BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

COAL GASIFICATION

A PRELIMINARY SURVEY OF DEVELOPMENTS

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SYSTEM DESIGN
DIVISION

Report No. 103

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A. Summary

Gasification of coal offers a method of producing clean fossil fuel derivatives in commercial quantities. High B.T.U. gas (900-1000 B.T.U. per cubic foot), comparable to natural gas values, can be produced from coal on a very large scale utilizing processes which have been partially proven commercially and fully proven on a pilot plant scale. These processes are the Lurgi Process and the Koppers-Totzek Process, each of which have been in commercial operation for a considerable time to produce low B.T.U. gas. The addition of a catalytic methanization stage allows low B.T.U. gas to be converted to high B.T.U. gas and this conversion has been satisfactorily demonstrated at the pilot plant stage. These processes are identified as first generation gasifiers.

The capital cost of the gasification plants using either the Lurgi or the Koppers-Totzek process is high. For a plant producing 200 million cu.ft./day of high B.T.U. gas the estimated cost in 1974 dollars would be in the order of $350 million. 200 million cu.ft./day would meet the full fuel requirements of the 900 MW Burrard Thermal Generating Station. Based on a capital cost of $350 million, together with operating and maintenance costs and a cost of mining coal equivalent to $5.00/ton, the unit cost of the high B.T.U. gas would be in the order of $1.75/1000 cu.ft.

There are other coal gasification processes being developed which are significantly different from the

A. Summary - (Cont'd)

Lurgi and Koppers-Totzek processes and which offer more efficient conversion of the coal to high B.T.U. gas at reduced capital construction costs. Two of these processes, the Hygas Process, and the CO_2 Acceptor Process have reached the demonstration stage and pilot plants are in operation. Pilot plants for the Bi-Gas Plant and the Synthane Process are presently under construction. These plants are considered to be second generation coal gasification plants.

Third generation coal gasification plants are represented by a number of assorted techniques presently at the laboratory-bench stage of development. These involve processes radically different from those used in existing commercial plants and would provide high utilization of coal carbon and high thermal conversion of coal to usable fuels and equivalent petroleum by-products.

Hat Creek coal would be suitable for gasification using, for example, the Lurgi Process. High B.T.U. gas could be produced at Hat Creek and transported to Vancouver through existing transmission gas pipelines and additional pipelines constructed on existing pipeline rights-of-way and could substitute completely for natural gas in B.C. Hydro gas pipeline networks. This high B.T.U. (950 B.T.U./cu. ft.) coal gas could substitute for natural gas at Burrard Thermal Generating Station without any modification to the boiler.

B. Introduction

Coal was the foundation of the gas industry. Early manufactured gas was produced by reacting coal coke at atmospheric pressure and high temperature with steam to form water gas, or with air and steam to make producer gas. These gases were low in B.T.U. value and quite expensive, but they did burn.

The development of the petroleum industry resulted in a large supply of natural gas and since it was low cost and clean, it became a highly desirable fuel. Together with oil, natural gas presently accounts for two-thirds of Canada's total energy consumption but the demand for natural gas especially, has now resulted in a most tenuous supply situation and knowledgeable people in the industry consider that the natural gas supply will never again equal the demand. Easily accessible, conventional and low cost sources of oil and gas in North America are running out and there is a clear need to conserve oil and gas reserves and to upgrade their use to premium markets in the petro-chemical industry. The bulk of the future difference between demand and the available natural gas supply will most likely come from the gasification of coal and it may well be that high B.T.U. gas from coal may supplant entirely the utilization of natural gas as a fuel.

Coal is the neglected material in Canada's inventory of resources. An estimated 200 billion tons (equal to about 750 billion barrels of crude oil) lie beneath the ground mostly in British Columbia, Alberta, and Saskatchewan with

B. Introduction - (Cont'd)

additional deposits in the northwest and the Arctic islands. Coal, which once accounted for half our energy needs, now provides only 11 percent of them. Because coal is more difficult to obtain, and more difficult to use, it has fallen into disfavour. A challenge and opportunity today is to develop processes to utilize our coal resources in the most efficient and cleanest manner possible, consistent with environmental protection standards and economic market prices for energy. A significant process among these is coal gasification. This would produce both low B.T.U. and high B.T.U. gases that can be used efficiently and economically by industrial and residential users.

Today there are no operating commercial coal gasification plants of any significance in Canada or the United States and the advanced technology that a modern gas-from-coal industry will require is just now being developed. It is confidently projected that with the research and development now underway in North America and Europe, that by 1980 coal gasification will provide a significant contribution to the gas supply for energy purposes. The product will not be cheap but the supply will be one of abundancy. It is estimated that a coal gasification plant to produce 200 million cubic feet of high B.T.U. gas per day will cost approximately $350 million (expressed in 1974 dollars). Such a plant would meet the full fuel requirement of the 900 MW Burrard Thermal Plant. Ten such plants could produce as much gas at comparable prices as the projected Mackenzie Valley Pipeline. !

B. Introduction - (Cont'd)

On a world scale known reserves of coal amount to about 6 trillion metric tons crude oil equivalent, according to United Nations survey, but even considering North America alone or even Canada alone, coal reserves are clearly enormous; but the problems associated with its use and primarily concerning environmental consideration are also of significant magnitude. Coal gasification offers a process which can provide a gaseous fuel acceptable for most environmental restraints and wherein the process of gasification can be carried out under rigidly controlled conditions so as to minimize ecologically detrimental effects.

The use of coal converted to a gaseous form cannot be achieved without some loss of thermal efficiency in terms of the utilization of coal thermal energy content and, in turn, if the coal gas is used to produce steam to drive steam turbine alternator units, additional inefficiency is added to an already inefficient chain of production. Energy is consumed in converting one fuel raw material to another form and although this is not completely logical from an energy conservation point of view, it does enable us to have a fuel which is more readily usable and transportable to the place of need. An illustration of these thermal inefficiencies is given by the comparison that it requires about 93% more natural gas to convert water from $32^{o}F$ to $212^{o}F$ in a hot water heater by using electrical immersion heaters than by a direct gas burner heat transfer.

B. Introduction - (Cont'd)

Clearly energy form coal via the gasification route might best be utilized by its substitution for natural gas in the gas industries' pipeline networks.

C. Description of Coal Gasification

The major constituents of coals comprise water, ash, fixed carbons, and volatile matter and smaller amounts of elements such as sulphur and nitrogen.

