Underground Gasification: An Alternate Way to Exploit Coal

Standing in the middle of the Wyoming highlands about 140 kilometers northwest of Hanna is a pipe about twice as tall as a pickup truck. From it spews a flame more than twice again as tall as the pipe itself. On a clear night, light from the flame can be seen from the distant Laramie Range, and its roar shatters the desert air like a fully loaded Concorde SST taking wing. The pipe flares off gas from an experimental underground coal gasification project operated by the Laramie Energy Research Center (LERC). It is the visible and audible symbol of a technology that may prove the ideal way to exploit low-grade coal resources throughout the West.

This is the second of three articles exploring unconventional approaches to fossil fuels.

Underground coal gasification, commonly called UCG, is not a particularly new technology. The Russians began developing the technique in the 1930's and have been operating two full-scale electric generating plants fueled by gas from UCG since the 1950's. Some work was done in this country in the 1940's at a site near Gorgas, Alabama, but the project was aborted because of the poor properties of eastern coal and the then unfavorable economics of the process. Work on western coals began in earnest only about 5 years ago, but the results of the first tests have been so promising that construction of commercial facilities in the near future seems all but inevitable.

The lion's share of work on UCG in the United States has been carried out by the LERC group, which is headed by Charles F. Brandenburg. The method that they have developed is conceptually quite simple. Two wells, between 20 and 50 meters apart, are drilled to the base of a coal seam (Fig. 1). Lighted charcoal is dropped into one well to ignite the coal, and air is injected into the second well. Wyoming coal is sufficiently permeable that air from the second well seeps to the first well and draws the flame front toward it.

By this process, known as reverse combustion, the two wells are linked at or near the base of the coal seam by a channel as large as 1 meter in diameter. Once the link is made, the fire expands and eventually consumes all the coal between the wells. By appropriate control of the flow rate of the injected air, it is possible to obtain partial combustion of the coal so that low-energy gas is emitted from the first well. The linking process takes about 10 to 12 days for wells 20 meters apart (during which time gas is also produced); the time required for gasification of the entire seam is dependent on well spacing and the thickness of the seam. The principal variations of this process involve the manner in which the wells are linked. Alternative methods of linking include conventional hydrofracturing, directional drilling, and detonation of shaped charges.

Because air is injected into the wells, the product gas contains substantial quantities of nitrogen. Its energy content thus ranges from about 100 British thermal units per standard cubic foot (1 Btu/scf = 2.98×10^5 joules per cubic meter) to as much as 170 Btu/scf. This energy content is too low for economic transportation of the gas for any substantial distance, and therefore the gas will probably be used on-site. The most likely use is as a fuel for electric power plants. In the preliminary experiments, the gas has simply been flared off.

The LERC group has so far conducted three underground burns in a 10-meter thick subbituminous coal seam 130 meters deep, and they are now in the middle of a fourth. The first test, called Hanna 1, was conducted between wells 20 meters apart. It consumed about 5000 tons of coal over a 1-year period and produced 3 million scf of gas per day with an average energy content of 126 Btu/scf. Hanna 2 was conducted with four wells arranged in a square with 20-meter sides. It consumed 4200 tons of coal over a 3-month period and, at its peak, produced 12 million scf of gas per day with an energy content as high as 170 Btu/scf—the highest value that had ever been obtained in UCG with air injection.

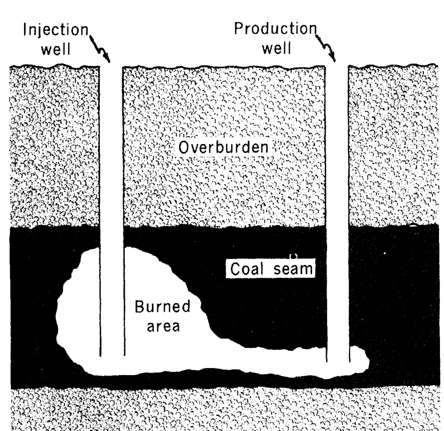

Fig. 1. A schematic for reverse combustion underground coal gasification. The link between the wells has already been made and gasification of the entire seam is beginning.

