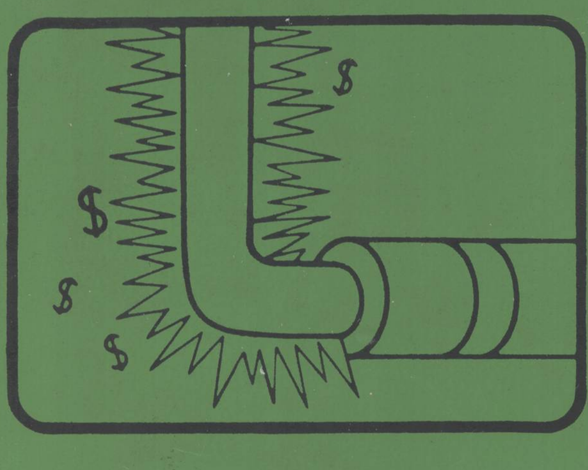
PROCESS ENERGY CONSERVATION



CHEMICAL ENGINEERING Magazine

PROCESS ENERGY CONSERVATION

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Introduction

This book is a guide that will help you to save energy in your process plant. Here are scores of articles that will show you methods to cut your electricity bills, improve boiler performance, design new plants to be energy-efficient, and help you in many other tasks.

The articles here appeared in *Chemical Engineering* from 1973 through 1981. It was in 1973 that energy began to become expensive—and energy conservation started to become a major part of the chemical engineer's job. Before then, of course, energy costs were not considered to be so important in plant design and operation. In fact, some of us can still remember performing energy-cost calculations after all other design considerations had been handled!

Included in this book are some more-recent news stories, as well as the usual engineering "how-to" articles. We feel that these stories indicate the ways people in the chemical process industries are thinking to save energy. Such direction should be helpful to you in the years ahead.

All the articles that appear here are in their original form. No attempt has been made to update the numbers or methods used in them. We trust you will be aware of any changes that have taken place since the time of original publication, and adjust for them when applying the ideas contained in this book.

The volume is divided into three parts. The progression is from the general to the specific. There is practical information for use by engineers in any process plant, as well as specific tips for many applications:

Section I: Overall Strategies and Ideas for Saving Energy—This section contains general tips for energy conservation. Information is provided on recent energy-related news, fuels, how to set up an energy-conservation program, and how to estimate and optimize energy needs.

Section II: The Energy-Efficient Plant—Here are methods to design and run plants and systems economically. Tips are given for new and existing plants. Also included are articles on how to accomplish distillation and save energy, and how to cut energy in steam systems. In general, this section covers the larger and more general aspects of process-plant energy conservation.

Section III: Equipment and Materials—This part is a guide to specific materials and types of equipment. The sections include refractories, insulation, boilers and furnaces, heat exchangers, motors and pumps.

These three parts contain a wealth of information and experience that will save you money. The methods have been proven by experience and were reported by leading experts. As energy costs continue to soar, this book will help you to keep your expenses down.

Section I
OVERALL STRATEGIES AND IDEAS FOR SAVING ENERGY

Contents

Energy-related meeting focuses on new routes

A coal-gasification process that needs no desulfurization equipment, and a flue-gas desulfurization technique that requires no gas pretreatment, were highlighted.

☐ Among the rich selection of energy-related papers presented at the 16th Intersociety Energy Conversion Engineering Conference held last month (Aug. 9-14) in Atlanta, Ga., two that described new processes, and another that told of advances in wood-gasification technology, had special interest for an audience filled with engineers knowledgeable in energy conservation.

Japan's Sumitomo Metal Industries, Ltd., unveiled a coal-gasification route that boasts high yields of a raw gas that does not have to undergo desulfurization. Georgia Institute of Technology (Atlanta) gave details* of a low-cost flue-gas-desulfurization (FGD) process based on the electrochemical concentration cell concept. And researchers at the University of Missouri-Rolla described a fluid-bed wood-gasification reactor that may be used to produce low-Btu gas for a municipal power plant.

LOW-SULFUR GAS—The Sumitomo process (*Chem. Eng.*, Aug. 24, p. 19) appears to be very similar to another molten iron coal-gasification route (*Chem. Eng.*, Apr. 6, p. 10), recently announced by Humboldt-Wedag AG (Cologne, West Germany).

Both processes employ a molten-iron bath for gasification. This reportedly makes the chemical reactions easier to control (by assuming characteristics more similar to a liquid/liquid reaction than to a solid/gas reaction, as in most gasification routes).

In the Sumitomo technique, pulverized coal, along with oxygen and steam, is blown through a water-cooled lance held above the bath, which has a temperature of 1,500-1,600°C. The hot metal cracks the coal, releasing hydrogen; the coal's ash and carbon dissolve in the iron.

Dissolved carbon reacts with the oxygen feed to form CO, and with the steam to generate additional hydrogen via the water-gas reaction.

The product gas is said to have a heating value of about 2,600 kcal/Nm³. The raw gas is composed of more than 90% CO and H_2 (hydrogen ranges from 29-33%, and CO from 60-64%).

The process has a gasification yield of over 98%, according to pilot-plant results. And the route generates a raw gas that contains only 10 to 300 ppm of total sulfur. S. Okamura, manager of Sumitomo's research and development department, points out that the molten iron has the ability to dissolve the sulfur present in the coal, forming FeS. This is removed in the slag. Because the desulfurization capability is higher than 90%, Sumitomo claims that no desulfurization facilities are needed for cleanup.

The company has operated a 60-ton/d batch deslagging pilot unit since the spring of 1980 at its Kashima steel works in Japan. In July, the firm started up a continuous pilot unit with an average capacity of 60 tons/d and a maximum of 90. A $74-million demonstration plant will begin operating in 1983-4; this facility will have a capacity of 500 dry metric tons/d of coal and will use three gasifiers, each containing 125 tons of molten iron (two of the gasifiers will be operational; the other will be on standby).

Okamura states that, with coal costing about $65/ton, the product gas would cost $7.50 to $8.50/million Btu.

