THE TOSCOAL PROCESS - PYROLYSIS OF WESTERN COALS AND LIGNITES FOR CHAR AND OIL PRODUCTION

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INTRODUCTION

Western coals and lignites generally have high moisture and organic-bound oxygen contents compared to Eastern coals. Arkansas lignites contain as much as 52% moisture (1), and Powder River subbituminous coals contain from 21 to 30% moisture (2). Pennsylvania bituminous and anthracitic coals contain only 3-6% moisture (3). To the extent that coal contains organically-bound oxygen, it has already been "burned" and its heating value has suffered accordingly. The oxygen values of coals vary inversely with coal ranking. Anthracites contain about 3% oxygen, on a moisture and ash free basis. Corresponding values for lignites are 20-30% (4).

The disadvantage of high oxygen and moisture contents in Western coals is offset by their low sulfur contents, and large volumes of Western coals are being shipped to the East despite freight rates which are very high when calculated on a heating value basis.

Any technique which effects selective removal of moisture and combined oxygen, primarily as carbon dioxide and water, will be of interest unless the cost is too high or an offsetting quality disadvantage results.

Removal of moisture has been widely discussed and examined (5,6,7). Lignites and subbituminous coals have been dried on a very large scale (5). Shipment, handling and storage problems were circumvented, and successful utility burning tests were run. While drying reduces shipping weight and increases the heating value of the solid fuel, it does not produce oil and high Btu gas coproducts.

Low temperature pyrolysis, i.e., to 800-900°F, removes any moisture remaining after the usual preheating steps and, more significantly, produces valuable oil and gas products while eliminating much of the organically-bound carbon dioxide and water. Both carbon dioxide and water are easily removed, if desired, from the gaseous and liquid hydrocarbon products.

The char product produced from low temperature carbonization can be used as a utility boiler fuel, potentially as the major component in the manufacture of formcoke and as a feedstock to gasification which would make a synthesis gas free of hydrocarbons and tars.

The oil product may be used as a fuel oil and as a source of chemicals. It may be converted to pitch binders for carbon and to metallurgical coke.

Previous reports have been given on the TOSCOAL process (8,9,10). Since these initial reports, we have continued our development efforts and have successfully extended our pilot plant test work to coals having caking properties and have found the char to be an attractive feed to gasification.

DESCRIPTION OF THE TOSCOAL PROCESS

Tosco Corporation has investigated oil shale retorting by the TOSCO II process at the pilot plant and semi-works scale since the late 1950's. Operations at our 1,000 ton/day Parachute Creek semi-works were terminated by Tosco Corporation and its partners in 1972, after total expenditures of more than 50 million dollars. In 1969 and 1970 we were successful in retorting subbituminous coal in our 25-ton per day oil shale pilot plant located near Denver, without significant changes in process conditions normally designed for oil shale. We have chosen the name TOSCOAL to designate the process which involves the application of our oil shale retorting technology to the low temperature pyrolysis of coal.

A diagram of the TOSCOAL process is shown in Figure 1. Coal is fed to a surge hopper and dried and preheated by dilute phase fluid bed techniques. This step may be modified, as required, to effect deagglomeration (decaking). The preheated feed is then transported to a pyrolysis drum where it is contacted with heated ceramic balls. The char product leaves the pyrolysis drum at 800-1000°F, passes through the trommel screen and is subsequently cooled and sent to storage. The cooled ceramic balls, being larger than the coal, pass over the trommel screen into a separate compartment and are returned to the ball heater by means of an elevator. Pyrolysis vapors are condensed and fractionated. Uncondensed gas, having a heating value of 500-1000 Btu/lb, may be utilized as a ball heater fuel or processed and sold after sulfur removal. Removal of contained carbon dioxide would raise the heating value of the gas to even higher levels.

The TOSCO II oil shale process produces essentially 100% of the oil yield measured by Fischer assay or about 0.8 barrel barrel of oil from a ton of oil shale having a Fischer assay of 35 gal/ton. TOSCOAL processing of coal also produces about 100% of the oil predicted by Fischer assay. Subbituminous coals yield 0.3 to 0.6 barrels of oil per ton of raw coal. Oil yields from bituminous coals are greater.