Existing commercial gasification techniques involve not only heating the coal, as in distillation to release the volatiles, but also the subsequent reaction of the solid residue with air, oxygen, steam or various mixtures of them. The distillation step releases from the volatile constituent a certain amount of gas that has a fairly high B.T.U. content but the subsequent gasification step produces a gas that is mainly a mixture of hydrogen and carbon-monoxide with a much lower heating value.

The amount of the distilled gas from the volatiles in the final mixture varies with the particular gasification process, but the main portion of the mixture is made up of hydrogen and carbon-monoxide and the B.T.U. value of the mixture is generally quite low.

Commercial production of high B.T.U. gas has not yet been attained but on a pilot scale the techniques have been developed.

C. Description of Coal Gasification - (Cont'd)

To produce high B.T.U. gas, the correct ratio of hydrogen to carbon-monoxide is prepared. The gas is then purified to remove the sulphur compounds that may be present. This is necessary in that catalysts that have been tested for the crucial step of methanation are all nickel-based and are highly sensitive to sulphur poisoning. The gas is then delivered to the methanation unit where, in the presence of the catalyst, methane of 97% purity is produced.

D. Problems in Using Coal

It has been stated that the effort to make synthetic natural gas from coal represents one of the most difficult chemical engineering problems in several decades. The major part of this problem is the coal itself. It is a solid and, as a result, cannot be pumped. This greatly complicates handling. When heated, many coals 'coke' and such behaviour in one type of gasifier stops the gasification process. Coal also contains many elements and compounds unnecessary to the production of synthetic natural gas such as nitrogen and sulphur. These elements and others can poison the reactions needed to produce synthetic natural gas and render catalysts ineffective in a short time. Purification of the partially processed gas is, therefore, a time-consuming and costly necessity. A problem related to the fact that the fuel is in solid form develops when charging a gasifier. The gasification chamber is under a high pressure (400 psi and up) and

D. Problems in Using Coal - (Cont'd)

introducing the coal without losing the pressure required for the reaction is an engineering problem of major proportions.

The two existing commercially proven processes are the Lurgi Process and the Koppers-Totzek Process.

The Lurgi Process in particular requires a sized coal with all fines removed and it is this process that can be halted by a coking coal which would form a solid, impermeable mass in the gasifier.

The ratio of carbon to hydrogen is much higher in coal than in oil. This fact makes the steps of shift conversion and methanation necessary when producing a pipeline quality synthetic natural gas from coal. It is said that coal is hydrogen-poor and synthetic natural gas is hydrogen-rich. Therefore, making synthetic natural gas from gasified coal involves the addition of hydrogen. The hydrogen comes originally from the reaction between coal and steam. It takes heat to drive this reaction and this heat is obtained from a second major reaction between oxygen and coal. The heat from this oxygen-coal reaction must be carefully controlled to maintain a proper heat-balance under equilibrium conditions and drive the coal-steam reaction. Control of heat loss is critical in the process of gasification. The product of the gasifier has too little methane in it and to increase the amount of methane a shift reaction to increase the hydrogen concentration and a final methanation step, along with purification, is performed.

D. Problems in Using Coal - (Cont'd)

North America changed from coal to oil because of oil's relatively clean-burning characteristics and easy handling aspects compared to the high cost and the attendant fly ash and sulphur dioxide pollution problems. However, for coal burning plants new stack scrubbing devices may provide an interim solution for the pollution problems. These stack scrubber units are showing promise in recent applications to power plants but costs are much higher than anticipated for two reasons:- the large volume of gas that must be treated; and the disposal of the entrapped, solid wastes in an acceptable manner.

A big investment in coal technology, its mining, handling and treatment, is necessary if the problems of using coal are to be solved. Indications are that such a program is underway in North America. The downward trend of coal production must also be reversed to provide the anticipated requirements of the next ten years.

E. Basic Operations of Gasification

Making gas from coal involves five basic operations as illustrated in Figure 1. These include:-

- Coal preparation; which usually involves grinding the coal to a powder or crushing it to the desired top size while removing fines and extraneous material.
- Feeding the reactor; getting the coal into the high pressure reactor either by use of lock chambers or pumpable slurries.