ELECTRIC ANSWER—For the past two or three years, Georgia Institute of Technology has been using a small test-cell to investigate the electrochemical removal of sulfur dioxide from stack gases. The idea, according to authors Dan Townley and Jack Winnick of the Institute's Chemical Engineering Dept., can be applied to SO_2 emissions from such sources as power plants, ore smelters, sulfuric acid plants, and Claus units.

The Institute's cell is of the electrochemical-concentration type, in which a reactive species is present at both electrodes, but at different concentrations, so that the reaction at one electrode is the reverse of that at the other. The cell itself is a high-temperature, molten-salt version that uses the eutectic of lithium, potassium and sodium sulfates as the electrolyte.

At atmospheric pressure, the cell can operate in two different modes. In the driven one, a carrier gas (air) is fed to the anode to carry away the reaction product (SO_3); this requires consumption of electricity. In the reducing-gas mode, hydrogen or another gas reacts with the sulfate present to produce H_2S and water. Since energy to run the cell is obtained from hydrogen oxidation, this mode consumes no electricity.

According to Winnick, the system doesn't generate sludge, doesn't require flue-gas pretreatment, and doesn't take a pressure-drop penalty. All this makes it cheaper than conventional FGD routes. In a power plant application, says Winnick, wet-scrubbing FGD units would have operating costs ranging from 1.5 to 2.0 mills/kWh, vs. about 0.5 mills/kWh for the electrochemical route operated in the driven mode. This does not include a credit for sulfuric acid produced (concentrated SO_3 is the anode product).

The authors conclude that for a 500-MW power plant that burns 3.5%-sulfur coal, the current needed for 90% SO_2 removal is 13×10^6 amp. At a cell potential of 0.8 V, this amounts to approximately 2% of the plant's power, which compares favorably with conventional FGD processes requiring up to 6% of a plant's power (e.g., lime scrubbing).

Winnick has patented the process, and the Institute now seeks funds to run pilot-plant tests.

FLUIDIZED WOOD—At the meeting, researchers from the University of Missouri-Rolla outlined the operation of a semicommercial-size fluid-bed

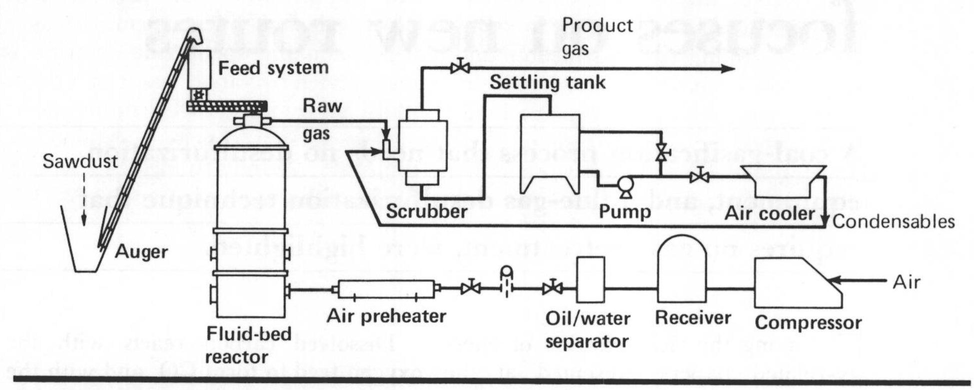
* The Institute's paper was not read at the conference, but is included in the proceedings.

Originally published September 21, 1981

wood gasifier. This pilot unit, operated with support from the U.S. Department of Energy, has a capacity of 2,000 lb/h of wood and produces a low-Btu gas (about 160 Btu/ft.^{3}).

In the system, a 40-in.-dia. fluid-bed reactor is fed wood, as sawdust (see figure). Preheated air is used to fluidize the sand bed. The air also provides oxygen needed for the gasification reactions. Product gas contains about 7% hydrogen and 5% methane.

The Missouri-Rolla unit has also been tried on a high-Btu mode, in which the product gas is recycled to the reactor, and a catalyst—potassium carbonate or wood ash—is used to increase methane output. However, says Virgil J. Flanigan, a professor of mechanical engineering, they have had "little success with catalysts."



Wood-gasifying scheme features a fluid-bed reactor

A feasibility study for a 100-ton/d unit, using the low-Btu technology, has been completed for the city of Detroit Lakes, Minn., which would use the product gas in a powerplant. If the plan is accepted, the gasifier could go onstream in two years. Fixed cost for the facility would be $900,000.

Reginald I. Berry

Energy topics pervade AIChE meeting

Processes and hardware aimed at saving energy were featured. Among the routes covered in sessions were methods for coal gasification, and production of ethanol, methane and methanol.

☐ Energy and most everything related to it are still very much in the news, to judge from the agenda of the 72nd Annual Meeting of the American Institute of Chemical Engineers (AIChE), held in San Francisco, Calif., Nov. 25-29, 1979.

The event, which attracted over 3,800 registrants (a record), devoted two sessions to the topic—one dealing with energy conservation, the other with alternative-energy processes.

TIPS FOR SAVING—A capital-cost reduction of 5 to 20% was claimed for a special evaporator design described by Richard C. Bennett, division manager of Swenson Div. of Whiting Corp. The unit replaces the conventional cylindrical vapor head with a special elbow that connects the heater with the condenser.

Swenson's elbow separator/evaporator uses centrifugal and gravitational forces to separate vapor and liquid components of an evaporated fluid, eliminating the need for a bulky vapor head. Bennett said that the equipment provides vapors as clean (liquid-free) as those leaving a conventional vapor head, and is capable of operating satisfactorily over a wider range of evaporation rates than do conventional units.

Two other papers—by D. A. Austin of Resources Conservation Co. (Seattle, Wash.) and A. H. Beesley of Aqua-Chem, Inc. (Milwaukee, Wis.)—dealt with vapor compression evaporation as a conservation method. In these systems, mechanical work is substituted for the heating steam required in single- and multiple-effect evaporators, thereby providing lower energy consumption and operating costs.

In distillation, R. M. Stephenson and R. F. Anderson of the University of Connecticut (Storrs) gave examples of minimum and actual energy requirements for common industrial separations, and made recommendations as to where modifications of conventional distillation systems could lead to improved energy efficiency.

