Gasification: A Rediscovered Source of Clean Fuel

Natural gas is one of our most precious energy resources. Not only is it the cheapest and most versatile fossil fuel available but, perhaps most important, it is also the least polluting. As industry and utilities have been forced to meet ever more stringent air pollution regulations, this fortuitous combination of attributes has elicited a strong surge in demand for natural gas. Domestic consumption rose to 22.7 trillion standard cubic feet (1 scf = 28.3 liters) in 1971, an increase of more than 73 percent since 1961.

This increased demand has pushed natural gas producers and distributors to the limits of their capacity. Many distributors no longer accept new customers, and some are even restricting the amounts of gas available to their present customers. Others are meeting their requirements only by importing liquefied natural gas at prices (about $1 per 1000 scf) that are generally more than twice the U.S. rate. Proven U.S. reserves, furthermore, are sufficient for only about 13 more years at the present rates of consumption (although the American Petroleum Institute projects that 66 percent of U.S. reserves has not been discovered yet). Some studies indicate that by 1980, demand could outstrip supply by 20 billion scf per day.

Frequently, however, a crisis proves to be the catalyst for new technological developments. The potentially massive gap between natural gas supplies and demand has thus brought to the forefront a host of both old and new technologies for producing synthetic natural gas (SNG) from other fossil fuels. Industrial plants incorporating this technology should begin contributing to gas supplies within 2 years, and by 1985 may contribute as much as 15 percent of the total.

The basic chemistry of gasification is simple. Carbon from coal or naphtha—the petroleum fraction with a boiling point between 175° and 240°C —is combined with water at high temperature to form methane, the principal constituent of natural gas. The overall reaction requires several steps, however, and is much more complex.

Naphtha gasification is considerably simpler than coal gasification and is in a much more advanced state of development. Three different naphtha processes have been commercialized: the catalytic rich gas (CRG) process developed by the British Gas Council, the methane rich gas (MRG) process developed by Japan Gas Company, and the Gasynthan process developed by West Germany's Lurgi Mineraloeltechnik GmbH and Badische Anilin-und Soda-Fabrik AG. These processes are very similar in concept. The main difference is in the catalysts used.

Naphtha, Steam Form Synthetic Gas

In the generalized process, vaporized naphtha is superheated under pressure and catalytically desulfurized. The sulfur-free vapor is then reacted with superheated steam at high temperature (500° to 540°C) and pressure (34 atm) to form "synthesis gas"—a mixture of methane, hydrogen, and carbon monoxide—and carbon dioxide. This gas is then subjected to a catalytic methanation in which three molecules of hydrogen are combined with one of carbon monoxide to form more methane. After carbon dioxide and water are removed, the product gas is about 95 to 98 percent methane with an energy content between 980 and 1035 British thermal units (1 Btu = 1054 joules) per scf—the same as that of natural gas.

Each of the three processes has been proved possible in small-scale plants abroad, but there are as yet no commercial plants in this country. American utilities and gas producers have, however, ordered at least 25 such plants with a total capacity of more than 3 billion scf per day, and the first of these should begin production in less than 2 years. Some 17 of these plants will be based on the CRG process.

But these plants may represent no more than a stopgap to the natural gas crisis, for they themselves face a future feedstock shortage. Almost all of the naphtha to be used in these plants must be imported and is thus subject to both rigorous U.S. import quotas and the caprice of the producing countries. Increasing quantities of naphtha are also being used as raw material by the world chemical industry, and this competition will further limit the amount of naphtha available for gasification. Gas producers will thus be forced to seek more abundant supplies of raw material, and the sole suitable alternative is coal.

The United States has massive reserves of coal—enough to last more than 500 years at current rates of consumption. Yet much of this coal contains such high quantities of sulfur that environmental regulations prevent its use, or the energy content is so low that transportation of the coal to power plants is economically prohibitive. Conversion of this coal to sulfur-free SNG may thus prove to be the only feasible way to use it.

Coal gas has, of course, been successfully used in the past in the United States and, particularly, in Europe. In its manufacture, however, no attempt is made to maximize the production of methane. The product thus usually contains more than 50 percent hydrogen and carbon monoxide, and the energy content is never higher than 450 Btu per scf. Such gas is useful in some applications and may, in fact, eventually find widespread use for onsite generation of electrical power. But it is not interchangeable with natural gas, and it cannot be transported economically over long distances.

The basic thrust of modern coal gasification technology has been to optimize methane production by conducting the initial hydrogasification reaction at much higher temperatures and pressures than are used in the production of coal gas. There are five major processes for coal gasification, but only one—developed by Lurgi—has been commercialized, and then only in Europe. A commercial facility based on the Lurgi process may be operating in this country by 1976, however; El Paso Natural Gas Company, Houston, Texas, has announced that it will build a $250 million, 250 million-scf-per-day facility in northwest New Mexico and, subject to Federal Power Commission approval, construction should begin within a year.