TOSCOAL processing offers several advantages:

1. The use of an indirect heat source results in the production of gas having a high heating value.

2. The process is continuous.

3. The process operates with a high throughput of solid product per unit volume of retort and with good heat transfer and moderate mixing.

4. Pollution control is much better than for conventional coke ovens used in high temperature carbonization.

Previously reported pilot plant runs with a non-caking Wyoming subbituminous coal have now been augmented by successful operations with coals having Free Swelling Indices (FSI) of 1 and 3.5. Prior deagglomeration, by fluid bed treatment with steam and air, was needed before processing the coal having the FSI of 3.5.

We have used the Tosco Material Balance Assay (TMBA) technique (11) to determine a product slate and to provide sufficient product for property determinations. Data obtained provide a useful benchmark with which to compare pilot plant retorting results. The TMBA procedure requires only 100 grams of representative coal. The apparatus used for TMBA is illustrated in Figure 2. The method is basically the well known Fischer assay procedure with provision for collecting all of the product gas for later analysis by gas chromatography. Coal is placed in the steel retort and the head is bolted on to assure no loss of vapors. The contents of the retort are heated to a terminal temperature of 930-950°F using a prescribed temperature-time profile. Oil and water are collected in the centrifuge tube which is immersed in ice water. The gas product passes through a pressure activated solenoid valve and is collected in the glass container shown. Good material balances are obtained on a routine basis.

PILOT PLANT RESULTS WITH COAL

1. Subbituminous Coal

Our initial pilot plant work was carried out on several hundred tons of subbituminous coal obtained from the Wyodak mine located near Gillette, Wyoming. A typical analysis of this coal, as received, is shown in Table 1.

It is our observation, in the pilot plant retorting of this coal, that the mechanical handling of the solid and liquid products was very similar to that experienced in extensive prior operations with oil shale.

Pilot plant retorting was conducted at three retorting temperatures with the results given in Table 2. TMBA data are included for comparison. The char yield decreased with increased retorting temperature, and the oil yield increased. The water yield was not defined accurately in the pilot plant since some steam was used in the process. Accordingly, the water yield was calculated from the moisture of the coal and from Fischer assay data. The compositions of the coal feeds to these four test runs were not identical, although each coal was from the Wyodak mine.

Product char properties are listed in Table 3 and plotted in Figure 3. The char volatile matter values decreased, and the heating values increased as the retort temperature was raised. The general range of heating values obtained is excellent for boiler fuel application and represents about a 50% increase over the heating value of the corresponding raw coal.

The properties of the oil products are given in Table 4. The oil properties change only slightly with increased retort temperature. The low sulfur values are to be noted. The oils are rich in potential chemical values. In particular, the IBP to 446°F portion of the tar produced in Run C-3 contained 65 weight percent of phenols, cresols, and cresylic acids.

The retort gas yields are given in Table 2. The product gases gave the analyses shown in Table 5. It is to be noted that the mixture obtained has a high heating value, and the heating value obtained after removal of acid gases is in the natural gas range. Removal of the butane and heavier components for other use would tend to slightly reduce the reported heating values.