Thermal energy storage was examined from a how-to standpoint. Among the options were the use of paraffins, phase-change materials and winter-chilled cold water stored in aquifers.

PROCESS-ORIENTED PAPERS—On the alternative-energy-process theme, several symposia were held that reviewed the status of various technologies, including process developments and economics for:

- Production of ethanol from wood, wheat straw, corn stover, and high-sugar-content plants by fermentation, and from certain aquatic plants by acid hydrolysis.
- Production of methane from mass cultures of certain algae, from bioconversion of animal manures and agricultural crop residues, and from anaerobic digestion of municipal solid waste.
- Production of various chemicals, including methanol, oils, chars and ammonia, from the thermal conversion (pyrolysis) of various biomass feedstocks.

In addition, the technical and economic ramifications of underground coal gasification merited an entire session. D. R. Stephens, of the University of California's Lawrence Livermore Laboratory (Livermore, Calif.), outlined the encouraging results of field tests to date, which indicate that the technology offers a "relatively low-cost, environmentally sound

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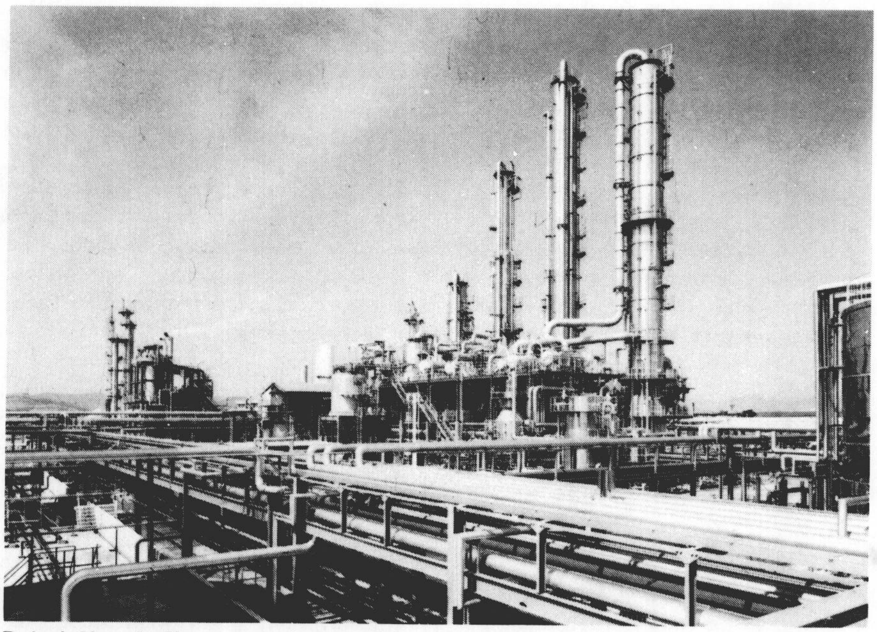
were given on diverse synfuels technologies, including high- and low-Btu coal gasification, coal liquefaction, and production of gasoline from coal by molten zinc-chloride hydrocracking. As described by C. R. Greene of Shell Development Co. (Houston), the route, in a single step, produces 4.5 bbl of gasoline per ton of coal processed. Gasoline is removed as a vapor and the spent zinc chloride is regenerated by vaporization in a fluidized-bed combustor. Currently operated in a 1-ton/d demonstration unit, the route is jointly funded by the U.S. Dept. of Energy, Continental Oil Co. and Shell Oil Co.

A symposium entitled "International Synfuels Technology" highlighted coal-conversion developments in five countries—South Africa, Australia, the United Kingdom, West Germany and The Netherlands.

Japanese thrift spawns energy-saving processes

With no natural fuel resources to speak of, Japan has had to pare energy consumption considerably since 1973. Savings realized in this decade are expected to come from process development work aimed at raising yields.



Daicel Chemical's new acetic acid plant will obtain methanol from CO

☐ It's been seven years since Japan, like other industrialized nations, was hit by the oil crisis, which caused the worst postwar slump experienced by that nation's chemical and petrochemical industries. All along, Japanese engineers have been doing wonders in cutting energy and raw materials. And now they are starting the 1980s with a more ambitious program aimed at further reductions.

During phase one of the conservation effort (1974-78), companies imposed relatively low-cost measures—what Nobuto Ohta, general manager of research and development for Mitsubishi Petrochemical Co., calls "turning off the lights"—that nevertheless yielded substantial results (see box). But the savings planned for the present decade will be keyed to process-oriented research and development. In effect, Japanese firms will be trying to cut raw-material consumption further by improving process yields.

MORE FOR LESS—The chemical industry will have to work harder to obtain (smaller) savings in coming years. For example, while Sumitomo Chemical Co. achieved a 15% energy cut during 1977-79, its next three-year target has been pegged at 12% (including a 5% cut this year). Similarly, Mitsubishi Chemical Industries Ltd. says it expects to save only an annual 2% during 1979-81. And Asahi Chemical, which reported a 40% saving since 1973, is trying for a 3-5%/yr conservation over the next few years.

Some of the gains made during the early slump years will indeed be difficult to match. Take the case of Teijin Ltd., which has reported a 38% boost in the production of polyester, nylon and acetate for the last six years, with no increase in energy consumption. Also during that period, Ajinomoto Co. has notched a 15% raw-materials saving (sugar-cane molasses, acetic acid), plus cuts in the consumption of steam (48%), electricity (15%) and water (50%)—all in the manufacture of monosodium glutamate.

The conservation efforts have enabled oil refiners to curb production somewhat. According to Japan's Petroleum Assn., oil refining in fiscal 1979 (ended in March) dropped 2.4%—to 21,392 million L—from the 1978 figure. Fuel oil sales underwent a bigger decline—3.4%, to 21,466 million L. Meanwhile, product inventories rose 23.6%, to 15,360 million L, by March 1980.