Figure 1

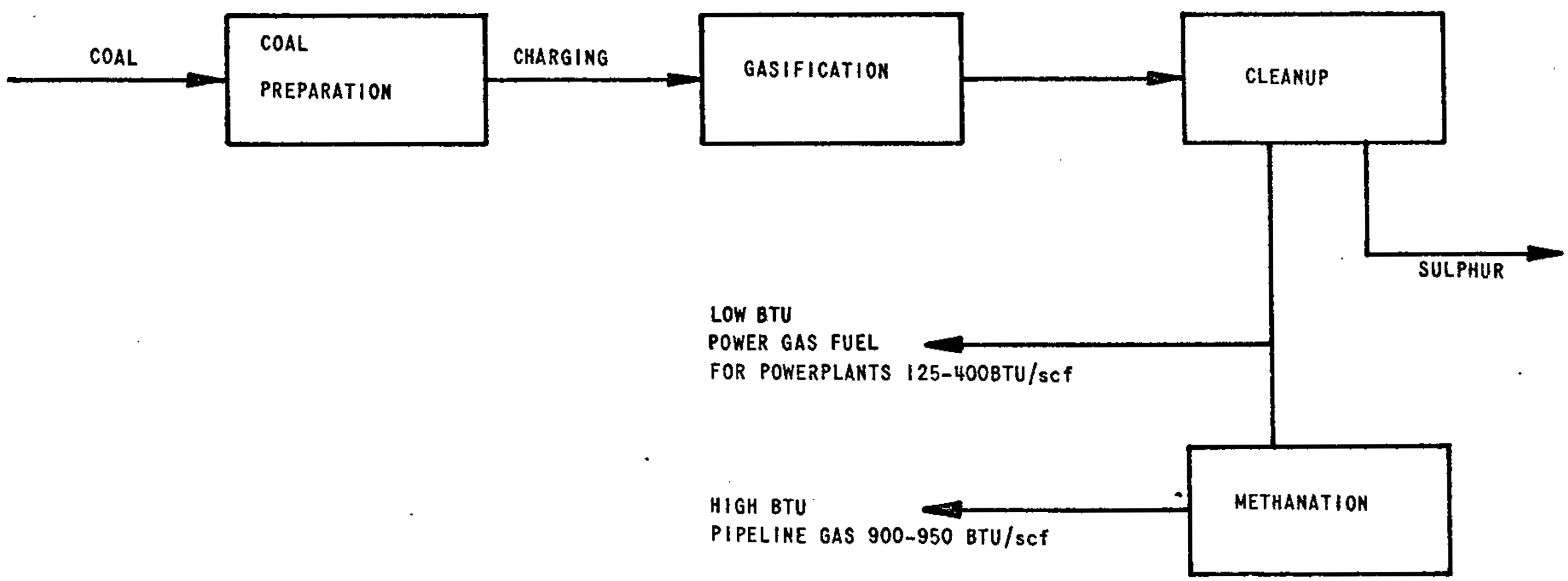


FIGURE 1

MAJOR STEPS IN COAL GASIFICATION

E. Basic Operations of Gasification - (Cont'd)

- Gasification; devolatilizing or distilling of the coal by use of various processes.
- Gas treating; removal of sulphur, dust, CO_2, water and other impurities from the gasifier gas.
- Methanation; the final step of raising the heating value of the gas to that required by modern gas-fueled equipment.

A 200 MM scf/day gasification plant producing high B.T.U. gas (950 B.T.U/ft^3) would have the capacity to meet the fuel needs of the Burrard Thermal Plant for the purposes of comparing relative size. However, such a commercial gasification plant delivering pipeline quality gas does not exist today although several larger commercial units of 250 MM scf/day capacity are in the design stage and one is in the construction stage with a scheduled commercial production date in 1977. Features known about the design of this latter plant are used to give a hypothetical view of a synthetic natural gas plant with 200 MM scf/day capacity and the flow diagram for such a plant is shown in Figure 2. From this diagram the option of obtaining a low B.T.U. producer gas is clear. In addition, the production of sulphur, naphtha and phenol chemicals in economic quantities as by-products of the process are indicated.

F. Design and Operating Data

The plant would process 20,000 tons per day of coal in the production of 200 MM scf/day of synthetic natural gas. Of

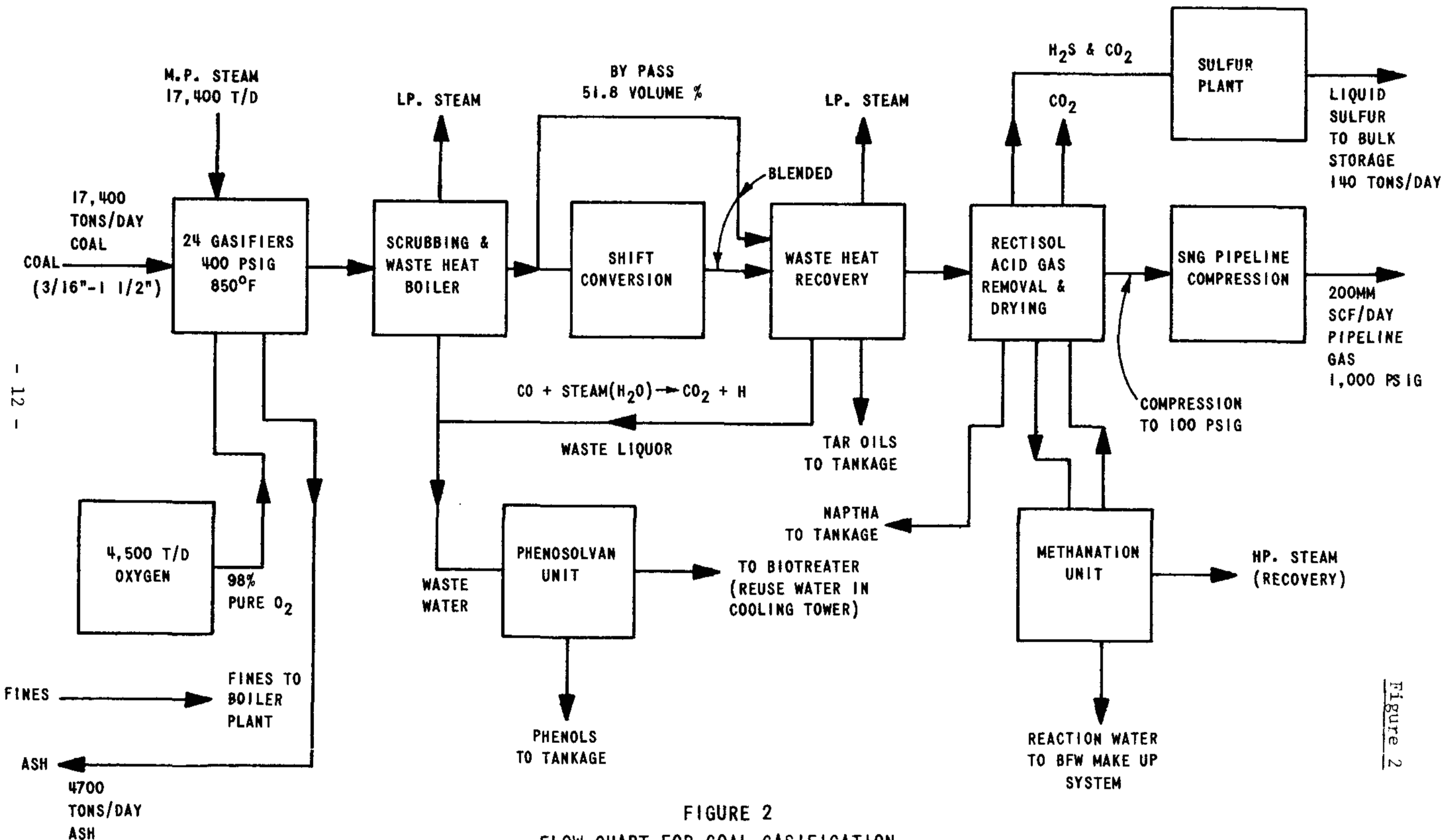


FIGURE 2
FLOW CHART FOR COAL GASIFICATION
200 MM SCF/DAY PLANT

Figure 2

F. Design and Operating Data - (Cont'd)

this 20,000 tons, about 17,400 tons or 87 percent would go directly to the gasifiers, and the remaining 13 percent would feed the utility plant for steam generation.

The oxygen plant would have a capacity of greater than 4,500 tons per day. Water requirements would total 1400 gpm for the complete plant.