These two tests seem to establish that UCG is a viable way to exploit subbituminous coal seams. The process, Brandenburg says, had an overall efficiency of 60 to 65 percent: about 80 to 85 percent of the coal was consumed, and about 80 to 85 percent of the energy thus produced was recoverable. In underground mining, in comparison, only about 50 percent of the coal in a seam is recovered. The gasification process yielded between 4.5 and 5.3 Btu of energy for each Btu invested. A large-scale installation, Brandenburg says, should yield about 8 Btu for each Btu invested; again, this is comparable to underground mining. Subsequent experiments were thus designed to explore the parameters for commercial production.

Hanna 3 was an environmental test of UCG. The burn was initiated last June in a portion of the coal seam that is a natural aquifer. The burn was quenched after about 2 months, and water was injected into the cavity to restore water levels to what they had been before the test—a process that would have required 1 to 2 years of normal rainfall. The site will be monitored for 18 months to determine the effects of gasification on water quality.

Hanna 4, initiated in October, is a larger test to determine optimum spacing between wells. The three production wells are in a straight line separated by distances of 33 and 50 meters. The two closest wells were linked first; while that coal is being gasified, the third well will be linked to the system. The test will run until March and is expected to produce about 27 million scf of gas per day at peak production.

The fifth and largest test, which will be begun in 1 to 2 years, will have nine wells and should produce as much as 75 million scf of gas per day. One of the major objectives will be to determine optimum spacing between adjacent sets of wells. The investigators also hope to study ways to remove the very small amount of sulfur present in the gas and to look at ways to use the gas in turbines or boilers. One alternative now being considered is solicitation of industry participation in construction of a 25- to 50-megawatt demonstration power plant to use the gas. The electricity would be transmitted to an existing transmission line a few kilometers away. Such a plant, says LERC director Andrew W. Decora, would be about a quarter to half the minimum size of a commercially viable facility.

Most other UCG projects in the United States have been attempts to adapt this basic technology to other types of coal and to explore alternative methods of linking the wells. Douglas R. Stephens and his associates at Lawrence Livermore Laboratory, for example, have conducted one burn in a 50-meter-deep subbituminous coal seam at Hoe Creek near Gillette, Wyoming, and are now in the process of conducting a second burn. The coal at Hoe Creek contains about 30 percent water, compared to an average of about 10 percent at Hanna. More energy is thus required to gasify the coal, Stephens says, and the overall efficiency of the process is slightly lower. Explosive fracturing was used in the first test to stimulate permeability in the coal seam, but the results were not as good as the group had expected, and reverse combustion was used in the test now in progress. The Livermore group plans to do further work on explosive fracturing this winter, however, detonating shaped charges in wells and abandoned mines (Fig. 2). Sometime during the current burn, moreover, they will inject pure oxygen into the underground chamber to study the feasibility of producing gas with an energy content of 300 to 400 Btu/scf. If this medium-energy gas could be produced, it might be used as a feedstock for the chemical industry or upgraded to produce synthetic natural gas.

James Jennings of Texas A & M University has conducted smaller experiments in lignite deposits on the Texas Gulf Coast. He began this past fall with wells 3 meters apart in a 2-meter seam, 130 meters deep, and is now preparing a test with the wells 10 meters apart. His results show that lignite can be gasified successfully, but that problems can arise if the overburden cannot support itself. In addition to examining some of the local problems, Jennings is concentrating on training students so that they will have had experience in the actual operation of an underground process.

Lawrence Strickland and his colleagues at the Morgantown Energy Research Center in West Virginia are planning a test of UCG in bituminous coal deposits in September or October of 1978. For several reasons, bituminous coals are more difficult to gasify in situ. The seams are deeper and thinner than those of the western coals, and bituminous coal swells and cakes when it is heated, reducing whatever permeability has been created by fracturing. The first tests, for example, will be in a 2-meter seam 300 meters deep.