WORKING ON PROCESSES—In phase two, Mitsubishi Petrochemical will aim for a 5% cost cut, equivalent to \$24 million/yr (in 1978 dollars) during 1979-82. The firm, while not increasing its R&D staff of about 100, will try to slash raw-material costs by improving yields of processes for: ethylene, benzene, styrene monomer, ethylene oxide, acrylic acid, higher alcohols, low- and high-density poly-

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Editor-in-chief Calvin S. Cronan interviews Asahi Chemical's Maomi Seko

ethylene, and polypropylene. Mitsubishi has already spent a considerable amount on making its styrene monomer process more efficient; the new route saves steam consumption by producing the monomer at lower than normal pressures.

A number of Japanese companies, including Mitsubishi Petrochemical and Nippon Petrochemicals Co., are working on gas-phase, fluid-bed, low-pressure and -density polyethylene routes along the lines of Union Carbide's Unipol process. As for polypropylene, Sumitomo Chemical Co. has developed a method that consumes no solvent or water and needs no de-ashing (*Chem. Eng.*, May 7, 1979, p. 42). This route will probably make its commercial debut in 1982, as part of a complex to be built in Singapore.

The brand-new polypropylene technology will not be the only improvement in evidence at Singapore. Says Takeshi Hijikata, president of Sumitomo Chemical, "We will make the Singapore complex, particularly the ethylene plant, the very best in terms of [reduced] feedstock and energy consumption."

(Ethylene units completed in Japan before the 1973 oil crisis consume some 10,000 kcal/kg of product ethylene. But industry sources say that Showa Denko K.K. and Ukishima Petrochemicals Co. cut those requirements to 6,000 kcal/kg at 300,000- and 400,000-m.t./yr plants they, respectively, built in 1977 and 1978. "At present, they are the best here," admits Hijikata.)

HELP FOR LICENSING—Of course, energy and raw-material conservation are not the only motives behind the process improvement drive—the Japanese also want to maintain their licensing competitiveness abroad. Says Susumu Takao, director of production and engineering for Nippon Zeon: "We cannot let our guard down. Others will quickly make similar improvements, and we are engaged in neck-and-neck competition."

Takao has a point, because his firm's butadiene extraction route is a close competitor of a process owned by West Germany's BASF. The economics of both are thought to be similar, though the Japanese method requires more steam, less electricity.

Now, Takao reports that steam requirements have been reduced from 3.2 m.t./ton of product to about 2 m.t. for new plants. In existing facilities, Nippon Zeon has managed to reduce steam consumption to 2.4 m.t./ton of product, mainly by heat recovery. Earlier this year, the Tokyo-based company concluded a licensing agreement with Mexico's Pemex—the thirtieth such contract for the firm's butadiene technique.

Lack of competition, according to Takao, has been responsible for the slow improvement (in terms of energy consumption) of Nippon Zeon's isoprene extraction process. To be sure, steam requirement has been nudged down from 12 m.t. to 10 m.t./ton of product. But this doesn't satisfy Takao, who quips, "I urge engineers to assume there is a competitor in the isoprene field, too."

CHLOR-ALKALI FRACAS—Takao's urging is one that Maomi Seko, executive vice-president of Asahi Chemical Industry Co., can easily dispense with. His firm and Asahi Glass Co. are experts in membrane processing for chlor-alkali production—a highly competitive field in which both companies have separately developed proprietary technology.

The Asahi processes will likely benefit from the Japanese government's

Post-crisis steps—modest spending yields savings

According to a survey by the Japan Chemical Industry Assn., 52 leading chemical firms spent about $230 million on conservation during 1974-78. The payoff was a drop in energy consumption from 206,544 billion kcal (equivalent to 20,863 million kiloliters of fuel oil) in 1973 to 189,363 billion kcal (equivalent to 19,128 million kiloliters of fuel oil) in 1978. The 1978 figures were reached despite a 5.8% rise in energy consumption for pollution abatement systems—mainly desulfurization and denitrification.

Responding to the JCIA questionnaire, the 52 companies, which operate 228 chemical plants, said there is room for a 9% saving during 1980-85. This would amount to a cut of 19,900 billion kcal, equivalent to approximately 2 million kiloliters of fuel oil. A capital investment of $544 million will be needed to reach the six-year goal.

Although a precise comparison is impossible, JCIA says that the chemical-industry savings rate of 17.2% during 1973-78 looks good on an international level, and compares favorably with other Japanese industries. In the same time-span, cement makers realized an estimated 18.5% energy conservation, and petroleum refiners saved an estimated 11.2%, while the steel industry achieved a reduction of only 9.0% (equivalent to 5.6 million kiloliters of fuel oil).

order to chlor-alkali producers to switch the remaining mercury-cell capacity (1.7 million m.t./yr, out of a total of 4.4 million m.t./yr) to non-mercury routes by December 1984. The Ministry of International Trade and Industry has requested both firms to expand their capacities by 1982, so that their plants can serve as model large-scale facilities.

Meanwhile, last year, in a London symposium, Seko compared the power consumption of Asahi Chemical's membrane process with that of other routes (per metric ton of caustic soda). His figures: 2,703 kWh for the membrane technique, 3,100 kWh for mercury cells, and 2,500 kWh for asbestos diaphragm cells. In an interview, Seko predicted that his company's process would eventually lower electricity consumption to 2,000 kWh. And the executive noted that the technique already produces more than 10,000 m.t./yr of caustic soda per cell, which surpasses the two other methods.

In addition to improvements in chlor-alkali processing, Asahi Chemical has bettered catalyst performance. The firm has recently licensed its high-density polyethylene technique to Exxon Chemical Co., which intends to build a 400-million-lb/yr plant at Mt. Belvieu, Tex. It will feature a highly active, modified Ziegler-type catalyst.

"New catalysts," notes Seko, "will play important roles in energy and raw-material conservation. Development of catalysts is one of the wisest ways because you do not have to change the plant's chemistry."