This plant would require 24 gasifiers to produce 200 MM scf/day of synthetic natural gas. Ash from these gasifiers would be quenched and returned for disposal within the mining area. The quantity of ash returned would approach 4,700 tons (dry weight) of ash per day. Steam usage within the plant would approach 1.5 million pounds per hour and it is estimated that 140 tons per day of sulphur would be recovered using the Claus process.

The properties of the coal available to the proposed plant is shown below and beside it is given the approximate analysis of 24 samples of Hat Creek lignite:-

	New Mexico Coal	Hat Creek Lignite
Moisture	12.4% by weight	16.6% by weight
Ash	25.6%	30.4%
Fixed Carbon	33.8%	32.1%
Volatile Matter	28.2%	20.8%
Sulphur Content	0.91%	n/a
H.H.V.	8310 B.T.U./lb.	7706 B.T.U./lb.

F. Design and Operating Data - (Cont'd)

The similarity is noteworthy and indicates that a study of a gasification plant to process Hat Creek coal could indicate a good chance of success.

It is expected that the overall thermal efficiency of the plant would exceed 70 percent. A material balance based on 200 MM scf/day of product gas is as follows:-

	Short Tons/Day	Weight, %
Inputs:		
Sized Coal	17,400	41.48
Steam and Water	20,000	47.74
Oxygen	4,500	10.78
Total	41,900	100.00
Outputs:		
Product Gas	4,250	10.32
Phenols	80	0.2
Ash	4,700	11.15
Rinse Water	14,200	33.87
By-Product Water	3,000	7.08
Tars, Oils & Naphtha	1,200	2.80
Off Gas	630	1.50
CO_2 Gas	13,200	31.56
NH_3 + Water	640	1.52
Total	41,900	100.00

F. Design and Operating Data - (Cont'd)

Such a plant is estimated to cost $350 million (in 1974 dollars) and the completed plant would employ 600 people representing an annual payroll cost in excess of $15 million dollars.

G. Gasification Methods

All the processes under investigation can be classified in various ways:-

- by the method of supplying heat for the gasification reaction (internal or external).
- by the method of making contact between the reactants (fixed bed, fluidized bed, or entrainment in the gaseous medium).
- by the flow of reactants (with the current, or counter-current).
- by the gasifying medium (hydrogen or steam plus oxygen, air or enriched oxygen).
- by the condition of the residue removed (slagging with a liquid ash residue or non-slagging with a dry ash).

Nearly all the combinations of methods to gasify coal represented by these classifications have been investigated.

The two processes employed successfully to date are the Lurgi fixed bed, pressurized gasifier and the Koppers-Totzek fully entrained atmospheric gasifier. Both types, whose flow diagrams are illustrated in Figure 3 and Figure 4, respectively, have been used to make synthesis gas for the manufacture of ammonia and other synthetic products, and in some cases Lurgi plants have made a gas distributed as city gas. Neither process meets all the requirements of an ideal gasification scheme. An ideal process would be a single stage, continuous operation employing air as the oxidizing medium; it would convert any type of coal into a combustible gas or a synthesis gas low in inert constituents.

Although both the Lurgi Process and the Koppers-Totzek Process are single-stage and continuous, they both rely on oxygen rather than air as the oxidizing medium. The Lurgi gasifier is pressurized, which for most applications of synthesis gas is an economic advantage over processes operating at atmospheric pressure. On the other hand, the Lurgi Process requires a sized coal with fines removed and a non-coking coal or weakly coking coal. These provisions are necessary to avoid the formation during gasification of a solid mass that would prevent the passage of gas through the coal bed and bring gasification to a halt. The Koppers-Totzek Process functions with any type of coal.

Renewed interest in coal gasification to produce a substitute for natural gas has led to serious consideration in installing Lurgi or Koppers-Totzek plants. The gas resulting from each process is basically a mixture of