Fig. 2. Scientists from Lawrence Livermore Laboratory are studying the fracturing of coal seams with chemical explosives at this coal outcrop of the Kemmerer Coal Company in Kemmerer, Wyoming. [Source: Lawrence Livermore Laboratory]

Laboratory tests have indicated that reverse combustion may work in the bituminous coals, but it may be necessary to employ what is known as the longwall generator concept. In this approach, a well is sunk to the seam; then the direction of drilling is shifted so that the well continues in the plane of the seam. If two wells were sunk in parallel 10 to 20 meters apart, it would then be possible to gasify the coal between them. The primary problem with this approach is that the technology for directional drilling is not highly refined. Investigators at Morgantown have succeeded in keeping a well in a 2-meter seam for a distance of 170 meters, but the process was slow and expensive. Strickland thus concludes that development of UCG technology for eastern coals is at least 2 years behind that for western coals.

Other countries are also exploring this approach. Albert A. Roehl and his associates at the Alberta Research Council in Canada conducted an underground burn in 1976 in low-grade bituminous coal near Forestburg, Alberta. Roehl's group, which is sponsored by 11 companies and four different levels of government, plans a larger burn next summer. That will be followed in a year or two by a still larger burn in an attempt to determine optimum spacing between wells and to develop a multiwell gas generator. Two European groups, the Institut National des Industries Extractives in Belgium and the Kernforschungsanstalt in West Germany, are planning an underground burn next summer in the Borenaga coal fields in southern Belgium. Like the Alberta group, they will use a variant of the LERC technology. In at least one experiment, however, they plan to inject hydrogen into the wells instead of air to explore the feasibility of generating synthetic natural gas.

The sole exception to this general use of LERC technology is the process developed in the Soviet Union. The Soviets have been rather closemouthed about the details of their technology, but it is known that it involves the linking of several wells by pneumatic fracturing of the coal through injection of air at high pressures. They have used the technology successfully on lignite seams several hundred meters deep, producing gas with an energy content of about 100 Btu/scf.

In 1975, Texas Utilities Services Inc., an affiliate of three Texas electric utilities, purchased an exclusive license for use of Soviet gasification technology in the United States for $2 million. The company, says president Perry Brittain, has since been working to adapt the process to Gulf Coast lignite. They completed a small test, about the size of Hanna 1, in 1976 at a site near Fairfield, and Brittain says the company is pleased with the results. Both the quantity and the quality of the product gas were predictable, he says, and the overall results indicated that the process can be applied in Texas. Texas Utilities is now preparing to file for permits to conduct a larger test, about the size of Hanna 4, to get a better idea of the economics of the process.

Those economics may be the critical problem with the Soviet process. The Soviet economy is structured in such a manner that cost effectiveness is not necessarily a consideration in the establishment of projects such as the UCG power plants. Some observers thus speculate that the cost of gas from the Soviet process may be higher than that from the LERC process. Beyond that, the consensus seems to be that the Soviet process is neither better nor worse than the LERC process. Its chief advantage is the years of experience that have been accumulated in its use, experience that may be sufficient to outweigh a slightly greater cost.

There are several potential problems with either the Soviet or the LERC process, but none of them seem too serious. One of them is the potential for subsidence of the overburden as the supporting coal is burned away beneath it. Decora estimates, for example, that burning a 10-meter seam 200 meters underground might produce a subsidence of about 1 meter. This would be a problem not only because of its effect on the landscape, but also because subsidence during gasification could allow gas to leak out of the chamber and disrupt the process. Initially, this problem might be avoided if the sites are chosen so that the overburden is strong enough to support itself. Another approach might be gasification of deep seams at sites where shallow seams have been strip-mined. Any damage from subsidence could thus be repaired when the surface was recontoured from the mining.