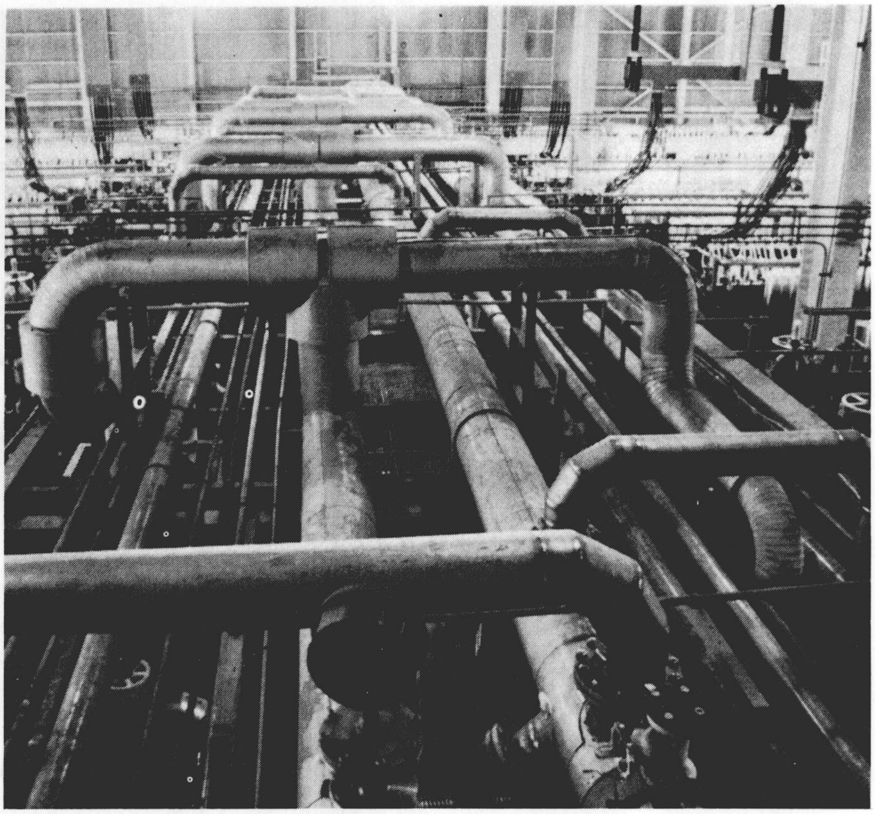
Following this approach, Mitsubishi Chemical has developed a more selective catalyst for its oxo gas process, said to achieve a 30% energy saving and more than a 10% cut in raw-material consumption. The revamped process is being offered for licensing. The firm also has improved its terephthalic acid route by emphasizing prevention of solvent (acetic acid) oxidation. As a result, acid consumption has been reduced by 50%.

ALUMINUM AND PVC—Sumitomo Aluminium Smelting Co., which was formed to take over Sumitomo Chemical's aluminum business, and Shin-Etsu Chemical Co. are two other companies that have used process improvements to gain licensing business.

The former's modified Soderberg technique consumes 14,000 kWh/m.t. of aluminum ingot, while its prebaked-anode process uses 13,500 kWh. This energy efficiency compares favorably with a world average of about 17,000-18,000 kWh/m.t. of ingot, and has helped—in combination with good environmental-protection features and labor economies—in securing $32 million in aggregate licensing income for the firm in recent years.

On the strength of the size (130 m³) and design of its polymerization reactor, Shin-Etsu has become the leading polyvinyl chloride producer in Japan. Through its subsidiary Shintech Inc., the firm is expanding its business in the U.S. Licensing elsewhere includes a 144,000-m.t./yr plant for Shell Chimie, S.A.; two 200,000-m.t./yr facilities for China, to be completed in Shengli and Nanking by 1982; and a 50,000-m.t./yr plant for Mexico's Primex S.A., also for completion in 1982.

MULTIFACETED TECHNIQUE—Attempts to curb naphtha consumption are getting a boost from Texaco's partial oxidation process, which Ube Industries Ltd. licensed years ago. Suitably modified, the Texaco-Ube process makes syngas from vacuum residue, and Tetsuro Yoshimura, manager of the plant engineering department's technical group, sees great possibilities for producing ammonia, methanol, and carbon monoxide.



Cell room of Asahi Chemical's chlor-alkali plant at Nobeoka

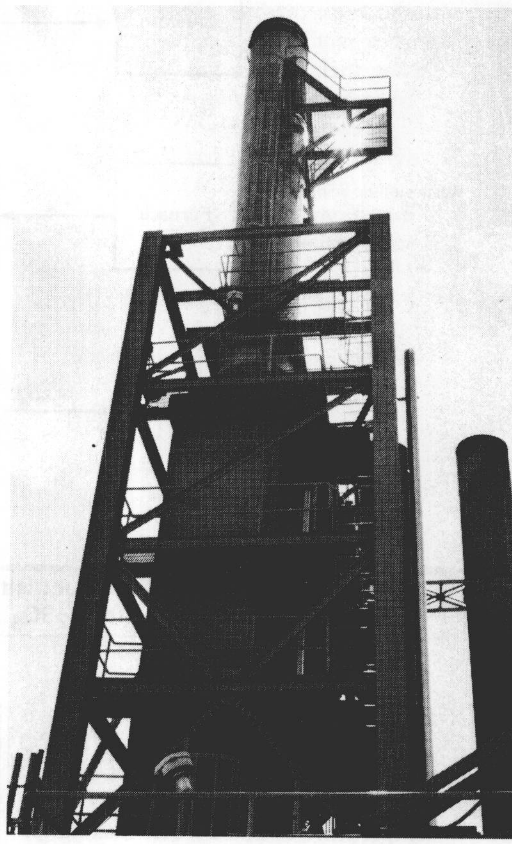
Ube, which has used the route to make ammonia for years, recently clinched a contract to export three 1,000-m.t./d vacuum-residue gasification plants to China. The Texaco-Ube process also will fit in well with plans by Daicel Chemical Industries Ltd. to start up a 150,000-m.t./yr acetic acid facility this month at Aboshi, west of Osaka. Raw-material methanol will initially be purchased from outside sources, but a CO plant built by Ube will eventually be the supplier.

Yoshimura hopes that the gasification process will find even wider application—e.g., as a source of hydrogen in refineries. "Refinery gas and naphtha, now the two main sources, can be better employed in making products with higher value-added," he says. Ube already uses the knowhow in the small-scale production of oxalic acid and derivatives. And Daicel is planning to use CO feed to make 1,4-butanediol.

