POTENTIAL FOR UNDERGROUND COAL GASIFICATION IN THE SOUTHWEST

E. A. Walters and H. E. Nuttall

Departments of Chemistry and Nuclear and Chemical Engineering

University of New Mexico, Albuquerque, New Mexico 87131

INTRODUCTION

In occasional outcroppings and beneath the surface of the high plateaus and just west of the southern Rocky Mountains are large deposits of sub-bituminous coals. These coals were formed in the estuaries, swamps, and lagoons at the edges of the extensive epicontinental sea of the Late Cretaceous Period. Many millions of tons of this coal lie strippable depths (overburden is less than 250 feet), but perhaps 90% of the total deposits lie deeper. These deposits will probably only be tapped if underground gasification proves feasible. In this paper the question of the suitability of Southwestern coals for underground gasification is examined.

COAL RESERVES

The coal fields of the United States are shown on the map in Figure 1. Of the sub-bituminous basins in the Southwest the largest and most extensive is the San Juan Basin located in northwestern New Mexico. This study focuses attention solely on the San Juan Basin. The San Juan Basin is somewhat arbitrarily subdivided into 19 separate coal fields or coal areas, Figure 2. The general orientation of the fields is an exposure of coal seams on the western edges at elevations of 7,000 or more feet above sea level dipping gently but steadily to the east at an incline of 2 to 6 degrees. At the eastern extremities the lowest Cretaceous beds lie some 2,000 feet below sea level.

Stratigraphically the deposits are very complex. The coal beds are highly lenticular, a consequence of their formation from peats at the edges of Cretaceous swamps or estuaries. The lenses tend to be long and narrow and reflecting the irregular shape of Mesozoic costlines. Lengths vary from 1 to 30 miles and widths from 1/2 to 5 miles. At their thickest the lenses rarely exceed 12 feet, though isolated examples of seams as thick as 22 feet are known, and the most common thickness are between 3 and 6 feet. Lenses are stacked one above the next so that generally the thin portion of one overlies a thicker section of one beneath it. The deposit between seams is a wide variety of coastal sedimentary rocks, for example sandstones, shales, siltstones, and limestones. Seams themselves are frequently infiltrated with fine layers of clays or other sedimentary deposits. Interspersed between the major lenses are numerous thin seams of coal. Detailed stratigraphy varies drastically from site to site and is known well only for a few locations. The fundamental geologic structure is simple, however, and the basin is generally free from faults (1,2,3).

The coals of the San Juan Basin consistently fall into the range of sub-bituminous A or B in the deepest beds to high-volatile C or B bituminous nonagglomerating coals near the surface (2). In this respect and with regard to the low sulfur content (generally less than 1% of which half is typically organic sulfur) these coals are suitable for gasification.

The Southwest is a semi-arid region; annual precipitation in the coal basin is 4-6 inches. The only perennial stream in the entire San Juan Basin is the San Juan River itself which rises in southern Colorado and crosses the northwest tip of the coal basin before continuing westward to the Colorado River. In the coal bearing areas only normally-dry arroyos feed the San Juan River. The aridness carries over to the coals which at strippable levels have moisture contents that average in the 12-15% range (3). There are no important aquifers at strip mining depths, the first aquifers lie about 1200 feet below ground surface. This water is of very low quality, but it is usable for livestock watering. There are persistent but largely unconfirmed reports of sporadic artesian activity in the basin. However, movement of ground water in the vicinity of most of the seams is restricted to a few feet per year.

There is coal at varying depths throughout the basin as pointed out above. The amount lying within 250 feet of the surface is estimated to be 5.97 billion tons (4). That lying between 250 feet and 3000 feet is estimated to be 122 billion tons while the amount still deeper is expected to be approximately double that amount (3,5). It is evident that in excess of 90% of the San Juan coal lies in deep seams.

The entire basin lies in a region of low population density and possess minimal agricultural value. The latter feature can be illustrated by the computation that the livestock carrying capacity of the western portions of the basin is about one adult sheep per 55 acres (3). The population density of the region is slightly more than seven people per square mile; this figure includes several sizable muncicipalities, so the population density of the vast open areas of the basin is very low indeed.

GASIFICATION PROPERTIES OF SAN JUAN COAL

Several properties of New Mexico's San Juan coal have been investigated and compared to Wyoming sub-bituminous coal in which successful in situ gasification tests have recent been performed by the Laramie Energy Research Center. In addition to chemical analysis, the properties compared are permeability, the extent of fracturing during pyrolysis and the apparent devolatilization rates.

