WYOMING COAL AND ITS USES

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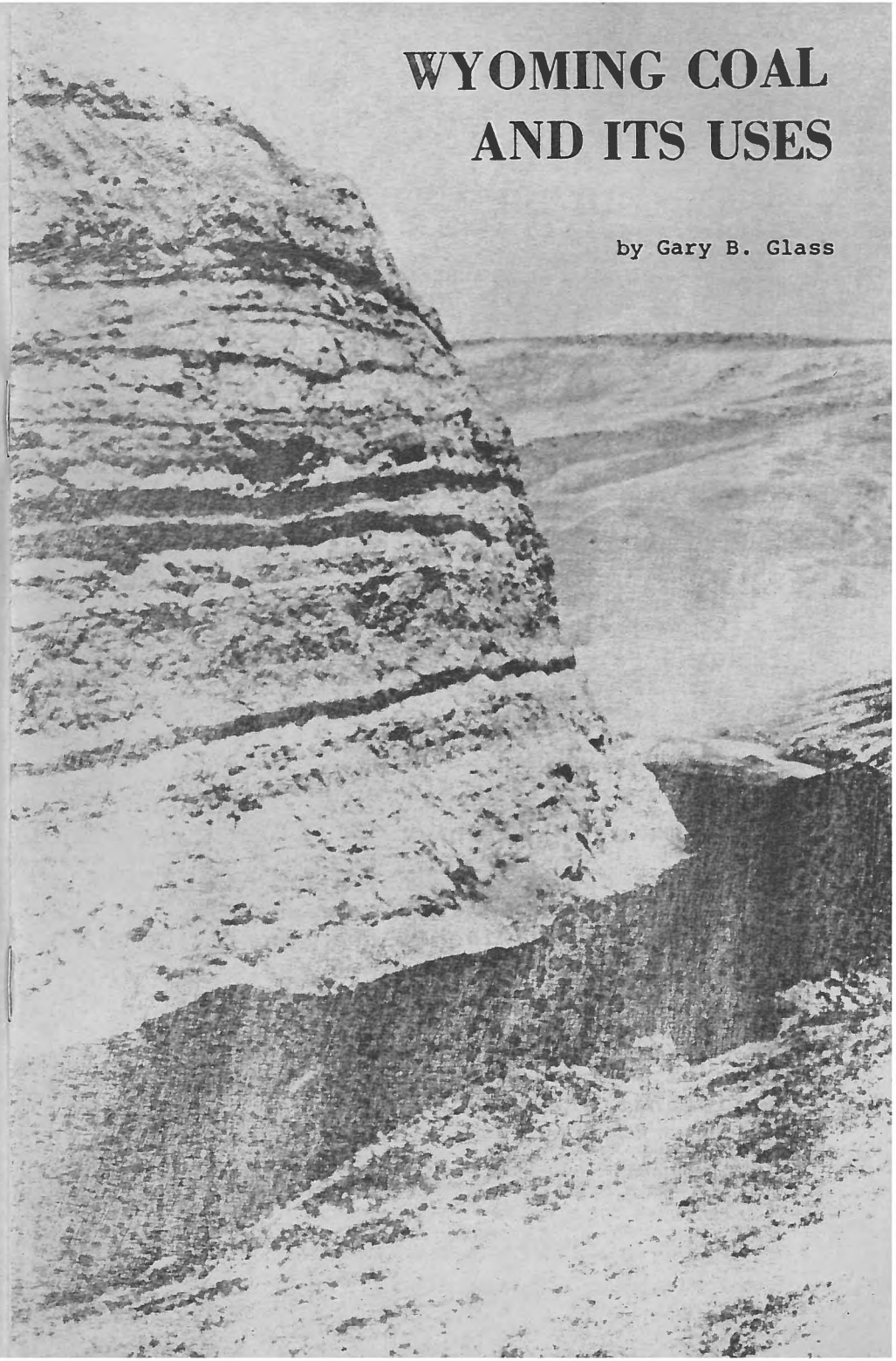

INFORMATION CIRCULAR

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THE GEOLOGICAL SURVEY OF WYOMING
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ABOUT THE COVER: This thirteen foot thick coal seam, which is exposed in the Sorensen mine in the Hams Fork Coal Region, is one of approximately forty seams currently mined in Wyoming. This seam is, however, relatively thin when compared to several 70 to 100 foot thick Wyoming coals that are also mined.