The four U.S. processes are the Hygas process developed by the American Gas Association and the Institute of Gas Technology, Chicago, Illinois; the CO_2 Acceptor process developed by Consolidation Coal Company, Pittsburgh, Pennsylvania; the Bi-Gas process

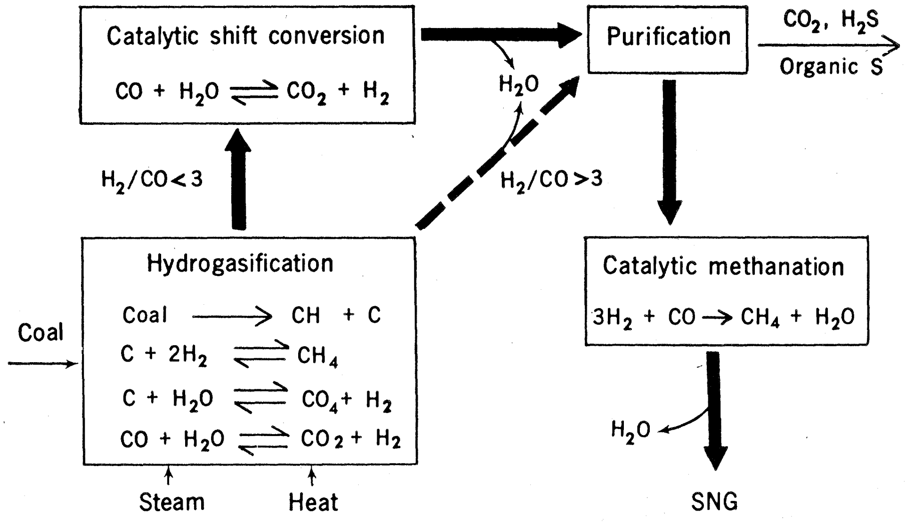

Fig. 1. A generalized flow chart for the gasification of coal. The scheme is similar for naphtha gasification, except that desulfurization occurs first.

developed by Bituminous Coal Research Inc., Monroeville, Pennsylvania; and the Synthane process developed by the U.S. Bureau of Mines. Major funding for the first three processes has come from the Interior Department's Office of Coal Research (OCR), which has spent about $40 million on coal gasification during the past 11 years and is expected to spend another $125 million by 1975. The Hygas and CO_2 Acceptor processes are being tested in pilot plants; construction was begun this summer on a pilot plant for the Bi-Gas process, and the design work for a Synthane pilot plant is nearly complete.

The Lurgi process is based on technology that was originally developed in the 1930's for the production of coal gas. The technology has been updated, but the reactor is still a low pressure (28 atm), fixed-bed unit with a very small capacity. Consequently, a 250 million-scf-per-day plant based on the Lurgi process requires 31 gasifiers, whereas a comparable plant based on U.S. technology requires only two or three. Although the initial cost of the two plants is comparable, the Lurgi plant would thus be expected to require much more maintenance and may also be less reliable.

All of the U.S. processes have been proved feasible on a laboratory scale. The various pilot plant programs will attempt to solve the mechanical and chemical engineering problems inherent in scaling a laboratory reaction up to commercial size. The programs will also permit assessment of the economic feasibility of the processes.

The basic unit in each process is the gasifier, operating at pressures ranging from 20 to more than 70 atm and temperatures as high as 1500°C. In the generalized reaction scheme (Fig. 1), coal is admitted to the reactor under pressure and brought into contact with synthesis gas at temperatures of 600 to 800°C to drive off volatile components. The system may be designed to convert these components to methane or to capture them for use by the chemical industry.

The devolatilized coal is then transferred to the second stage of the reactor, where it is brought into contact with steam at temperatures greater than 900°C to form synthesis gas containing 40 to 65 percent methane. If necessary, the synthesis gas is subjected to a catalytic shift conversion similar to that employed in naphtha gasification. Carbon dioxide, hydrogen sulfide, organic sulfides, and water vapor are then stripped from the gas, and it is subjected to catalytic methanation. After further removal of water, the product is identical to the SNG produced by naphtha gasification.

The principal differences between the processes include the manner in which the coal is admitted to the gasifier, the type of reactor bed used (fixed or fluidized), and the source of heat for the gasification reaction. In the Hygas process, for example, the coal is admitted as a slurry in organic solvents, while in the other processes it is admitted as powder or lumps through a lock-hopper. In the Hygas and Synthane processes, moreover, some types of coal must be treated beforehand to prevent agglomeration in the reactor. Heat for the gasification process is generally provided by burning char—partially gasified coal—in either oxygen or air. In the CO_2 Acceptor process, however, heat is supplied by the exothermic reaction of calcined dolomite (CaO) with carbon dioxide to produce dolomite ($CaCO_3$).

Each pilot plant, furthermore, will incorporate a different system for shift conversion, cleanup, and methanation. By the time a proposed 60 to 70 million-scf-per-day demonstration plant is operating in 1976, therefore, most potentially useful processes will have been tested, and the best can be incorporated in the plant. It is quite possible, though, that no one process will be best in all cases. The CO_2 Acceptor process, for example, currently seems best suited for the more reactive lignite and subbituminous coals found in the western United States, whereas the Bi-Gas process appears best for eastern bituminous coals.

Numerous engineering problems have been encountered in operation of the pilot plants. Foremost among them has been the problem of melding all the subprocesses into a continuous one operating at high temperatures and pressures. Other problems have included structural failures and corrosion at high pressures, packing of the reactor beds caused by agglomeration of the coal, and the mechanical problems of transporting the coal through the system.

Despite these problems, OCR is optimistic about progress at the pilot plants. If work continues on the present schedule and at present funding levels, says Edward Larson, chief of OCR's division of contracts and administration, design of a $250 million, 250 million-scf-per-day plant (to be built with private funds) could begin by 1977, with the first such plant going into operation by 1981. From 12 to 37 such plants could be in operation by 1985, he suggests, with a total production of more than 9 billion scf per day.

Many subsidiary benefits could arise from the construction of such plants. Since all the materials used in the plant are domestic, they would help ease the growing balance of payments deficit. Total capital investment for each plant, including mines to produce 15,000 tons of coal per day per plant, will approach $350 million, bringing a modest boom to the chemical construction industry and pouring hitherto unprecedented amounts of capital into the economically depressed regions where most coal resources are located.

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