Another potential problem is water pollution. There has been concern that by-products of the gasification process, particularly aromatic hydrocarbons and phenols, would contaminate aquifers near the site. According to Stephens, however, this may not be as big a problem as it once appeared. Results from initial tests suggest that unburned coal in the seams adsorb these by-products much like activated charcoal, so that few pollutants escape the site. The Soviets have experienced no water pollution problems, even though they have gasified deposits very close to the municipal water supply of Angren in the Uzbeckistan Republic.

In sum, then, the technology for UCG will apparently be readily available in the very near future, and the sole remaining question will be the economics of the process. These should be relatively good. The capital investment for a UCG project should be sharply lower than that for a surface gasification plant of comparable capacity. UCG would have the additional advantage that gasification can be started as soon as part of the drilling is completed, whereas no gasification can be performed in a surface plant until the entire plant is finished.

Texas Utilities obviously thinks the economics look favorable, as do most of the other investigators. Apparently this view is shared by some of the major energy companies. Few of them are willing to discuss their plans, but at least two companies are thought to be contemplating their own tests of UCG, and they and other companies are believed to be investigating the acquisition of coal resources that would be suitable for UCG. As is the case with oil shale, it is easy to be overoptimistic about the prospects for UCG. Nonetheless, it would appear that at least some of that optimism is justified and that underground coal gasification stands a very good chance of becoming a commercial reality.—THOMAS H. MAUGH II

Oil in the Ocean: Circumstances Control Its Impact

What happens to oil entering the ocean and how it affects marine life are among the most complex problems in environmental research today. New analytical sophistication and the increasing duration of studies on spills have allowed investigators to clarify some long-term, subtle effects of petroleum in a number of situations. A striking finding of this work is that oil from major spills disperses rapidly and has minimal effects in some areas, such as open coastal waters, but may persist and remain toxic for many years in protected coves and marshes. Even in the latter areas, the original biological communities appear to return to normal as the oil is dispersed and degraded, sometimes within 5 to 10 years of the spill. A major type of oil pollution, the chronic discharge of oil into estuaries and coastal zones, is receiving less intensive study.

Although it is generally agreed that tanker accidents are responsible for only a few percent of the oil entering the ocean, large spills from tankers have received much attention from researchers. Among the more thoroughly studied spills are the *Argo Merchant* spill in shoal waters off Nantucket in December 1976, the *Florida* spill near the marshes of West Falmouth, Massachusetts, in 1969, and the *Arrow* spill in Chedabucto Bay, Nova Scotia, in 1970.

Each of these spills involved different refined petroleum products and each encountered a different physical environment. The *Argo Merchant* carried a heavy fuel oil, which was nearly congealed when it was spilled in the open waters of Nantucket Shoals. Prevailing winter winds moved the oil, which had "pancaked" in large lenses on the surface, toward the southeast where it was picked up first by a slowly rotating Gulf Stream ring and then by the Gulf Stream itself. None of the oil ever touched land, and the slick was never sighted again.

The barge *Florida* spilled lighter, more toxic fuel oil, which was driven by winds onto the sandy beaches and into the peaty marshes of Cape Cod. The *Arrow*'s heavy fuel oil was whipped into a frothy water emulsion, dubbed "chocolate mousse," as it was swept onto the rocky, storm-churned shores and quieter lagoons of Chedabucto Bay.

Researchers have found that spilled oil not only mixes with water and sediments but that it also undergoes changes in its chemical composition. Studies of possible biological effects demand that the composition of such altered, or weathered, oil be analyzed in the greatest detail possible. An increasingly important tool in such analyses is the combined use of gas chromatography and mass spectroscopy (GC-MS) in place of simpler methods to identify and measure the components of oil.

Crude oil is a mixture of many tens of thousands of different chemical compounds containing hydrogen and carbon. Some of these compounds may contain oxygen, nitrogen, or sulfur. Their properties vary over a continuous range depending on their molecular structure and size. Products as diverse as gasoline and asphalt result from the distillation of a single crude oil. After making a preliminary extraction of oil from a sample, investigators use gas chromatography to sort out individual compounds and groups of very similar compounds on the basis of these varying properties, specifically volatility and chemical affinity for an adsorbent. Then the sorted com-