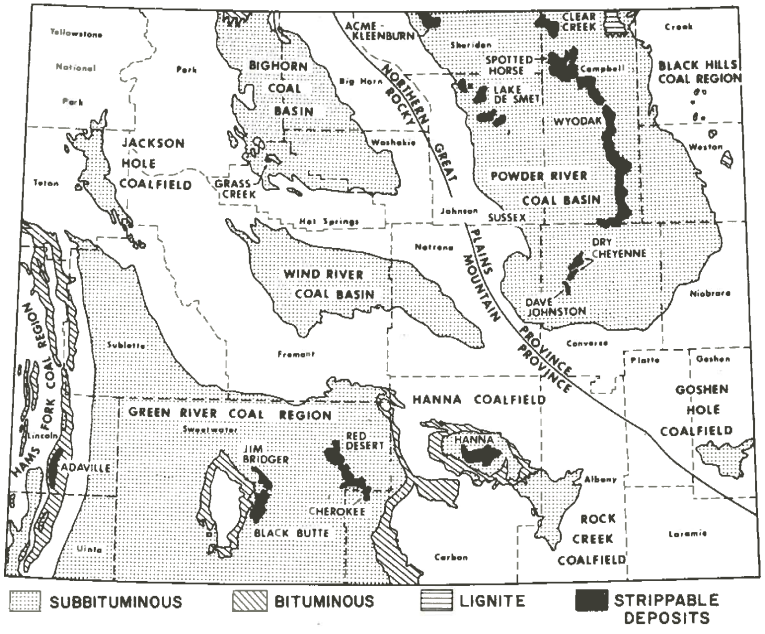
INTRODUCTION

Coal is defined by the dictionary as a "carbonaceous rock used as fuel." While this is true, there is more to it than that.

Coal is the fossilized remnant of once densely forested swamps which periodically covered many areas, millions of years ago. It can vary in age from 38 to 350 million years.

Coal was formed from the altered but preserved remains of trees and grasses which inhabited these ancient swamps. As the plants died they fell to the bottom of the swamp waters, forming layers of dead plant material called peat. As thousands of years passed, sediment was deposited atop the plant accu-

FIGURE 1: COAL-BEARING REGIONS OF WYOMING



mulation and the heat and pressure generated by these added layers compressed the peat beds and gradually transformed them into coal.

Wyoming coals occur in rocks that range from 38 to 130 million years old. The younger coals occur in all coal-bearing areas of the State except the Black Hills Region (Fig. 1). The older coals occur in most of the areas also, but they are only important in the Hams Fork Region, Green River Region, Black Hills Region, and Bighorn Basin.

Although many Cretaceous coals are bituminous in rank, (next to the highest grade coal—see Fig. 2) some are only subbituminous. The Tertiary coals in Wyoming are all subbituminous to lignitic coals. These rank differences alone account for a significant geographic variation in the quality of coals presently mined.

FIGURE 2: CHARACTERISTICS OF COAL RANKS

COAL RANK	*CHARACTERISTICS*	*AVERAGE HEAT VALUE*
Graphite	Pure carbon, black with a slick feel.	———
Anthracite	Hard, black coal with about 94% carbon content.	13,600 Btu/lb.
Bituminous	Softer, brown to black coal containing from 82 to 91% carbon.	14,350 to 11,250 Btu/lb.
Subbituminous	A soft, black coal containing about 78% carbon.	9,300 Btu/lb.
Lignite	A very soft, brownish-black coal containing about 72% carbon.	7,000 Btu/lb.
Peat	Semi-carbonized plant matter with a high moisture content and a carbon content of around 60%.	4,500 Btu/lb.