As a first consideration in comparing New Mexico's San Juan and Wyoming's Hanna sub-bituminous coal, the chemical analysis and heating values of deep seam coals from both locations are very similar as shown in Table 1. San Juan coal, however, did exhibit a lower moisture content but this factor tends to vary widely depending upon sample handling.

Coal permeability is an important parameter for the in situ process. Western sub-bituminous coals typically display moderate permeability upon drying. The axial permeability of New Mexico's sub-bituminous coal was experimentally and the resulting values are presented in Table II. The measured permeabilities for dry samples compare favorably to values reported by Rozsa (6) for Wyoming Wyodak coal and to values published by Schrider, et. al., (7) for Hanna, Wyoming sub-bituminous coal. The nitrogen permeabilities were in the range of 1 to 5 darcies for coals from all these sources. This rather high natural permeability of sub-bituminous coals seems to result from cracks and fissures exposed during dehydration of the coals.

Devolatilization studies of San Juan coal have been performed recently and the results compared to Wyoming sub-bituminous coals. Coal devolatilization rates were determined by measuring the weight and product gas composition history of one inch diameter coal particles. The single particle reactor and system are shown in Figure 3. The reactor and its operation have been described elsewhere (8). Briefly, the sample is placed in a basket suspended from a load cell which is interfaced to a PDP-11 computer signal for data storage. Carrier gas is introduced at the desired temperature through a fluid heater. Thermocouples and pressure transducers located at various points are also interfaced with the computer so continuous temperature and pressure recorded is maintained. Product gases were sampled and collected and then analyzed either on a mass spectrometer or a gas chromatograph.

From these studies two factors relating to coal reactivity were observed. First from examining specially prepared and cross-sectioned samples of pyrolyzed particles, an extensive network of fissures and cracks was observed. Similar internal fissuring was also reported by Campbell (9) for Wyoming sub-bituminous coal. He found internal surface area increased from 4 to 200 m^2/g during pyrolysis of the coal. The observed immense increase in internal particle surface area accounts in part for the high reactivity of western sub-bituminous coals. Shrinking coals generally exhibit large surface area increases upon devolatilization.

The devolatilization rate of San Juan coal has also been measured by using weight data obtained from the single particle reactor mentioned previously (10). Comparison data but for smaller coal particles has also been taken using Wyoming coals. Both San Juan and Wyoming sub-bituminous coals exhibit similar devolatilization rates.

From these preliminary laboratory comparisons of San Juan and Wyoming coals, it appears that New Mexico's sub-bituminous coal behaves in a similar manner to the Wyoming coals which have recently been successfully gasified underground.

OTHER FACTORS INFLUENCING IMPLEMENTATION OF UNDERGROUND GASIFICATION IN THE SOUTHWEST

In addition to questions about coal reactivity, seam structure and stratigraphy, and quantities of reserves, several other factors are important in determining the likelihood of the actual implementation of underground gasification in the Southwest. First, there are environmental considerations. Sulfur content of these coals is low and approximately half of it is organic sulfur, so problems arising from this element will be minimal. Subsidence is very likely to occur but it should not be a problem because the land has little aesthetic value and currently has no agricultural value except for low density support of cattle or sheep. The impact on ground water is less clear. There are aquifers in the region, but most of these are deep and migration of water to them from gasification residue is unlikely. If gasification is conducted below the known aquifers then mechanisms exist for contamination of the water. Just how serious this might be is an unanswered question that must be addressed soon.

Secondly, gasification of coal with such a consistently low moisture content has not been well studied. Water plays a minimal role in the initial devolatilization but can be crucial in determining the nature of the product gas of the higher temperature gasification phase. In the Hanna tests there have always been rather large quantities of moisture in the reaction zone which can lead to a reductive reaction with coal. This will generally not be a possibility in the San Juan Basin.

Next, the southern and western portions of the country are those that are growing most rapidly, and ranking high among these are the areas around Phoenix and Tucson plus much of southern California. Southwestern coal is the closest sources of fossil energy available for the generation of electrical power demanded by these centers. Consequently, it is very likely the Southwestern coal will be consumed at ever increasing rates to meet an expanding regional demand for electrical power.

In the southwestern region a number of large power plants are presently operating on strip mined coal. As an example, the Four Corners Complex for electrical generation is fed by the Navajo mine which is the largest coal mine in terms of production in the United States. The current production rate is approximately 7 million tons per year. All of this coal is used to generate 2,100 megawatts of electrical power. The Four Corners Complex is a jointly owned enterprise in which 48% of the power goes to Southern California Edison, 15% to Arizona Public Service Co., 13% to Public Service Company of New Mexico, 10% to Salt River Project and 7% each to Tucson Gas and Electric and El Paso Gas and Electric. Since the distribution of power generated in the San Juan Basin is established and the demand is increasing, this serves as an incentive for the development of the deep seam coal reserves through underground gasification.