Shota Ushio
World News (Tokyo)

CPI firms map strategy for energy-saving plans

Such measures as steam and heat recovery, cogeneration of electricity, and use of coal and other materials for fuel and feedstocks figure prominently in many firms' energy-conservation manuals.



☐ What can the chemical process industries (CPI) do to conserve energy? The question can, of course, be answered in a thousand different ways. To pinpoint where the CPI are focusing their energy-saving efforts, CHEMICAL ENGINEERING interviewed a group of experts in the matter, and complemented the information with data from the Second Pacific Chemical Engineering Congress (held Aug. 28-31 in Denver, Colo.), which devoted a morning and afternoon session to such topics as how chemical process and equipment design can be modified to reduce energy consumption.

Most interviewees agreed that the CPI are concentrating on the following three approaches:

- The development of new technology—i.e., of energy-efficient processes and operating techniques.
- Increased integration of processes—e.g., more emphasis on electricity cogeneration, recovery and reuse of steam and heat now wasted, and interprocess transfer of energy.
- A drop in consumption of crude oil and natural gas, to be achieved by a combination of energy-conservation procedures and an increase in the use of coal and other materials for fuel and feedstocks.

While pursuing this three-pronged plan of attack, many CPI firms are discovering that many of the old ground rules from the era of cheap, abundant natural gas and crude oil no longer apply. For instance, because it has always been traditionally desirable to hold down the capital cost of projects, energy-efficient process design has been, until recent years, too expensive to be worthwhile.

Now, however, it is more likely that a heavy capital outlay to ensure high efficiency is more than paid back in fuel-cost savings over the life of a project. And this is not the sole reward of more-efficient processes: in many instances they can further lower manufacturing costs by increasing product purity and yields.

HEAT THRIFTINESS—Although heat recovery plays a big part in efficient process design, there have been virtually no significant modifications made in recent years in the design of heat-exchange equipment. Such noted manufacturers as Pfaudler Co. (Rochester, N.Y.), Thermxchanger, Inc. (Oakland, Calif. and Wiegmann & Rose International Corp. (Richmond, Calif.) agree that they haven't been making changes in basic equipment design, nor are they contemplating any.

The manager of the heat-transfer section of a large U.K. engineering design firm explains why. "Energy conservation in the CPI," he says, is much more a function of process design than of heat-transfer equipment design. By the time a flowsheet has been drawn up and finalized, there is relatively little gain to be made in equipment design. Don't forget, this technology is fairly mature."

This sentiment is echoed by B. D. Coffin, manager of power-plants engineering for H. K. Ferguson Co. (Cleveland, Ohio), who adds, "We are applying the same equipment today as we did before, but with more diligence, to capture waste heat that was previously lost. There is more consideration given to insulation, equipment sizing, pumps and motors . . . We are striving for optimum efficiency through proper consideration and operation at design levels."

What these experts are saying is that heat recovery today is based on the use of available equipment—units that may have been too expensive when fuel costs were low. Notes Milton J. Buffington, regional manager of Bumstead-Woolford Co. (Los Alamitos, Calif.), an engineering and construction firm specializing in energy and power: "A good deal of energy conservation results from old design techniques applied under a new economic banner."

Buffington cites the example of one

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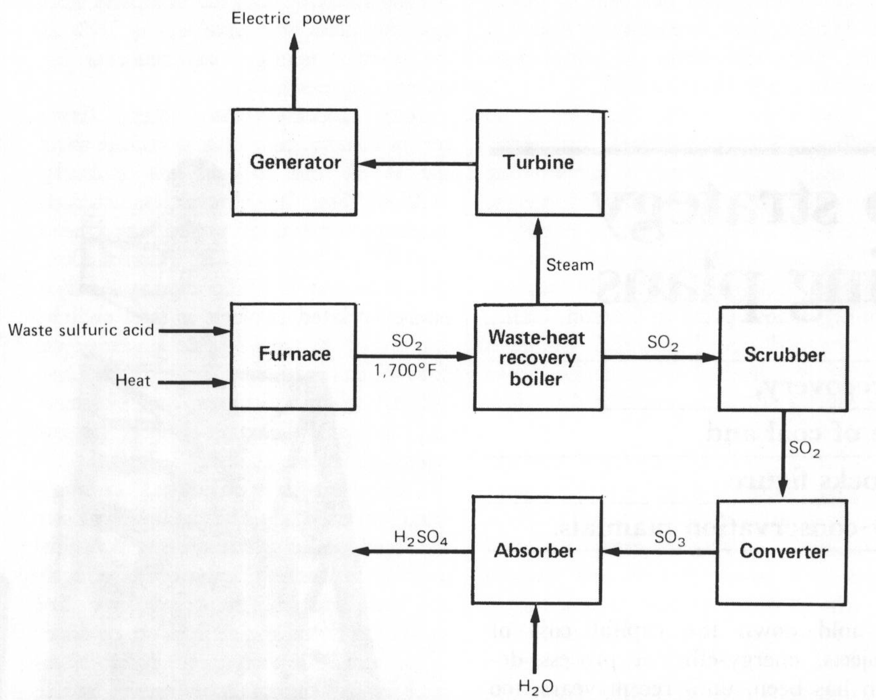

Heat recovery fuels nearly all electricity generating needs at a Stauffer H_2SO_4 plant

large U.S. oil refinery, which is installing a waste-heat unit on its CO boiler. About 900,000 lb/h of exhaust gas leaves the boiler at an average temperature of 600°F. The installation of a waste-heat boiler and an economizer at the back end of the unit produces saturated steam at about 175 lb/in² and approximately 300°F.

What makes these additions attractive is the current cost of fuel oil (about $2.40/million Btu), when compared with the price tag of a few years ago ($1.50/million Btu). The refiner that put in the heat-recovery equipment is saving about 45 million Btu/h, which amounts to slightly more than $100/h. At an installed cost of $1.25 million to $1.6 million, these units can be amortized in little over a year, at today's energy costs. (Of course, the pay-back time would shorten if fuel oil became more expensive.)