FIGURE 3: GEOLOGIC TIME SCALE

TIME (MILLIONS OF YEARS BEFORE THE PRESENT)	ERA	PERIOD	EPOCH	EVENTS IN WYOMING
0	CENOZOIC 65 M.Y.	QUATERNARY	HOLOCENE	PRESENT CLIMATE
3			PLEISTOCENE	ICE AGE GLACIERS
12		TERTIARY	PLIOCENE	TETONS FORMED. TERRESTRIAL DEPOSITION.
26			MIOCENE	INTENSE VOLCANIC ACTIVITY IN YELLOWSTONE AREA. TEMPERATE CLIMATE.
38			OLIGOCENE	TERRESTRIAL DEPOSITION OF GREAT AMOUNTS OF VOLCANIC ASH. WARM TEMPERATE CLIMATE.
58			EOCENE	GREEN RIVER LAKE AND TERRESTRIAL DEPOSITION. SUBTROPICAL CLIMATE.
65			PALEOCENE	TERRESTRIAL DEPOSITS. TROPICAL CLIMATE.
135	MESOZOIC 160 M.Y.	CRETACEOUS		TRANSGRESSION AND REGRESSION OF SEAS. ROCKY MOUNTAINS BEGIN TO RISE. ABUNDANT CEPHALOPODS.
180		JURASSIC		SEAS WITHDREW, BROAD FLOOD PLAINS. MANY DINOSAURS.
225		TRIASSIC		FLUCTUATION OF SHORE LINE. WIDE TIDAL FLATS, MILD CLIMATE.
270	PALEOZOIC 375 M.Y.	PERMIAN		SHALLOW SEAS IN WESTERN WYOMING. INVERTEBRATES COMMON.
		PENNSYLVANIAN		LOCAL UPLIFT IN SOUTHCENTRAL AND SOUTHERN PART OF STATE.
350		MISSISSIPPIAN		ENTIRE STATE SUBMERGED IN WARM TROPICAL SEAS.
400		DEVONIAN		SEAS IN NORTHWESTERN AND WESTERN WYOMING.
440		SILURIAN		PROBABLY EMERGENT. RECORD INCOMPLETE IN WYOMING.
500		ORDOVICIAN		STATE INUNDATED BY SHALLOW WARM WATERS.
600		CAMBRIAN		SEAS TRANSGRESSED FROM WEST ACROSS ENTIRE STATE.
	PRECAMBRIA			LONG INTERVAL OF EROSION AT CLOSE OF ERA.
				LAND REDUCED TO BROAD PLAINS OF LOW RELIEF.
1000				MOUNTAIN BUILDING.
4500	FORMATIVE ERA			FORMATION OF THE EARTH

COAL QUALITY

The lowest ranked mined coals occur in the Powder River Basin of northeastern Wyoming. Heat values of Powder River Basin coals average only 8200 Btu/lb., compared to 9000-11,000 Btu/lb. recorded in mines in southern Wyoming and the Bighorn Basin (Fig. 1). There are, of course, exceptions. While the Big Horn No. 1 Mine in Sheridan County produces a coal with a heat value of 9000 Btu/lb., the coal mined in the Jim Bridger mine in Sweetwater County rarely exceeds 8500 Btu/lb.

Moisture content varies across the State as a result of differences in rank. The lower rank coals invariably contain more moisture by weight than the higher rank coals. Moisture content is important because it not only adds unwanted weight to a coal but also decreases a coal's heat value.

Ash and sulfur contents show some variation that is more complicated than rank. At least in the case of sulfur, the older, higher ranked coals generally contain more sulfur than the younger coals. The feature is not a result of their age, but is a consequence of the environment under which the coal was originally formed.

Older coals were derived from coalification of plant debris that accumulated as swamps growing along a seacoast. This nearshore environment allowed periodic flooding of the swamp and, thus, frequent contact with sea water. This probably accounts for their higher sulfur content.