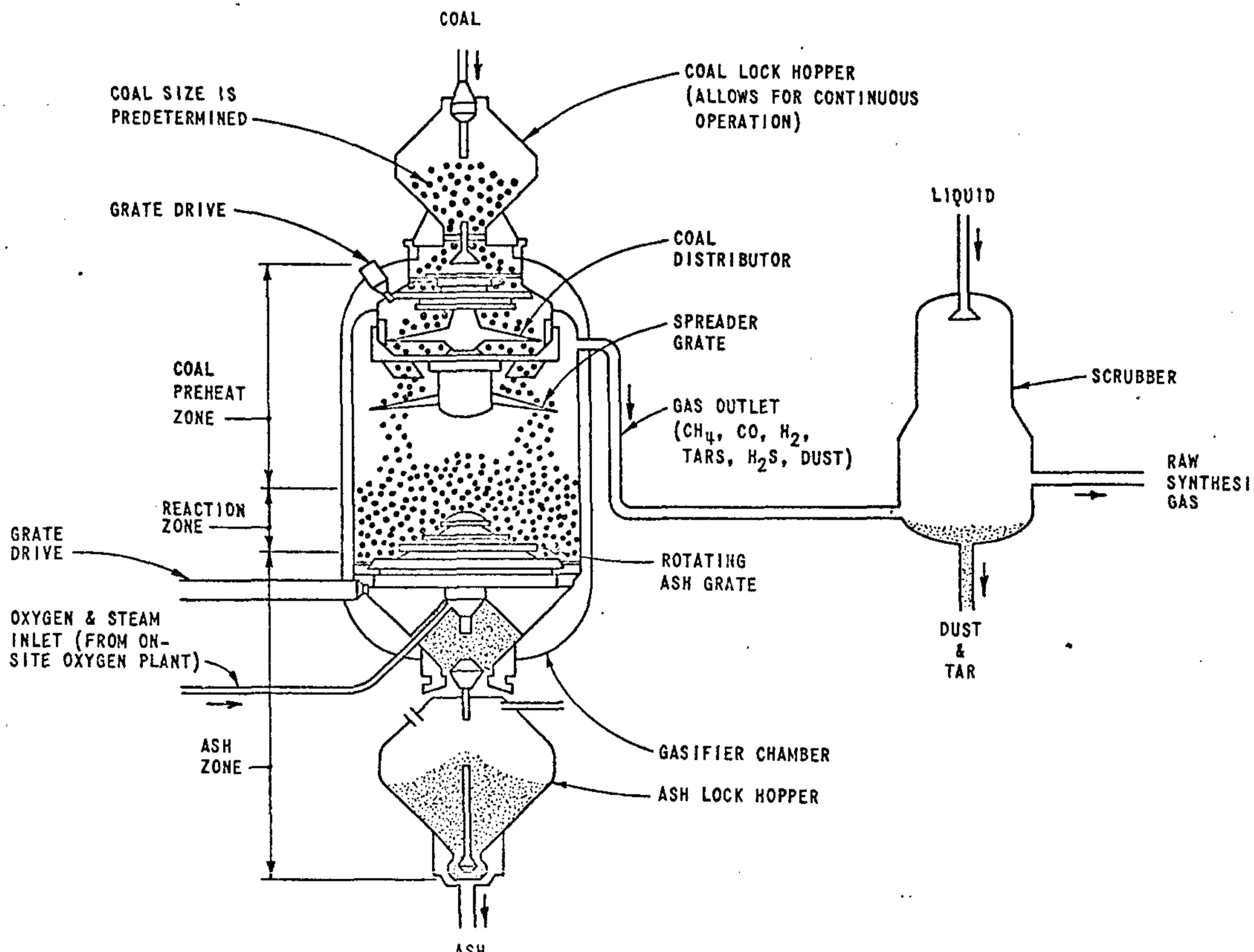


FIGURE 3
LURGI PROCESS

Figure 3

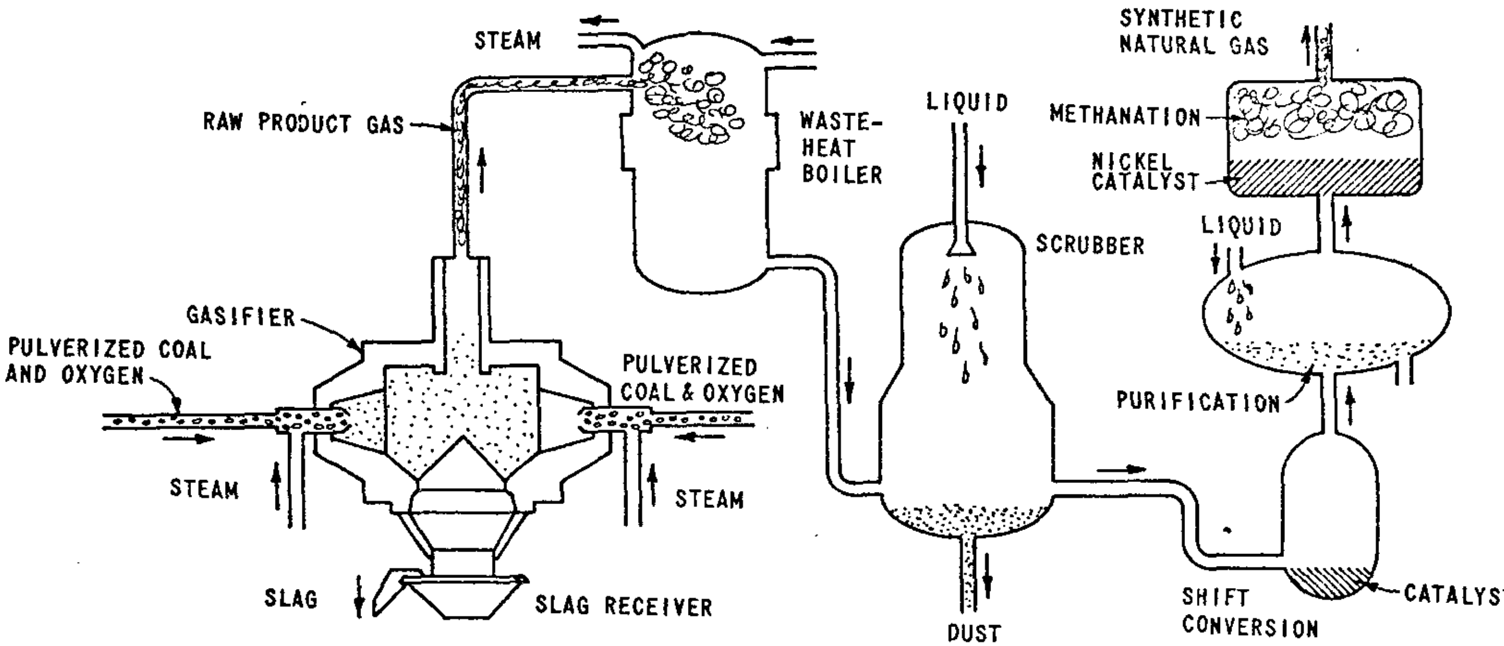


FIGURE 4

KOPPERS - TOTZEK PROCESS

G. Gasification Methods - (Cont'd)

carbon-monoxide, hydrogen and distilled methane with heating values of between 300 and 400 B.T.U. per cubic foot; far below that of natural gas. Thus, neither process by themselves can yield a gas which can substitute for natural gas. However, both processes can make a raw synthesis gas that, after purification, can be methanated to yield a gas suitable as a synthetic natural gas. Methanation involves passing the gas over a special nickel catalyst to convert it into almost pure methane, the constituent of natural gas. This step has not been performed in a commercial system as yet but large-scale, long-term tests indicate its feasibility with certain coals.

(i) Lurgi Process

As mentioned above, all phases of the Lurgi Process have been proved in operating plants except the methanation step. A Lurgi gasifier normally produces a gas with about one-third the heating value of natural gas; the ingredient in short supply is methane, the main component of natural gas. Continental Oil Company has joined with the Lurgi Company, the British Gas Corporation, and the American Gas Association in financing the development of a commercial scale test plant to produce high B.T.U. coal gas. In addition, Conoco have designed and built methanation facilities adjacent to the Scottish Gas Board's Westfield

G. Gasification Methods - (Cont'd)

(i) Lurgi Process - (Cont'd)

Lurgi Process gasification plant and for the Scottish plant, unofficial reports indicate that a long run was successful using Montana 'Rosebud' coal and synthetic natural gas was produced. Other coals are being investigated.

Three major energy companies, Texas Eastern Transmission Company, Utah International Inc., and Pacific Lighting Corporation, have started technical and economic feasibility studies for the construction of a gasification plant to produce high B.T.U. gas in northwestern New Mexico. They hope to begin operating a 250 million scf/day plant by 1976.