PINCH THOSE PENNIES—One firm that has benefited from selective equipment- and process-modifications is Union Carbide Corp. (New York City). M. A. Williams, energy-conservation manager of the firm's Chemicals & Plastics Div., says that, since 1972, Carbide has managed to save the equivalent of nearly 12.8 million bbl of crude oil—a saving of $64 million, assuming a price of $5/bbl—through an investment of $20 million. This year, adds Williams, the company expects to save about 2.5 million bbl (worth about $30 million, assuming an oil price of $12/bbl) by means of changes that will cost about $10 million.

Typical of the alterations that Carbide has made this past year are the installation of new trays in a distillation column of a plant in Brownsville, Tex., and the rerouting of overhead vapors from an ammonia column at a Taft, La., plant.

The novel trays have variable and directional slotting, and box-type promoters, which improve distillation efficiency. Savings in steam, due to less reflux and heat input to the column, exceed $700,000/yr—the equivalent of 53,000 bbl/yr of crude oil.

By installing some piping at a cost of $60,000, Carbide has been able to reroute overhead vapors from the ammonia column directly to an existing recycle compressor, rather than through a condenser and vaporizer. The resulting savings in steam and water will run to some $375,000/yr, or more than 32,000 bbl/yr of oil.

Lyman Gilbert, director of control operations at Environmental Data Corp. (Monrovia, Calif.), points to the importance of proper instrumentation when trying to conserve energy. Says Gilbert: "New instrumentation techniques allow automatic, continuous flame analyses, so it is possible to optimize air/fuel chemistry to get peak fuel-burning efficiency. *In situ* measurement of flame chemistry of each burner results in an evenly balanced furnace. In one system for the multi-burner boiler of a pulp and paper mill, the saving exceeded $2 million/yr, and the complete installation was made for only about $500,000."

A TIGHT FIT—"The recovery of large quantities of low-level heat rejected in processing probably represents our single greatest design challenge," said Robert I. Taylor, of Exxon Research and Engineering Co. (Florham Park, N.J.), at the Denver meeting. "This loss is typically about three to five times what we lose from furnace stacks."

Another speaker at the Congress—Harold Huckins, vice-president of Halcon Research and Development Corp. (New York City)—noted that various studies show that more than 75% of the heat transferred in industrial processing units that Halcon designs is at 350°F or less.

Recovery of this heat is very much a part of new installations, according to Nosh Mistry, manager of energy systems for Betz Environmental Engineers Inc. (Plymouth Meeting, Pa.). He says that energy utilization is very efficient in new plants, since high efficiency is built into them during the design phase. But older units, designed when energy was cheap, pose a problem: the lack of available space impedes the installation of often-cumbersome, low-temperature heat-exchange equipment.

Consider, for instance, the experience of the Western Kraft Paper Group (Oxnard, Calif.). The company had a boiler, built in 1938, which was nevertheless in good condition. But the flue-gas exit temperature was 500°F, resulting in a significant loss of heat. Western Kraft wanted to install a heat-recovery device, but the plant layout left almost no room for the necessary equipment.

Despite the space limitations, management finally decided to install an economizer in an outlet duct to reduce exit-gas temperature to 300°F. The work took two days—and it was laborious. As plant engineer Earl Shook puts it, "We had to squeeze it in with a shoehorn."

Was it worth the effort? The total installed cost was $60,000. But heat savings are 2,035,500 Btu/h—equivalent to $43,978/yr, with fuel oil at 33¢/gal.

FOREIGN EFFORTS—European and Japanese observers feel that traditionally higher energy costs in those regions have led to the use of process designs and equipment that are at least as energy-efficient as those employed in the U.S., if not more so.

Several British firms, for instance, have installed waste-heat boilers to replace fired heaters on various units. According to an oil-refinery spokesman, use of the recovered heat results in energy savings equivalent to one-third of the total fuel oil previously consumed.

In Japan, where the energy problem is even more pressing, the search for ways to save takes on an aura of urgency. A source at Showa Denko K.K. (Tokyo) says that "a few percent of energy saving may be possible by turning off lights, etc., but cuts of 10% or more require process modifications and improvements."

The Japanese firm has certainly gone far beyond turning off lights. It reports energy savings of 20% in metal production at its 40,000-metric-ton/yr, high-carbon ferrochrome plant in Chichibu, near Tokyo. The plant features a special prereduction step for chrome-ore roasting. This is said to halve electricity consumption, compared with a conventional electrolytic furnace fired with heavy fuel oil.

Showa Denko reports another 20% cut in energy consumption, at its 300,000-metric-ton/yr ethylene plant at Oita, Kyushu Island. According to the firm, this is done mainly by recycling steam.

PROCESS INTEGRATION—Energy-efficiency improvements need not be confined to a specific piece of equipment or part of a process. As Halcon's Huckins points out: "The process designer and the company's management must look beyond the battery limits of an individual processing unit to maximize steam utilization and conservation. We believe there are situations today where it is economically attractive to add equipment that can reduce the overall purchased energy-consumption per unit of product. Where there is energy to spare, a plant can add units to efficiently consume the surplus energy."

"Obviously," adds Huckins, "in developing such complexes, consideration should be given to generating some or all of the power requirements, along with the steam-heating needs."

This advice has been followed by Stauffer Chemical Co. (Westport, Conn.), whose plant in Carson, Calif., has earned an Industrial Concern Award for energy conservation from the Southern California Gas Co. (Los Angeles).

Stauffer uses acid sludge—a waste product collected from local refineries—and sulfur to produce sulfuric acid. In early 1976, the firm connected waste-heat boilers to two acid reactors in which sulfuric acid is generated. The boilers use heat from those reactors to make steam, which drives a turbine generator to produce electricity. This scheme generates about 2.5 MW—nearly all of the plant's power needs. And the company has reduced its annual electric bills by $500,000.

The waste-heat boilers also allow Stauffer to reduce the amount of water needed to cool the acid-reactor exhaust before it is released to the atmosphere. This is an added bonus in the drought-stricken West.

Some companies are even turning a profit from the sale of excess steam. Big Three Industries, Inc. (Houston, Tex.), for example, sells more than 2 million lb/h of medium-pressure steam exhausted from turbines in its air-separation plant to industrial users in the Bayport industrial district; the steam goes to process heating.