Conversely, Tertiary swamps were growing in closed basins that had no contact with sea water. Only fresh water from the surrounding mountains contacted these primeval coal swamps. For this reason, Wyoming's younger coals generally are lower in sulfur content than Cretaceous coals.

COAL RESOURCES

Wyoming has nearly a trillion tons of coal underlying about 41% of its land surface. These coals range from less than a foot in thickness to over 240 feet thick and occur at both shallow and great depths. Of this trillion tons, however, less than 54 billion tons are currently considered recoverable by conventional mining techniques.

Mined Wyoming coals now range from six to 110 feet thick and average 13-70 feet in thickness. This compares with an average thickness of only four feet in Pennsylvania and Ohio.

PRODUCTION

Wyoming's total annual production tripled between 1971 and 1975 with an estimated 1975 tonnage of almost 24 million tons (Fig. 4). This ranks Wyoming as the ninth largest coal producing state in the country. The U.S. produces about 600 million tons annually.

Coal is mined in five of the ten major coal-bearing areas of the State: the Powder River Basin, the Hanna Coal Field, the Green River Region, the Hams Fork Region and the Bighorn Basin. The largest production, however, is from large strip mines in the Hanna Coal Field and the Powder River Basin. The Hams Fork Region is the next largest producer, followed by the Green River Region. Only a very small amount of coal is mined in the Bighorn Basin.

MARKETS

Currently, 89% of the coal mined in Wyoming is used in coal-fired power plants in both Wyoming and other states. A map of Wyoming coal markets in 1974 (Fig. 5) shows that the midcontinent states