FIGURE 1. TOSCOAL Process

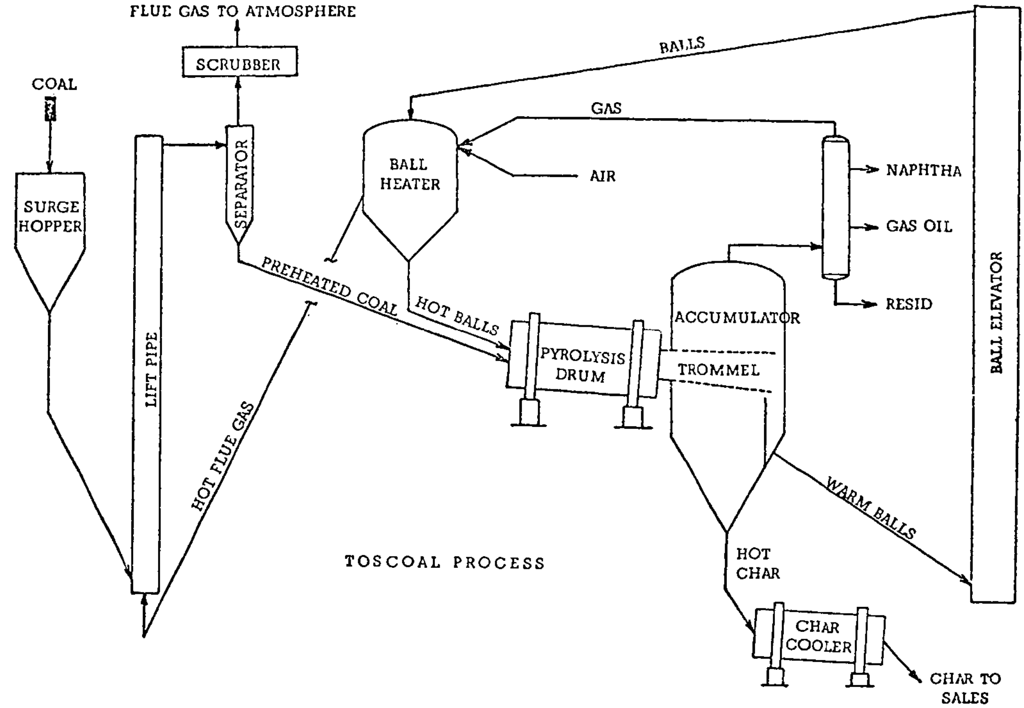


FIGURE 2. Product Collection Assembly - Tosco Material Balance Assay

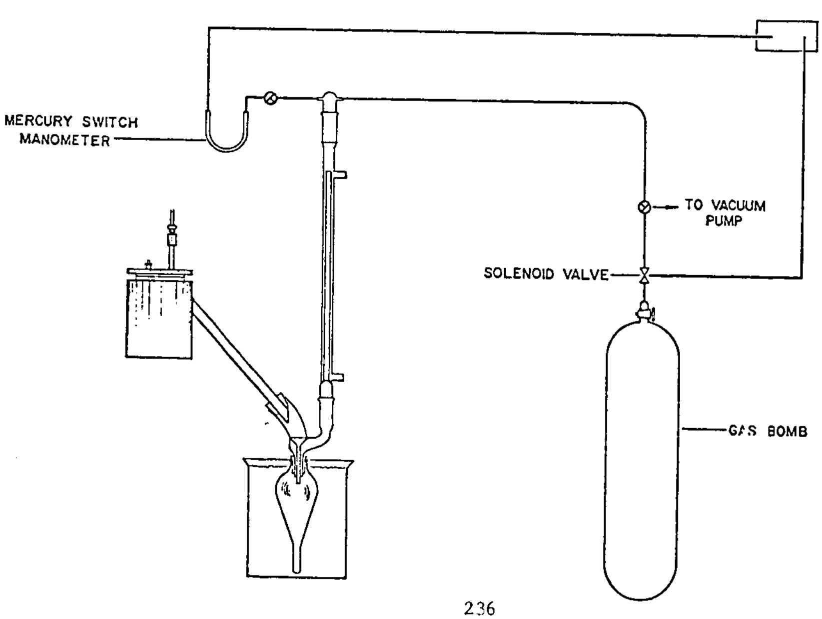


TABLE 1

WYODAK COAL ASSAY

(Samples 120-8, 120-10)

Proximate (wt %)		Ultimate (wt %)	
Moisture	30.0	Carbon	46.4
Ash	5.3	Hydrogen	2.8
Volatile Matter	30.7	Oxygen	14.7
Fixed Carbon	34.0	Nitrogen	0.7
Total	100.0	Sulfur	0.3
Heating Values,		Moisture	30.0
Gross, Btu/lb	8,139	Ash	5.3
Net, Btu/lb	7,570	Total	100.2

Other Data

Free Swelling Index	0
Hardgrove Grindability	56
Lb SO_2/MM Btu	0.74

TABLE 2

TOSCOAL RETORTING OF WYODAK COAL

Product Yields (lb/ton of as-mined coal)