TWO IN ONE—A fuel switch and a special cogeneration agreement are combined in a $15-million power-generating facility, to be built at Celanese Corp.'s (New York City) plant in Pampa, Tex. The firm will first spend more than $50 million to replace its natural-gas-fired boilers with coal-fired ones. Then a nearby utility, Southwestern Public Service Co., will install a 30-MW steam-turbine generator. High-pressure steam from the new boilers will run the turbine, producing all of the plant's power requirements, and effluent steam, at lower pressure, will supply the plant's process heating.

This way, Celanese will obtain both its electricity and process steam from one installation. And the company says that the plan will save up to 50% of the normal energy requirements for generating electricity.

FUEL ALTERNATIVES—Many firms are, of course, planning to reduce their use of oil and natural gas as fuels. William van der Hoeven, operations manager for energy systems at Union Carbide's Chemicals & Plastics Div., says that one of the company's major energy-related projects is fuel switching aimed at reducing dependence on natural-gas supplies, improving Carbide's fuel-cost position, and conserving gas for higher-value petrochemical-feedstock use.

"The long-term objective," says van der Hoeven, "is to shift as much of our gas-fired boiler capacity as is practical to more-abundant, less-expensive coal. In the interim, however, we are switching from gas to fuel oil in order to provide the time needed for planning major capital investments to use coal in all new facilities."

From now through 1983, Union Carbide plans to spend $140 million to wean its facilities from natural-gas consumption. The company has earmarked an additional $75 million for major energy-conservation projects aimed at further reducing its total fuel requirements.

The entire program is designed to cut gas needs from about 60% of the total fuel demands to about 10% in 1985. Use of byproduct fuels, residues, steam and electricity would account, by that time, for 40% of Carbide's total energy requirements.

A good example of how Carbide plans to achieve this last goal is the new boiler installed at the firm's Brownsville, Tex., site. The unit uses aqueous chemical wastes as primary fuel to generate 600-lb/in² steam for process use. Combined with the burning of other chemical wastes in conventional boilers, operation of the new equipment enables the Brownsville plant to use 97% of its wastes as fuel, cutting natural-gas needs by 3 million ft³/d. This represents a fuel-cost saving of approximately $600,000/yr.

The Brownsville plant's new boiler blends chemical wastes—containing a heating value of 5,000 Btu/lb—with fuel oil in an 80:20 ratio. The final mix has a heating value of about 8,000 Btu/lb.

Philip M. Kohn

Converting gas boilers to oil and coal

A transition from gas-fired to oil- or coal-fired boilers requires extensive engineering to obtain satisfactory performance. Many factors must be considered, and new equipment is needed for the change.

Arlen W. Bell and *Bernard P. Breen*, *KVB Engineering, Inc.*

☐ Today, there is public pressure toward operating more boilers on coal—which is an abundant resource—rather than on oil or natural gas, both of which are scarce. Regulatory agencies will therefore ask plant managers and engineers to convert from gas to oil, or preferably to coal-burning boilers.

Natural gas and light distillate oils are in increasingly short supply, as proved by extensive shutdowns for lack of fuel, particularly in the winter of 1973. Even No. 6 fuel oil is considered a premium fuel due to increases in electric-utility demand.

Because of the complexities involved in each conversion, only elements to be evaluated and possible alternatives are presented here. Some relative cost estimates are also presented, but final decisions will undoubtedly be made for other reasons than the lowest steam-generating cost.

Considerations involved in boiler-fuel conversion are fuel availability, fuel purchase cost, environmental requirements, and socio-economic pressures.

For the boiler owner, the most important subject is cost. There may be overall increased product costs due to fuel-price increases, or production losses due to lack of fuel. Fuel costs to competitors may also prove to be significant.

Environmental requirements for low-sulfur oils and coals have further tightened the short- and long-term supply and have shifted geographical production plans. Environmental considerations have actually been responsible for the original shift to high natural-gas consumption, which is now being recognized as a waste of this valuable resource.

Socio-economic pressure on a local, regional or national level can also cause a change in fuel usage. There are strong justifications for maintaining local fuel sources in operation, or shifting to either more-economic or lower-sulfur fuels from a great distance (i.e., substitution of low-sulfur western coal for some of the higher-sulfur eastern coals.).

Technical problem areas

Many engineering problems must be solved in conversion of a gas- or oil-fired boiler to coal, but such problems can be solved by several alternate methods. Such problems can be grouped into three major classifications: coal handling and ash removal, boiler and related equipment, and emission control.

Coal handling and ash removal—Coal presents some unique requirements in contrast to gas and oil. Coal-storage areas for 30–90 days' supply are normally required, and mechanical conveying equipment is needed for transport from the storage area to the hopper, which is usually sized for a day's supply. Unlike oil, coal combustion generates large volumes of ash that must be temporarily stored in hoppers and shipped out for removal on a daily or weekly basis.

Boiler requirements—Each of the three fuels—gas, oil and coal—imposes unique requirements on the design of the boiler: the burner(s); fuel-supply system; accessory support-equipment such as soot blowers, forced-draft and induced-draft fans; and control systems. Particularly important is boiler-furnace sizing, as well as convective-tube spacing. A boiler designed originally only for gas firing may be almost impossible to convert economically to coal firing.

Emission-control requirements—Emission-control equipment is required to some degree on all boilers. For coal firing, the most troublesome area is the removal of ash and carbon carryover from the flue gas. SO_x control is usually done by limiting the sulfur content of the fuel. In the future, more-elaborate flue-gas cleaning devices, such as wet scrubbers, may be needed. NO_x control is ordinarily performed by burner design and minimum excess O_2 operation. CO can be controlled by proper air distribution to the burner(s), or coal grate.

Comparative efficiency—In general, conversion from gas or oil to coal will involve some loss in efficiency. For example, on boilers without combustion-air preheating, steam-generating efficiencies based on gross heating value are in the range of 81% for oil, 78% for gas, and 76% for stoker-fired coal. Efficiencies should be established by tests on operating boilers in normal service. Claimed efficiencies based on heat-transfer area, or tests on new boilers from factories, can be considerably higher than long-term, actual operating efficiency.

Fuel costs are really a larger economic factor than

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