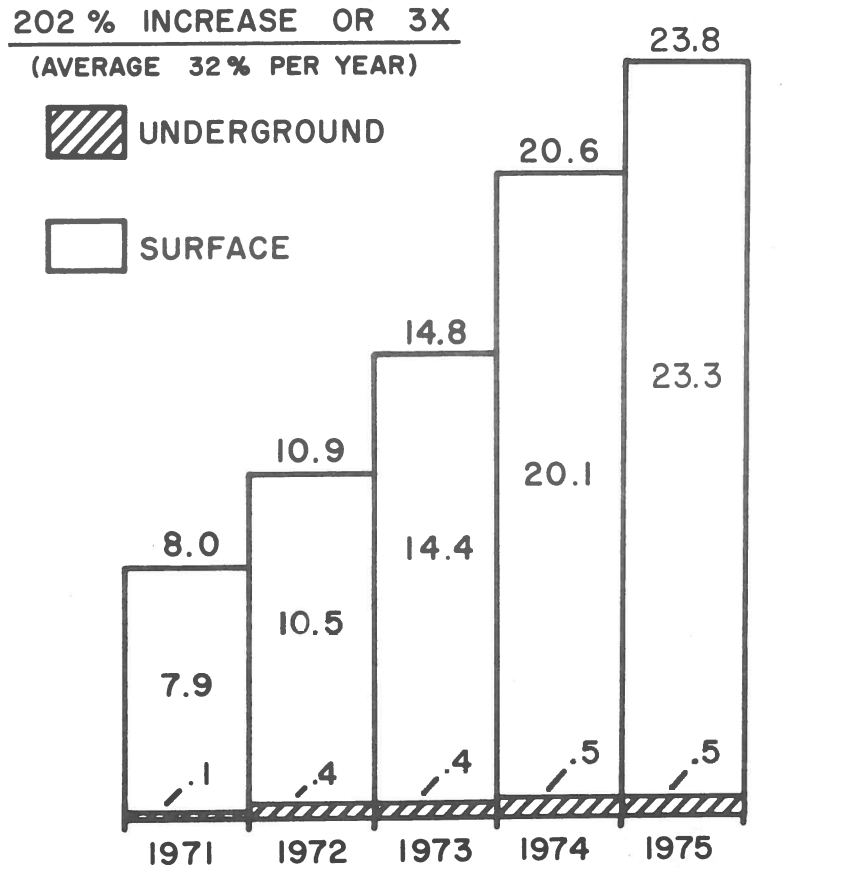


FIGURE 4: WYOMING COAL PRODUCTION

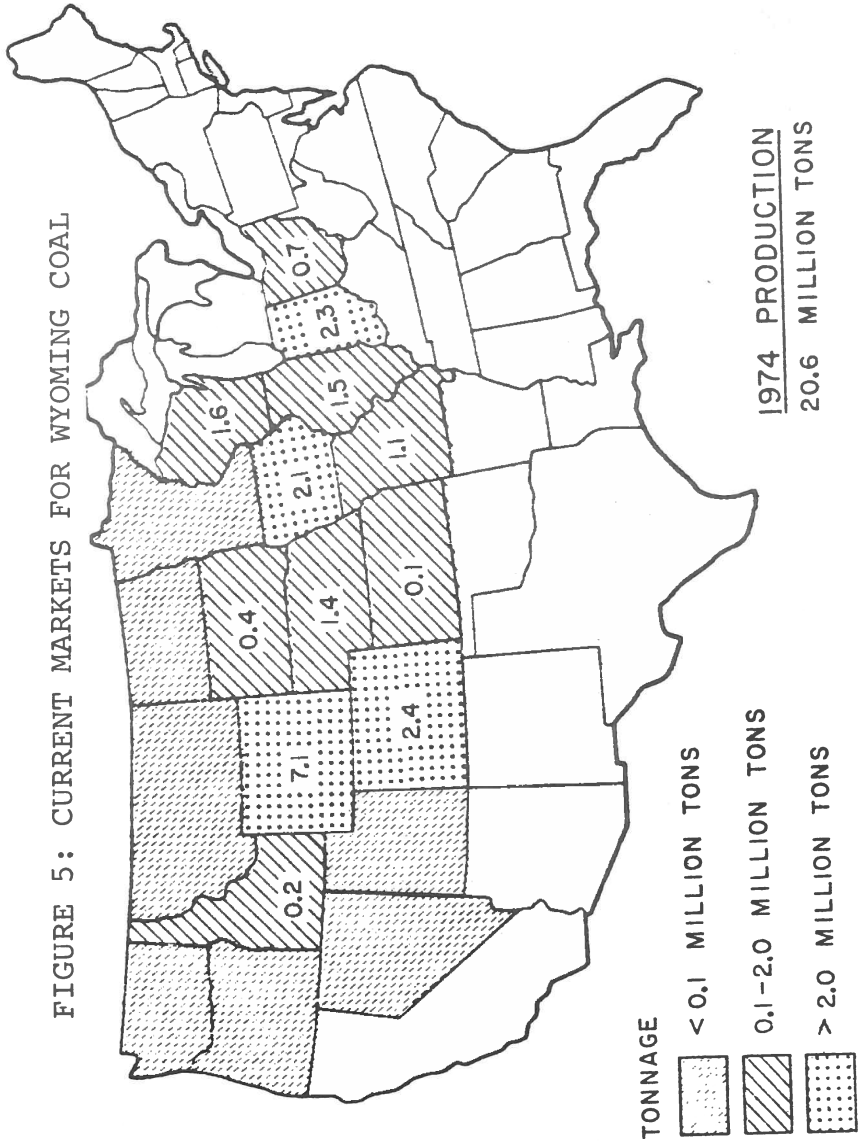


FIGURE 5: CURRENT MARKETS FOR WYOMING COAL

between the Rockies and the Mississippi River are the prime consumers of the State's coal. By 1980, Wyoming coal will also be going west to Oregon and Idaho, south to Arkansas, Oklahoma, Texas, and Louisiana, and even further east to Ohio, Indiana, and Kentucky.

Annual production for power plant usage alone will exceed 80 million tons by 1980. Additional uses, which may include one coal gasification plant, could raise production in 1980 to over 96 million tons.