El Paso Natural Gas Company has announced plans to build a 250 million scf/day gasification plant based on the Lurgi technology with a methanation step added. Initial plans call for start-up in 1976 with full production scheduled for 1977. The plant is being designed to produce a gas with a heating value of 950 B.T.U./ft^3.

Figure 3 outlines the basic Lurgi Process to produce low B.T.U. synthesis gas.

G. Gasification Methods - (Cont'd)

(ii) Koppers-Totzek Process

Koppers Company has the sole general license in the United States and Canada to design and build Koppers-Totzek coal gasification plants from Heinrich Koppers GmbH, Germany. This process is outlined in Figure 4 which also shows a methanization stage to convert the low B.T.U. gas to high B.T.U. synthetic natural gas.

In the process, coal is reacted with steam and oxygen in a patented gasifier to form a raw synthesis gas. The gas is cooled and all particulate matter is removed. Upgrading to natural gas quality would involve chemically removing the acid gases produced and then employing a shift-conversion and a methanation step. The process is claimed to be free of condensable organic compounds because of the high, 2700°F temperature reaction in the gasifier. Potential gaseous and liquid pollutants such as phenol chemicals are not produced as a result.

Koppers designed and built the first demonstration unit for gasifying coal in suspension based on the Koppers-Totzek Process in 1948 for the U.S. Bureau of Mines. The first commercial unit was designed and built by the parent firm in 1952 in Finland. Since then, 15 plants have been built for the

G. Gasification Methods - (Cont'd)

(ii) Koppers-Totzek Process - (Cont'd)

chemical industry although this experience is not considered comparable to producing pipeline gas.

(iii) New Methods

Four new methods for coal gasification are being investigated and two have reached the demonstration stage. These are the Hygas Process; CO_2 Acceptor Process; Synthane Process; and Bi-Gas Process; and the first two of these have reached the demonstration plant stage.

Each of the Hygas, Bi-Gas, and Synthane processes require subsidiary oxygen plants to operate while the CO_2 Acceptor plant does not. However, the latter is limited by the type of coal it can gasify. These are described in more detail in Section J - Research Project.

Since most research has been directed toward producing a substitute for natural gas, all the processes have attempted to retain in the product as much as possible of the methane that is released during the early part of the process when the coal is being heated. In this way, the overall capital cost and the materials requirements per unit of methane are reduced.

H. Commercial Projects

As of March 1974, there were in the United States, 14 proposed commercial coal gasification projects. Some of these are firm undertakings with work presently going ahead to bring them to fruition and the balance have not yet progressed beyond the study stage.

Three projects are planned around the Lurgi pressure gasification process. The planned output of each plant is 250 million cubic feet per day of synthetic natural gas using 26,000 tons per day of non-coking coal. The estimated cost of each plant is in excess of $350 million dollars. The owners and locations of these plants are as follows:-

- El Paso Natural Gas Company, Burnham Complex.	Northwest New Mexico
- Transwestern Coal Gasification, Pacific Coal Gasification, and Western Gasification.	Northwest New Mexico
- Panhandle Eastern Pipeline Company and Peabody Coal Company.	Eastern Wyoming

A fourth project using the Koppers-Totzek gasification process is being installed at a plant at Verona, Pennsylvania. This will use all types of coal to provide low B.T.U. gas suitable for methanating to give 950 B.T.U./scf pipeline gas. This unit is in the nature of a pilot plant.

Ten other commercial projects, representing the balance of the fourteen plants, are in the early planning stages with few details except some information on the coal reserves

H. Commercial Projects - (Cont'd)

that are available. The owners and locations of these plants are as follows:-

- Michigan Wisconsin Pipe Line Company and North American Coal Corporation.	North Dakota (lignite)
- Northern Natural Gas Company and Cities Service Gas Company.	Powder River Basin, Montana
- Natural Gas Pipeline Company of America.	Dunn County, North Dakota (lignite)
- Colorado Interstate Gas Company and Westmorland Resources.	Southeast Montana
- Columbia Gas System.	West Virginia
- Texas Gas Transmission Corporation and Consolidation Coal Company.	Illinois Basin
- Texas Eastern Transmission Corporation and Fastern Gas and Fuel Association.	Northwestern New Mexico
- Transcontinental Gas Pipeline Corporation.	Power River Basin, Wyoming
- Consolidated Natural Gas Company.	Southwest Pennsylvania
- Island Creek Coal Company and Assoc.	Kentucky

I. Research Projects

Work on four new major ways of gasifying coal to synthetic natural gas is being funded totally or in part by the U.S.

