the estimate reached $740 million; and in early 1975, El Paso executives indicated a cost of $1 billion.

Of course, not all of the cost escalation has been due to inflation. Obviously, as a project advances from the planning stage to commercial reality, its scope broadens and its true cost begins to emerge. At any rate, early studies dealing with coal-based synthetic fuels and chemicals proposed attractive but illusory economics based on early-1970s investment figures.

In this article, economic appraisals of the coal-based technologies closest to commercial reality will be based on the startup of plants in the early 1980s, not ten years earlier. The most likely candidates for commercialization are: (1) giant SNG plants, and (2) large-volume synthesis-gas chemicals, specifically ammonia and methanol.

Costs of SNG from giant plants

Estimating the future cost of a giant SNG-from-coal plant must necessarily be speculative. No commercial plant of this kind is currently in operation, so cost data cannot be based on actual plant construction and operation. Further, much of the cost data that are available are inconsistent regarding how much one of these plants would cost today, much less in 1980 and beyond. Probably the most reliable data at hand come from three SNG-from-coal projects that have progressed considerably past the planning stage—those of El Paso Natural Gas Co., Wesco (Western Gasification Co.) and American Natural Gas Service Co.*

All three projects are based on the Lurgi process, with lignite the feedstock. Because it would take about four years to build one of these commercial plants, any large-scale plant coming onstream in the early 1980s would be based on Lurgi technology. So all the economic data presented are based on that process.

Table I itemizes the capital investment by plant sections for 1980 and 1985 startups of a commercial coal-based SNG plant. The total capital required would be approxi-

This article is based on a paper presented at a Delaware Valley AIChE Symposium on chemical feedstock alternatives, Drexel University, Mar. 14, 1978. Although the cost figures given would not necessarily be those that the author would present today, they would certainly be similar, and probably within the range of engineering accuracy in comparison to earlier estimates. Certainly, the conclusions reached remain valid today.

*The chances of project completion for the El Paso and Wesco projects appear quite slim at this time. Great Plains Gasification Associates (a recently formed consortium that has expanded participation in American Natural Resources' high-Btu coal-gasification project to five major U.S. natural-gas systems) has asked the Federal Energy Regulatory Commission for a certificate to build a 137.5-million-ft^3/d high-Btu coal-gasification plant, using the Lurgi process, in Mercer County, North Dakota. Under the present schedule, the plant should start commercial operation by December 1983.

Originally published March 26, 1979

Estimated capital investment for SNG from coal by Lurgi process* **Table I**

	Plant investment million $† 1980 startup	Plant investment million $† 1985 startup
Coal preparation	89	125
Oxygen plant	134	188
Coal gasification	148	207
Shift conversion	36	51
Gas purification	181	253
Methanation	52	73
Dehydration and compression	19	27
Total onsites	**659**	**924**
Utilities and offsites	341	479
Contractor's overhead and profit	Included above	Included above
Engineering and design costs	Included above	Included above
Subtotal	1,000	1,403
Project contingency, 15%	150	210
Total plant investment	1,150	1,613
Initial charge of catalyst and chemicals	6	8
Royalties	25	34
Interest during construction	242	339
Startup	31	43
Working capital	27	38
Total capital requirement	**1,481**	**2,075**

*Based on information from El Paso, Wesco and American Natural Gas, including original FPC filings and correspondence updating the filings.

†Based on a 4-year construction period of a 250-million-Btu/d plant with the following construction schedule: 1st year—5%, 2nd year—20%, 3rd year—50%, 4th year—25%.

mately $1.58 billion in 1980, and $2.18 billion in 1985. The design capacity would be 250 billion Btu/d (950 Btu/std ft^3 gas), with an onstream factor of 90%. The total capital represents the entire cost of building the plant and getting it ready for startup. It includes all process and general facilities, and utilities.

The plant would require only water and coal. A coal mine and any additions to the gas pipeline system are not considered part of the investment. However, because the plant is assumed to be located near a coal mine in the Western U.S. (in all probability, in a very dry area), the cost of a water pipeline is included.

These cost figures are typical yet generalized capital-cost estimates. There will obviously be differences between these figures and those of actual projects.

Estimates of operating costs for producing SNG from coal via gasification in 1980 and 1985 are summarized in Table II.

The cost of SNG from coal can be calculated a number of ways, depending on the method of financing. Table II summarizes the economics of coal-based SNG calculated via: utility financing, first-year cost; utility financing, 20-year average cost; and private investor financing, 12% discounted-cash-flow-rate-of-return (DCFRR).*

Also shown is the cost of SNG from coal if the U.S. government were to put up half the total capital requirement with no return or interest taken on that portion of the investment. These government-subsidized gas costs were calculated using the 20-year average cost via utility financing. The gas cost has been calculated for two different coal prices, to permit sensitivity analyses on the

*For an explanation of utility financing, see Robert Skanser's "Coal Gasification: Commercial Concepts, Gas Cost Guidelines," C. F. Braun & Co., Alhambra, CA 91802, Jan. 1976, prepared for the U.S. Energy Research & Development Admin. and American Gas Assn., under Contract No. E(49-18)-1235. Copies are available free from ERDA, AGA and C. F. Braun.

Estimated annual net operating costs for SNG from coal by the Lurgi process **Table II**

	1980 startup		1985 startup	
	Million $	$/million Btu	Million $	$/million Btu
Coal (7.466 million tons/yr)*	59.7	0.72	76.2	0.92
Catalyst and chemicals	5.0	0.06	6.4	0.08
Raw water (2 billion gal/yr)	1.1	0.01	1.4	0.02
Labor:				
Process operating	5.4	0.07	7.1	0.09
Maintenance	18.2	0.22	25.5	0.31
Supervision	4.7	0.06	6.5	0.08
Administration and general overhead	17.0	0.21	23.5	0.28
Supplies:				
Operating	1.6	0.02	2.1	0.03
Maintenance	12.1	0.15	17.0	0.21
Local taxes and insurance	31.1	0.38	43.6	0.53
Total gross operating costs	**155.9**	**1.90**	**209.3**	**2.55**
Byproduct credits:				
Sulfur (48,700 long tons/yr)	1.7	0.02	2.0	0.03
Ammonia (73,700 short tons/yr)	14.0	0.17	17.5	0.21
Total byproduct credits	15.7	0.19	19.5	0.24
Total net operating cost	**140.2**	**1.71**	**189.8**	**2.31**

*Based on an overall thermal efficiency of 65.0% and a coal heating value of 17 million Btu/ton, using western coal at $0.47/million Btu in 1980 and $0.60/million Btu in 1985.