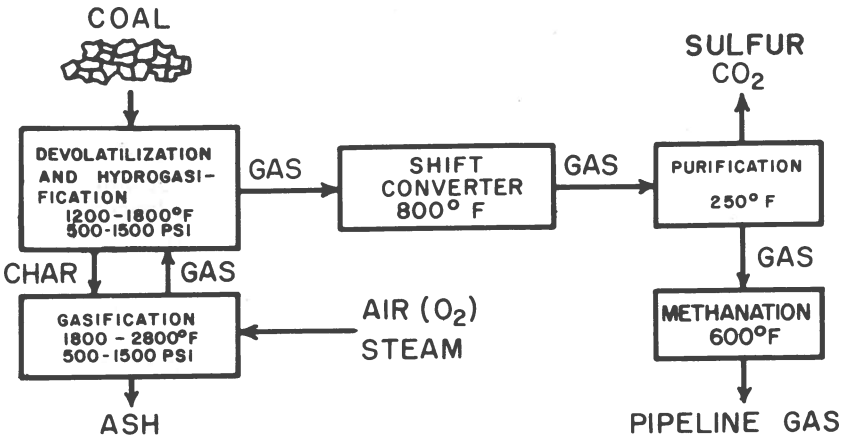
The industrial market for Wyoming coal has also seen some recent increases. The trona, beet sugar, cement, and phosphate industries are already using the State's coal. Continued growth of these markets are anticipated as supplies of natural gas and oil that used to fuel these industries continue to dwindle.

COAL GASIFICATION

Gasification plants are a potential future market for coal that could even exceed power plant demands. Wyoming's coals are under serious consideration for feedstock to a great number of coal gasification plants—plants that take mined coal and convert it into synthetic gas.

The idea isn't new. It dates back to the 1870's in Germany when "water, coal, or city gas" was made for kitchen stoves and heaters by reacting glowing coal or coke with steam. By 1936, the Germans were producing a synthetic natural gas suitable for industrial purposes.

Although the U.S. examined the processes and did some experimentation in the 1940's, it wasn't until the 1960's that research took a new serious turn. Pilot scale and demonstration plants have been built and run with varying success in the 1970's and at least one 250 million cubic feet per day commercial plant will be on line before 1980. Panhandle Eastern Pipeline Co. has announced intentions to build one such plant north of Douglas, Wyoming, perhaps by



TYPICAL COAL GASIFICATION PROCESS

Modified from Gillmore, 1975

Fig. 6

1980 or 1981. Cost is now estimated at $1 billion per plant, up from an estimated $250 million several years ago.

Wyoming is being considered for gasification plants because its coals are chemically and physically well suited for the conversion processes, which currently require noncaking coals.

Equally important, however, the State's coals are available in large enough deposits to supply the 150-300 million tons of coal required over the life of a large plant. A plant will annually consume 8-13 million tons of coal.

In contrast, the greatest obstacle to conversion plants in Wyoming is the scarcity of water needed for the conversion processes and for plant cooling.

Conversion of coal to synthetic natural gas is most readily explained in terms of the composition of the raw material and of the products (Huebler, 1975). Subbituminous coal has a carbon/hydrogen ratio of about 14 compared to natural gas with a ratio of 4.

Therefore, to upgrade coal to gas, one must either add hydrogen or remove carbon. Research has shown that the addition of required hydrogen is the most efficient method.

What is actually done, however, is to react coal, water, and air at high temperature and pressure to form a variety of products in addition to methane (CH_4). Some of these other products are hydrogen (H), carbon monoxide (CO), and carbon dioxide (CO_2) (Fig. 6).

The carbon dioxide (CO_2) is scrubbed out and the carbon monoxide (CO) and hydrogen (H_2) are catalytically combined to produce additional methane and water. This last reaction is called methanation and, to date, has been the one unproved part of the gasification process. This step, however, is needed to raise the product gas from heat values of 200-300 Btu/cu. ft. (low Btu gas) up to near that of natural gas at 1000 Btu/cu. ft. (high Btu or synthetic natural gas).