Lastly, the potential market four southwestern coal is expanding not only because more people in the Southwest are requiring more electrical power, but also because the natural gas and oil supplied in the region are dwindling. Since an extensive pipeline network runs from this region. BTU gas and/or liquid fuels generated by underground methods could readily be shipped to distant consumers. Recognition of this fact has already been a major incentive for proposed sufrace gasification facilities and could well be a determining factor for the commercialization of underground gasification in the Southwest.

Summary

Laboratory studies of samples of San Juan (New Mexico) and Hanna (Wyoming) sub-bituminous coals reveal strong similarities in permeability, devolatilization reactivity, and fracturing when subjected to simulated underground gasification conditions. The results suggest that San Juan basin coal can be expected to gasify in a manner similar to Wyoming coal. The seam and bed structures are vastly different in the San Juan basin and the limitations imposed by thin, multiple seams that have low moisture content are not clear. On the other hand, underground gasification is a viable alternative from the point of view of environmental and economic considerations. More detailed reactivity studies of various coals of the basin and much more stratigraphic information followed by field tests are required before a definitive statement can be made about underground gasification in the Southwest. What can be said now is that indications are mixed, but tend to be positive.

REFERENCES

1. U.S. Energy Outlook - A Summary Report of the National Petroleum Council, National Petroleum Council, Washington, DC, 1972, pp. 135-171.

2. F. E. Kottlowski, J. W. Shomaker, and E. C. Beaumont, "New Mexico Coal Resources," in 1973 Keystone Coal Industry Manual, McGraw-Hill, Inc., 1973, pp. 503-510.

3. F. E. Kottlowski, "Report of the Coal Resources Committee," Governor's Energy Task Force Publication, NM Energy Resources Board, June, 1975.

4. E. C. Beaumont, "The Impact of Coal on Northwestern New Mexico," in Shomaker, et.al., Strippable Low Sulphur Coal Resources of the San Juan Basin of New Mexico and Colorado, NM Bureau of Mines and Mineral Resources, Memoir 25, 1971.

5. F. E. Kottlowski, "Annual Report for the Fiscal Year July 1, 1973 to June 30, 1974," NM Bureau of Mines and Mineral Resource, 1975.

6. Rozsa, R. B., "Overview of Laboratory Experiments in Support of the Lawrence Livermore Laboratory In-Situ Coal Gasification Program," Lawrence Livermore Laboratory, UCID-16845, July 15, 1975.

7. Schrider, Leo A., and J. Pasini III, Underground Gasification of Coal Pilot Test Hanna, Wyoming, American Gas Association Fifth Synthetic Pipeline gas Symposium, October, 1973.

8. H. E. Nuttall, W. G. Stoddart, and W. J. Chen, "Reactivity and Kinetics of Subbituminous New Mexico Coal". Department of Chemical and Nuclear Engr., University of New Mexico, Albuquerque, New Mexico.

9. Campbell, J. H., "Pyrolysis of Sub-bituminous Coal as it Related to In-Situ Gasification (Part 1: Gas Evolution)," Energy and Technology Review, 1 April, 1976).

10. Stoddart, Wendell, A Reactivity and Kinetic Comparison of Large Single San Juan and South African Sub-bituminous Coal Particles," M.S. Thesis, The University of New Mexico, 1977.

TABLE I

Analysis of San Juan and Wyoming Core Coals

	NM Core	Wyoming Core
Proximate Analysis		
% Moisture	3.22	7.82
% Ash	4.06	8.21
% Fixed Carbon	56.02	49.57
% Volatile Matter	39.92	42.22
Ultimate Analysis (Dry and ash-free basis)		
% Carbon	79.34	73.68
% Hydrogen	5.34	5.69
% Oxygen	12.60	18.22
% Nitrogen	1.72	1.82
% Sulfur	0.45	0.60
Calorific Value (Moisture free), Btu lb^{-1}		
	13,801	11,641