I. <u>Research Projects</u> - (Cont'd)

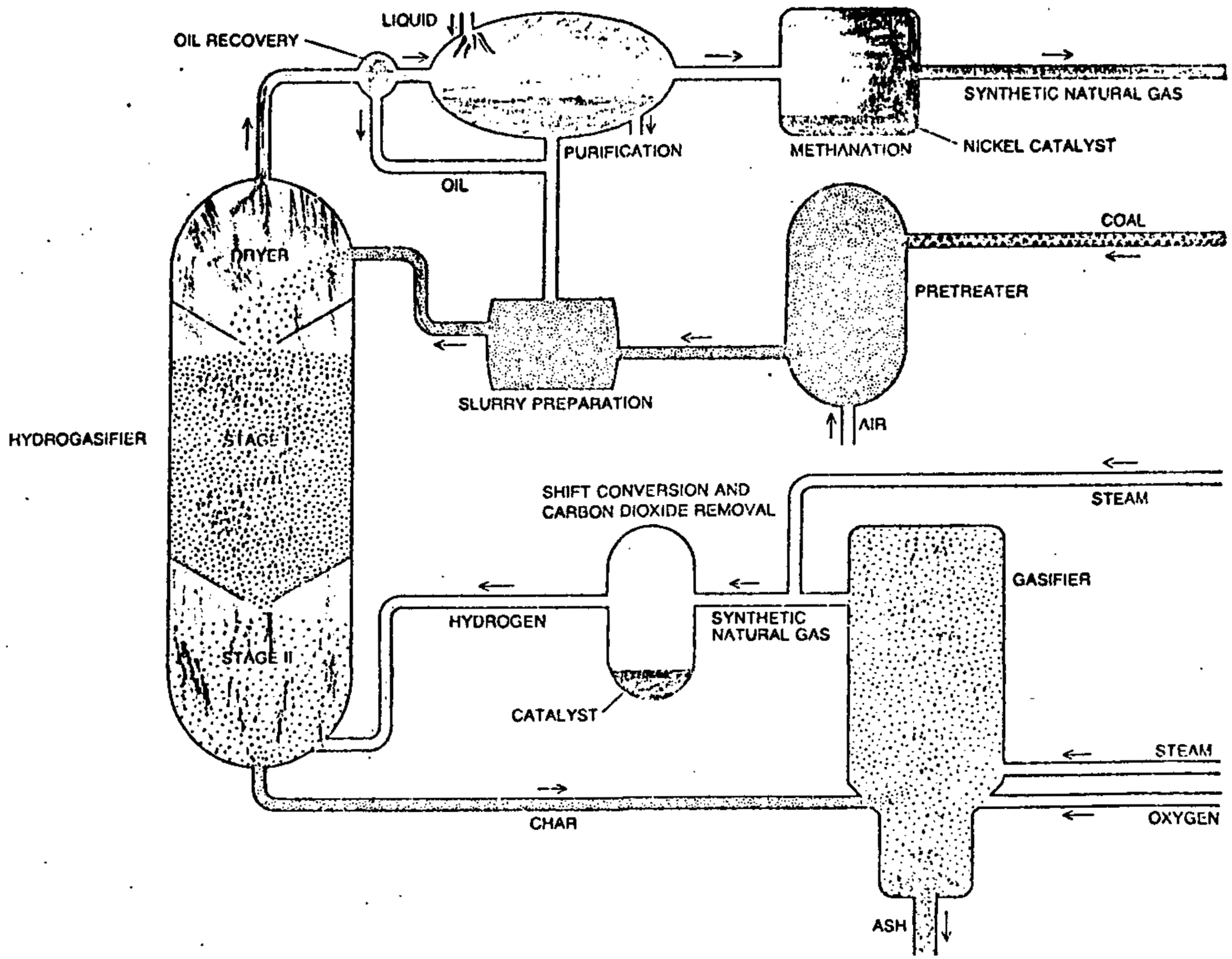
government. These schemes are at the pilot-plant stage with two operating plants and two under construction, and range in coal processing capacity from 40 to 120 tons per day. None can yet produce synthetic natural gas on a continuous basis.

The two pilot plants now operating are the Hygas plant in Chicago, which operates at high pressure and with a fluidized bed of coal, and the CO_2 Acceptor plant in Rapid City, South Dakota, which also uses a fluidized bed but, in this case, of lignite char. The two pilot plants under construction are the Bureau of Mines Synthane plant in Bruceton, Pennsylvania and the Bi-Gas plant in Homer City, Pennsylvania. Three of these plants require subsidiary oxygen plants; the Hygas, Bi-Gas, and Synthane processes. The CO_2 Acceptor plant does not require oxygen but cannot accept all types of coal.

The Hygas plant, the CO_2 Acceptor plant and the Synthane plant diagrams are shown on Figures 5, 6, and 7 respectively.

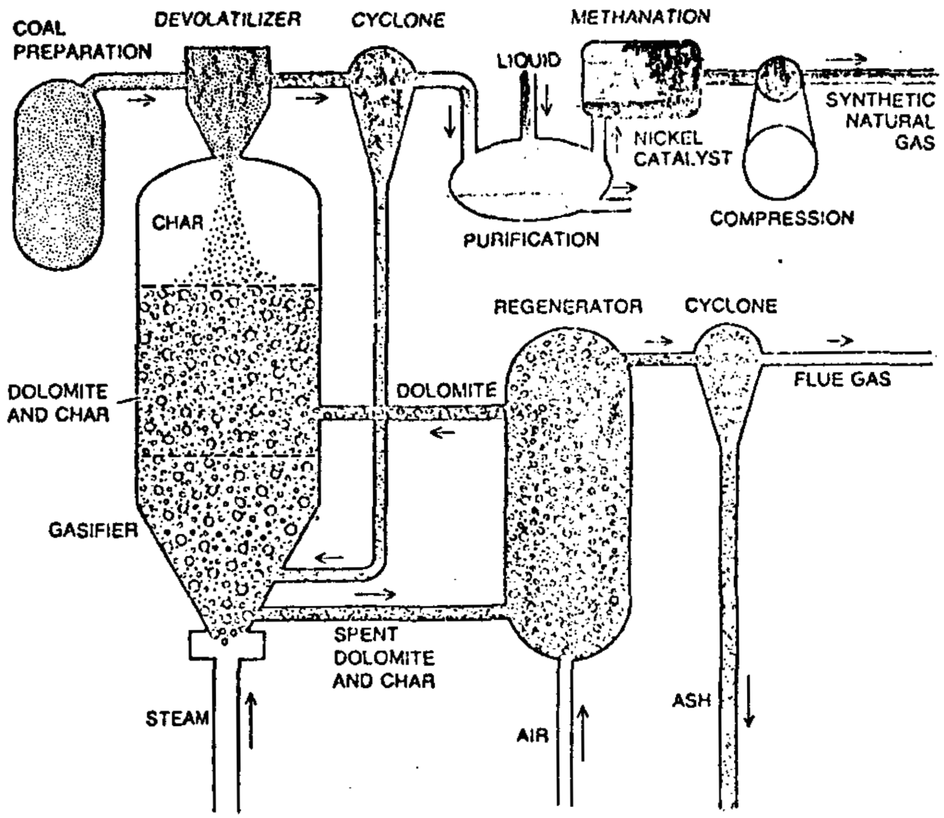
Data on 20 research and development projects currently in progress including the Hygas, CO_2 Acceptor, Synthane and the Bi-Gas plants, are identified below according to the type of process each employees. The owner, location and type of coal ised is presented with the data.