The latter low Btu gas is too low in quality to pipe

FIGURE 7: TYPICAL GAS COMPOSITION FROM A GASIFICATION PROCESS

CO_2.....32%	N.....0.5%
CO.....17%	CnHm.....).5%
H_2.....37%	Heat....300Btu/ value scf
CH_4.....12%	

any distance and would not work in home furnaces without alterations. It could generate steam or run a turbine at an industrial site, but in Wyoming's case there is presently little heavy industry in need of such a fuel.

In all gasification processes, the sulfur in the coal appears as hydrogen sulfide (H_2S) in the product gas

and is removed as elemental sulfur. Provisions must also be made to remove other impurities and dispose of them in an acceptable, safe manner.

Additionally, chemicals and synthetic materials are derived from the coking of coals in nearby states even now. Although Wyoming has no significant coking coals, similar chemical feedstock will become available in Wyoming as by-products of proposed synthetic fuel plants. In the longer term, Wyoming

FIGURE 8: SOME OF THE MORE COMMON GASIFICATION PROCESSES

Lurgi.....	Lurgi Gesellschaft
Hygas.....	Inst. Gas Technology
Bi-gas....	Bitum. Coal Research, Inc.
Synthane.....	U.S. Bureau of Mines
CO_2 Acceptor.....	Consolidation Coal Co.
(CSG)	
Hydrane.....	U.S. Bureau of Mines

coal will probably also be used as a direct chemical feedstock to augment or replace the by-products of the petroleum industry from which countless hundreds of chemicals, tars, oils, waxes, fibers, foodstuffs and other materials are now made.

COAL LIQUEFACTION

An alternative use of Wyoming coal might be liquefaction or hydrogenation of coal. The reactions are similar to coal gasification in that portions of the coal are also gasified at the same time liquid hydrocarbons are formed (Fig. 9).

The heavy oils formed by this process are catalytically reacted with hydrogen (H_2) at high pressure and temperature to produce synthetic crude. Most processes are geared to produce fuel oils, but they

can also produce gasoline. Again, the technology goes back to Germany in 1927 with further refinements perfected by 1933.

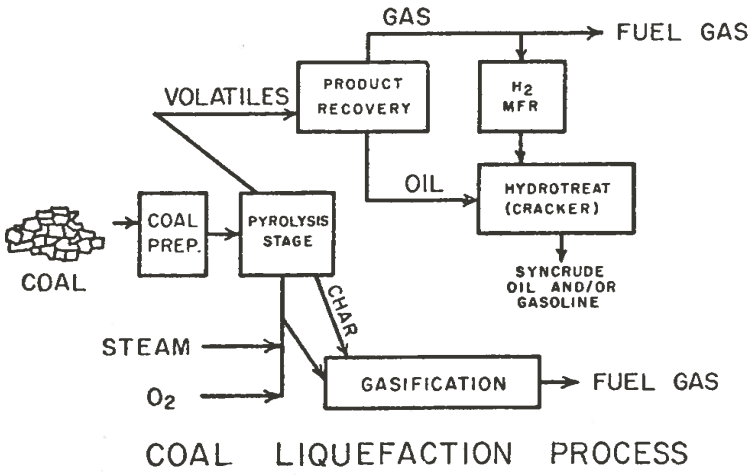


Fig. 9

IN SITU COAL GASIFICATION

In situ gasification is presently under evaluation as another future use for Wyoming coal. The U.S. Bureau of Mines has conducted tests near Hanna, Wyoming since 1971. They began by drilling an array of 400 foot holes into a 30 foot coal seam. They ignited the coal at the bottom of a centrally located borehole and pumped air into it to maintain a fire front.

As the fire front advanced, the coal gasified ahead of it. Product gas was collected from other holes in the array. Additional, more sophisticated experiments are underway that include an instrumentation experiment that should monitor the temperatures and speed of the flame front as well as other parameters needed for commercial evaluation of the technique.

In 1975 a similar project was initiated in Campbell County, Wyoming by Lawrence Livermore Laboratories.

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