	Pilot Plant			TMBA
Retort Temperature	800°F	900°F	970°F	935°F
Run No.	C-8	C-2	C-3	3383
Char	1049.0	1011.7	968.7	989.7
Gas (C_3 and lighter)	119.0	156.7	126.0	156.5
(SCF/ton)	(1250.0)	(1777.0)	(1624.9)	(1876)
Oil (C_4 and heavier)	114.0	143.0	186.2	157.8
(gal/ton)	(13.2)	(17.4)	(21.7)	(19.8)
Water	702.0*	702.0*	702.0*	702.0
Totals (lb)	1984.0	2013.4	1982.9	2006
Recovery (%)	99.2	100.7	99.1	100.3

* Value assumed from Fischer assay and moisture content. The addition of steam to the process prevented accurate measurement of water produced in retorting.

TMBA Tosco Material Balance Assay, No. 3383

TABLE 3

TOSCOAL CHAR PROPERTIES

	Pilot Plant			TMBA
Retort Temperature	800°F	900°F	970°F	935°F
Run No.	C-8*	C-2	C-3	3383
Proximate (wt %)				
Moisture	0.0	0.0	0.0	0.0
Ash	12.4	10.0	9.8	8.9
Volatile Matter	25.3	19.7	15.9	15.8
Fixed Carbon	62.3	70.3	74.3	75.3
Total	100.0	100.0	100.0	100.0
Ultimate (wt %)				
Carbon	68.8	74.7	77.5	76.5
Hydrogen	3.4	3.0	2.9	3.0
Oxygen	13.3	11.8	8.3	7.8
Sulfur	0.5	0.2	0.3	0.4
Other Data	1.0	1.2	1.3	
Equilibrium Moisture (wt %)	10.0	10.8	9.9	ND
Hardgrove Grindability	59.5	49.1	45.6	ND
Heating Values				
Gross, Btu/lb	11,826	12,560	12,963	13,155
Lb SO_2/MM Btu	0.85	0.32	0.46	0.61

* Feed Wyodak coal was different from that used in runs C-2 and C-3.

ND Not determined TMBA Tosco Material Balance Assay, No. 3383

TABLE 4

TOSCOAL OIL PROPERTIES

Retort Temperature	Pilot Plant 800°F	900°F	970°F	TMBA 935°F
Run No.	C-8*	C-2	C-3	3383
Ultimate (wt%)				
Carbon	81.4	80.7	80.9	81.4
Hydrogen	9.3	9.1	8.7	9.4
Oxygen	8.3	9.4	9.3	7.0
Nitrogen	0.5	0.7	0.7	0.6
Sulfur	0.4	0.2	0.2	0.2
Total	99.9	100.1	99.8	98.6
Heating Value (Gross, Btu/lb)	16,590	16,217	15,964	16,465
API Gravity	7.9	4.5	1.9	12.8
Pour Point (°F)	90	100	95	ND
Conradson Carbon (wt%)	7.6	9.9	11.4	ND
Distillation** (vol%)				
2.5	413°F	420°F	390°F	ND
10	490	475	405	
20	575	550	455	
30	645	625	545	
40	710	700	640	
50	765	775	725	
Viscosity (SUS)				
180°F	122	123	128	ND
210°F	63	66	69	ND

* Feed Wyodak coal was different from that used in Runs C-2 and C-3.