TABLE II

Permeability of San Juan Core Coal

Gas	B_o, darcys
air	3.45
N_2	3.66
Ne	11.09

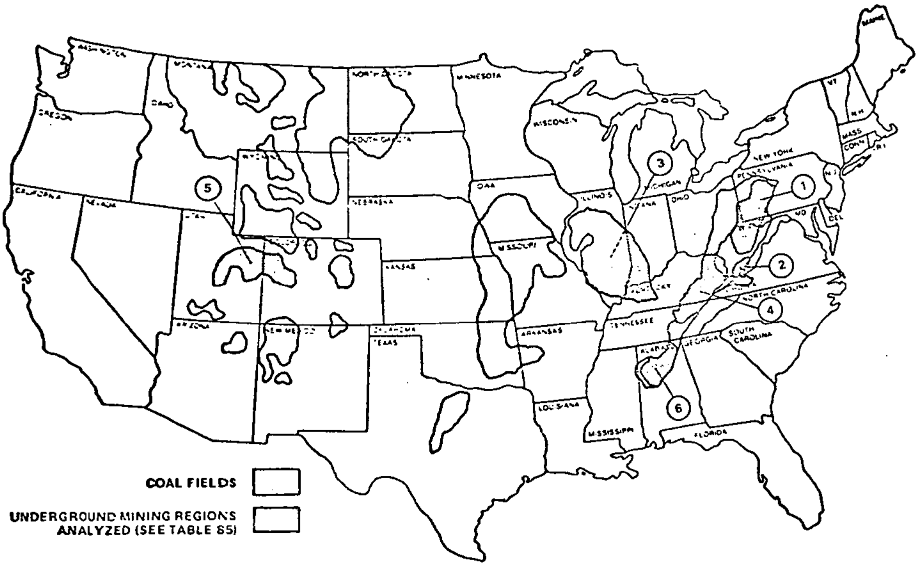

COAL FIELDS
UNDERGROUND MINING REGIONS ANALYZED (SEE TABLE 85)

Figure 1

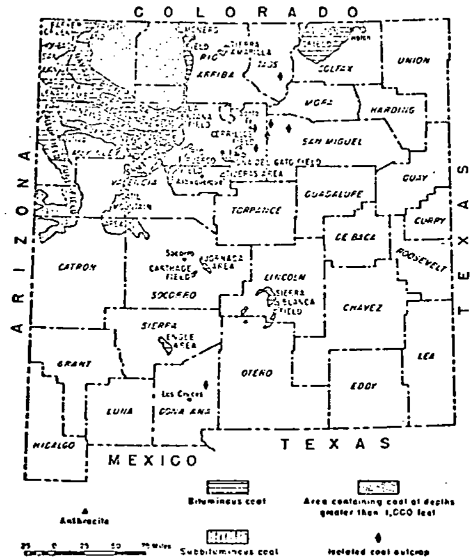
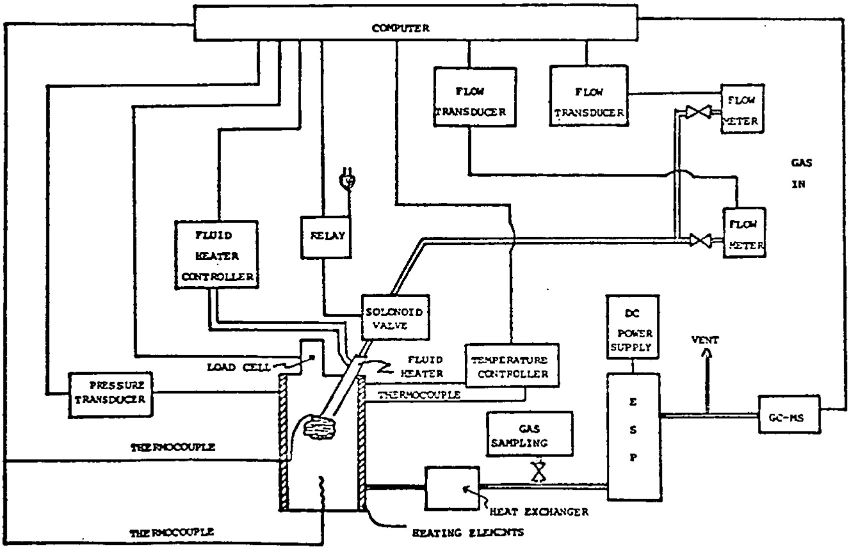

COLORADO
ARIZONA
TEXAS
TEXAS
MEXICO
UNION
COLFAX
MORA
HARDING
SAN MIGUEL
QUAY
GUADALUPE
TORRANCE
CURRY
DE BACA
ROOSEVELT
CATRON
SOCORRO
LINCOLN
CHAVEZ
SIERRA
GRANT
OTERO
EDDY
LEA
LUNA
DONA ANA
HIDALGO
Las Cruces
Socorro
Bituminous coal
Area containing coal at depths greater than 1,000 feet
Anthracite
Subbituminous coal
Isolated coal outcrop

Figure 2



SCHEMATIC DIAGRAM OF COAL PARTICLE GASIFICATION REACTOR AND SUPPORTING EQUIPMENT.

Figure 3