Figure 5



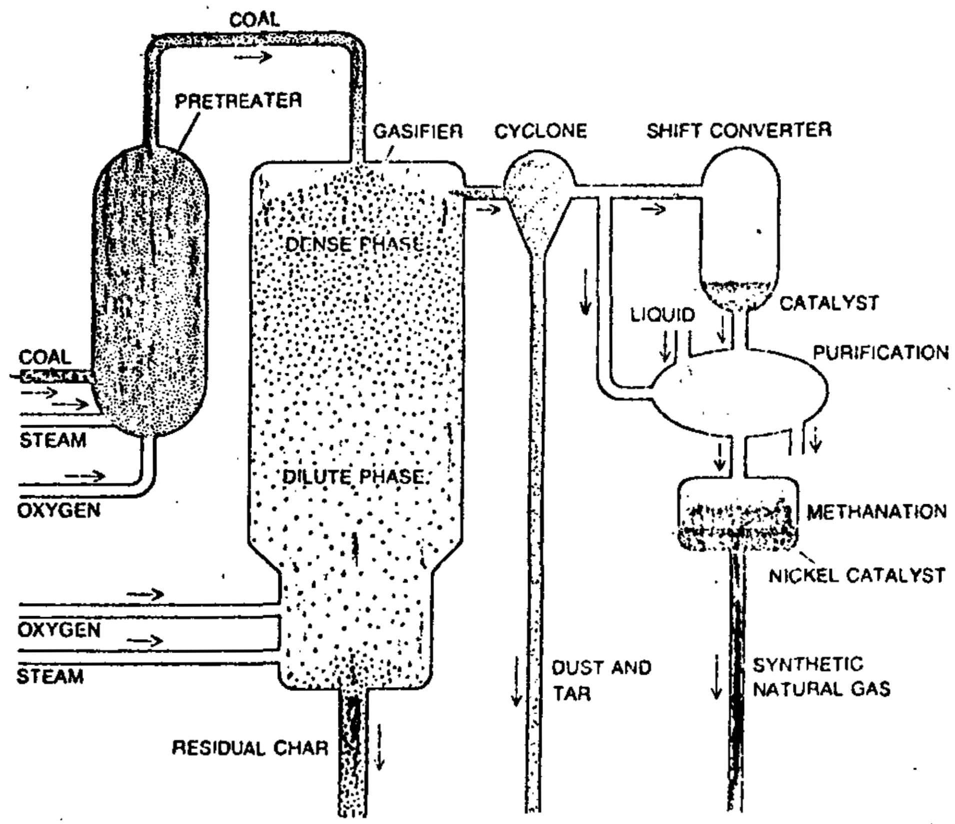
HYCAS PROCESS being developed by the Institute of Gas Technology is at the large-pilot-plant stage. Part of the coal put into the gasifier is gasified to form a mixture of carbon monoxide and hydrogen, which after shift conversion is converted to hydrogen. The hydrogen is reacted with coal or char, yielding a product that is largely methane. The gas is subjected to a final methanation reaction to attain a gas of pipeline quality. The HYCAS gasification process operates at high pressure and with a fluidized bed of coal.

Figure 6



CARBON DIOXIDE ACCEPTOR PROCESS, a project of Consolidation Coal Company, is also at the large-pilot-plant stage. Calcined dolomite is circulated through a fluidized bed of lignite char. The dolomite reacts with carbon dioxide produced in initial gasification of coal, liberating enough heat to sustain the carbon-steam reaction. Raw gas produced, containing methane, hydrogen and carbon monoxide, is subjected to a final methanation step.

Figure 7



SYNTHANE PROCESS of the U.S. Bureau of Mines is at the small-pilot-plant stage. It is designed to produce a synthetic gas that would serve as a substitute for natural gas. Coal is pretreated to destroy its caking properties, carbonized in the dense phase of the gasifier and then gasified with oxygen and steam in the dilute phase. Shift conversion to yield a 3 : 1 ratio of hydrogen to carbon monoxide is followed by methanation with a nickel catalyst.

I. Research Projects - (Cont'd)

Lurgi Pilot Plants

- El Paso Natural Gas Company.	Four Corners, New Mexico (non-coking coal)
- Conoco Methanation Company and Scottish Coal Board.	Westfield, Scotland
- South African Coal, Oil and Gas Corporation and Lurgi.	Sasolburg, South Africa

COGAS Process

- COGAS Development Corporation.	Princeton, N.J. (bituminous & semi-bituminous)

HYGAS Process

- Institute of Gas Technology.	Chicago, Illinois (all types of coal)

CO_2 Acceptor Process

- Consolidation Coal Corporation.	Rapid City, South Dakota (lignite and sub-bituminous)

BI-GAS Process

- Bituminous Coal Research Inc.	Homer City, Pennsylvania (all types of coal)

Synthane Process

- U.S. Bureau of Mines	Bruceton, Pennsylvania (all types of coal)

I. <u>Research Projects</u> - (Cont'd)

In addition, there are a number of coal gasification processes under study in the laboratory stage and these are listed below.

<u>Assorted New Techniques</u>

- Steam-Iron Process - Institute of Gas Technology - Chicago, Illinois.
- Kellogg Molten Salt Process - M. W. Kellogg Company (all types of coal).
- Union Carbide Process - Chemical Construction Corporation.
- Nuclear Coal Gasification Process - General Atomic and Stone & Webster.
- Atgas Process - Applied Technology Corp. (all types of coal).
- Hydrane - U.S. Bureau of Mines (all types of coal).
- Unk - Exxon Corporation - Baytown, Texas.
- Union Carbide/Battelle Agglomerating Ash Process - Battelle Columbus Labs, West Jefferson, Ohio.
- Industrial Flue Gas Process - Woodall-Duckham Ltd.
- Low B.T.U. Gas/Combined Cycle Electric Power Process - Westinghouse Electric Corp., Waltz Mill, Pennsylvania.

Two experimental projects as yet unnamed are under study by Garrett Research and Development Corp. at La Verne, California, and the General Electric Company in Schenectady, New York.

I. Research Projects - (Cont'd)

The improved technology represented by these research programs will be necessary in face of rising coal mining costs. One of these bench scale research projects provides for the liquification of coal as a first step and, subsequently, to obtain high carbon and hydrogen conversion without the need for methanization. The heat source for such a process would be provided by nuclear reactor. Projected capital costs for a plant producing 710 billion B.T.U./day of pipeline gas are about $800 million (in 1974 dollars) including the nuclear heat reactor source. Current estimated cost for an equivalent sized plant using processes now being developed would be about $1,100 million. However, in the absence of full scale commercial plants, the cost of coal gasification can only be roughly estimated and these estimates must be viewed with caution.

J. References

King Coal's Last Chance:- Power Engineering of March 1974.

Coal Gasification - A New Look:- Pipeline & Gas Journal March 1974.

Coal Gasification - An Alternative:- Combustion Engineering Inc. March 1974.

Energy's Technology in Self-Sufficiency:- Combustion Engineering Inc.

Energy Enigma:- Deveirman & Meier, Universal Oil Products 1974.

The Gasification of Coal:- Scientific America March 1974.