** Combination of TBP and D-1160 distillations.

TMBA Tosco Material Balance Assay, No. 3383 ND Not Determined

TABLE 5

TOSCOAL GAS ANALYSES

Retort Temperature	Pilot Plant 800°F	Pilot Plant 900°F	Pilot Plant 970°F	TMBA 935°F
Run No.	C-8*	C-2	C-3	3383
Component (mole %)				
H_2	0.8	1.0	7.8	5.6
CO	18.0	17.3	18.4	15.1
CO_2	51.1	42.3	36.4	44.7
H_2S	1.7	1.3	0.3	0.8
CH_4	16.9	22.0	24.9	22.4
C_2H_6	3.6	4.7	4.4	4.6
C_2H_4	1.9	1.9	2.4	2.3
C_3H_8	1.3	2.2	1.2	1.2
C_3H_6	1.6	3.7	1.6	1.4
iC_4H_{10}	0.1	0.1	0.0	0.1
C_4's (other)	0.3	2.0	1.1	1.0
C_5's	1.0	1.8	0.7	0.5
C_6's	0.7	0.6	0.4	0.5
C_7's	0.5	0.1	0.3	0.0
C_8+	0.2	0.0	0.1	0.0
Total	99.7	101.0	100.0	100.2
Average Molecular Weight	35.9	35.0	30.6	32.3
Weight Percent Carbon	40.5	45.9	44.7	42.0
Heating Values (Calculated)				
Gross, Btu/SCF	534	717	630	552
Net, Btu/SCF	494	663	580	508
Calculated with CO_2 and H_2S removed				
Gross, Btu/SCF	1,113	1,234	995	998
Net, Btu/SCF	1,029	1,138	920	919

* Feed Wyodak coal was different from that used in Runs C-2 and C-3.

2. Higher Rank Coals

The successful operation of the TOSCOAL pilot plant with subbituminous coal was encouraging and suggested access to most of the Western coals and lignites. However, some Western coals and most of the Eastern coals are of higher rank and have an FSI ranging from 1 to 9. The feasibility of retorting with heated ceramic balls was in question since caking coals fuse below the retorting temperature range of 800-1100°F. Some short process tests with Illinois No. 5 coal (FSI-4) confirmed that the retort mix became "sticky" and resistant to flow.

We first processed six tons of coal from the Plateau Mine (Price, Utah) which had an FSI of 1, i.e., only a slight tendency to swell on heating. Coal assays are listed in Table 6 and pilot plant product yields and properties are given in Table 7, along with comparative TMBA results. No problems were encountered with this coal and no pretreatments, other than the usual drying and preheating, proved to be necessary.

Processing of Illinois No. 6 coal, having an FSI of 3.5, required pretreatment with steam and air at 570°F in a fluid bed before retorting. Pilot plant operability was good after this deagglomeration.

Assay data for the raw and pretreated coal are given in Table 6. The effect of deagglomeration was to decrease the TMBA oil yield and to increase the char yield. Deagglomeration presumably involves uptake of oxygen by the coal since subsequent pyrolysis (TMBA) shows an increase in product carbon dioxide in the gas. The raw coal yielded 11 pounds of CO_2 per ton of coal, and the corresponding value for coal treated with steam and air was 31 pounds.

Pilot plant processing of three tons of the deagglomerated coal was carried out to produce the results given in Table 7. Due to the short run length, material balances were not attempted at each of the two conditions.

LABORATORY RETORTING

It is not always possible to obtain sufficient test coal for pilot plant operations. As described above, we have used the TMBA procedure to investigate retorting of small quantities of coal. Although TMBA is a batch operation and TOSCOAL processing is continuous, we have found the product yields and product properties to be sufficiently similar to encourage wider use of this relatively simple laboratory procedure.

An excellent application of the use of low temperature carbonization as an assay technique for coal was reported by Landers in 1961 (12). Data, similar to those produced using TMBA, were reported on 220 domestic and foreign coals.

The Tosco Fischer assay procedure has been applied to a number of Western coals and lignites. Five examples, other than those discussed above, are described in Table 8. The assays of the coals and product chars are shown. The increase in the heating value of the char, as compared to the raw coal, is to be noted. In examination of product yields, it is apparent that low temperature carbonization of the materials shown produces about a 50% yield of char, based on the as-mined raw coal or lignite. Gas, oil and water yields vary with the source of the coal and with the retorting conditions.

TABLE 6

ASSAYS OF PLATEAU COAL, ILLINOIS NO. 6 COAL AND DEAGGLOMERATED ILLINOIS NO. 6 COAL

	Plateau Coal	Illinois No. 6 Coal As Received	Illinois No. 6 Coal Deagglomerated
Proximate (wt%)			
Moisture	10.0	8.8	0.7
Ash	13.0	6.7	8.3
Volatile Matter	34.1	32.0	31.6
Fixed Carbon	42.9	52.5	59.4
Total	100.0	100.0	100.0
Sulfur	0.9	0.7	0.7
Free Swelling Index (FSI)	1.0	3.5	1.5
Heating Value (Gross, Btu/lb) (Dry Basis)	11,906	13,293	13,071
TMBA Results (Dry Coal Basis)			
TMBA No.	1252	1340	1341
TMBA Temp. (^{o}F)	970	932	932
Oil, lb/ton	358.3	245.9	166.6
(gal/ton)	(45.6)	(27.9)	(19.0)
(API)	(18.6)	(2.2)	(2.7)
Char, lb/ton	1,417.9	1,603.6	1,675.2
Gas, lb/ton	140.1	79.1	103.8
(SCF/ton)	(2,039)	(1,360.8)	(1,630.7)
(Btu/SCF)	(945)	(1025)	(857)
Water, lb/ton	76.5	39.9	40.8
Total lb/ton	1,992.8	1,968.5	1,986.4

TABLE 7

TOSCOAL PROCESSING OF HIGHER RANK COALS
PLATEAU COAL AND DEAGGLOMERATED ILLINOIS NO. 6 COAL

PILOT PLANT AND TMBA YIELDS

	Plateau Mine, Price, Utah		Inland Mine No. 1 - Illinois No. 6 Coal Sesser, Illinois - Pilot Plant**			
			Pilot Plant			
	Pilot Plant	Tosco Material Balance Assay No 1252	Low Temp	High Temp	Total of Two Runs	Tosco Material Balance Assay No 1341**
Retorting Temp (^{o}F)	960	970	945	1075		932
Products (lb/ton, dry coal basis)						
Char	1399	1418	ND	ND	1469	1675
Oil	308	358	ND	ND	107	167
Gas	216	140	93	171	131	104
Water	77*	77	ND	ND	41*	41
Total Material	2000	1993			1748***	1987
Total Hydrocarbon as Oil & Gas (includes CO & H_2)	436	437				236
PRODUCT PROPERTIES						
Char, Volatile Matter (wt%)	14.0	ND	13.9	9.7		ND
Oil, ^{o}API	14.3	18.6	ND	ND		2.7
Gas						
SCF/ton	2448	2039	1395	3088		1631
Btu/SCF	1173	945	944	852		857

* Value from TMBA was used

** Prior to retorting, the coal was deagglomerated by treatment with steam and air in a fluid bed.

*** Material balance closure was not good due to small amount of total feed to the pilot plant.

ND Not Determined

TABLE 8

FISCHER ASSAY PRODUCT YIELDS AND PROPERTIES

(Fischer Assay Temperature - 950°F)

	Big Horn(1)	Big Sky(2)	Savage(3)	Arkansas Lignite(4)	Elkol(5)
Coal					
Proximate (wt %)					
Moisture	22.0	21.9	33.2	24.2	19.5
Ash	4.8	9.5	6.0	10.8	3.0
Volatile Matter	34.8	29.6	29.5	ND	30.6
Fixed Carbon	38.4	39.0	31.3	ND	46.9
Total	100.0	100.0	100.0		100.0
Heating Value, Btu/lb	9,578	8,948	7,230	ND	10,484
Product Yields (lb/ton of as-mined coal)					
Char	1,023.3	1,144.6	879.1	899.6	1,143.0
(Volatile Matter, wt%)	(13.2)	(15.0)	(13.0)	(ND)	(15.4)
(Heating Value, Btu/lb)	(13,249)	(11,997)	(12,252)	(ND)	(13,543)
Gas (C_3 & lighter)	136.6	118.9	155.7	155.2	131.8
(SCF/ton)	(1,940.4)	(1,674.9)	(1,886.7)	(1,875.1)	(1,933)
(Btu/SCF)	(617)	(613)	(451)	(500)	(693)
Oil (C_4 & heavier)	222.2	162.7	126.9	295.9	187.0
(gal/ton)	(27.5)	(20.5)	(15.8)	(37.8)	(22.9)
Water	617.2	568.5	807.3	650.2	535
Total (lb)	1,999.3	1,994.7	1,969.0	2,000.9	1,996.8
Recovery (%)	100.0	99.7	98.5	100.0	99.8

(1) Big Horn Coal Company, Sheridan, Wyoming
(2) Peabody Coal Company, Big Sky Mine, Colstrip, Montana
(3) Knife River Coal Mining Company, Savage, Montana
(4) Fischer Assay No 1258
(5) Kemmerer Coal Company, Elkol Mine, Frontier, Wyoming
ND - Not Determined

Using the type of data given in Table 8 it is feasible to estimate the yields and product properties to be obtained from commercial operations at any desired scale.

UTILIZATION OF PRODUCT CHAR

Utility Boiler Fuel

Important characteristics of solid fuels include the temperature of ignition, the temperature at the maximum rate of ignition, and the temperature at which complete burnout occurs. In most cases higher volatile matter and higher surface area are reflected in improved ignition characteristics. Chars from lower rank coals, such as lignite and subbituminous, generally ignite and burn rapidly due to the large surface area.

Laboratory tests have been conducted on TOSCOAL chars by three major boiler manufacturers. One found that the ignition characteristics were satisfactory and concluded that the char could be burned readily in a conventional, horizontally-fired boiler. Babcock and Wilcox personnel conducted burning profile tests on char in comparison to other solid fuels using the procedure published by Wagoner and Duzy (13). The results are illustrated in Figure 4. The "C-4 TOSCO" char was produced in our pilot plant from Wyodak coal by retorting at 800°F. The Tosco char ignited more readily and burned out completely at a lower temperature than did bituminous coals.

Another boiler firm conducted small scale firing tests with char from the C-3 pilot plant run. They concluded that this low VM char (16%) burned in a similar fashion to Pennsylvania low volatile bituminous coal.

Commonwealth Edison (Chicago) and others have extensively investigated the utility boiler firing of partially dried lignite (5). Improvements over firing raw lignite were observed.

Texas lignite has been used as a boiler fuel after both charring and drying (14). The current practice of Texas Utilities is to burn dried lignite at their Rockdale mine facility.

Formcoke

There is currently great interest in finding a substitute for the conventional blast furnace coke used in making iron for subsequent conversion to steel. The coke is made from expensive coking coals, and the manufacturing process involves substantial air pollution. The use of non-coking coals, such as those found in the Western United States would be attractive since they are cheap and the supply is virtually limitless. Much of the technology currently being investigated for manufacturing synthetic coke (formcoke) involves pyrolysis of non-coking coals and subsequent production of calcined briquettes or pellets from the char (15,16,17,18). The addition of a pitch binder and sometimes some coking coal and other solids is required. Our judgment is that the TOSCOAL process can produce a satisfactory char and, after further oil processing, the pitch binder in an efficient and environmentally clean manner.

Feed to Gasification

One of the major problems encountered in coal gasification is handling the tars produced along with the primary gas product. These tars may cause

FIGURE 3

EFFECT OF TOSCOAL PROCESSING TEMPERATURE ON CHAR VOLATILE MATTER AND GROSS HEATING VALUE (Pilot Plant Results)

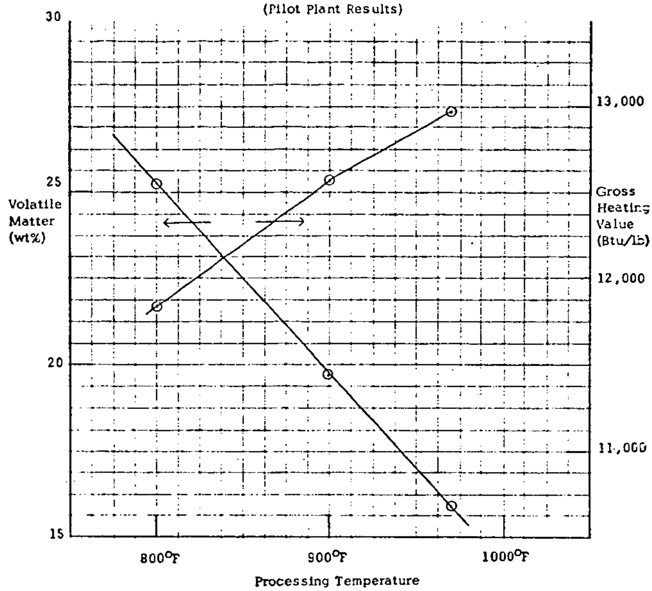
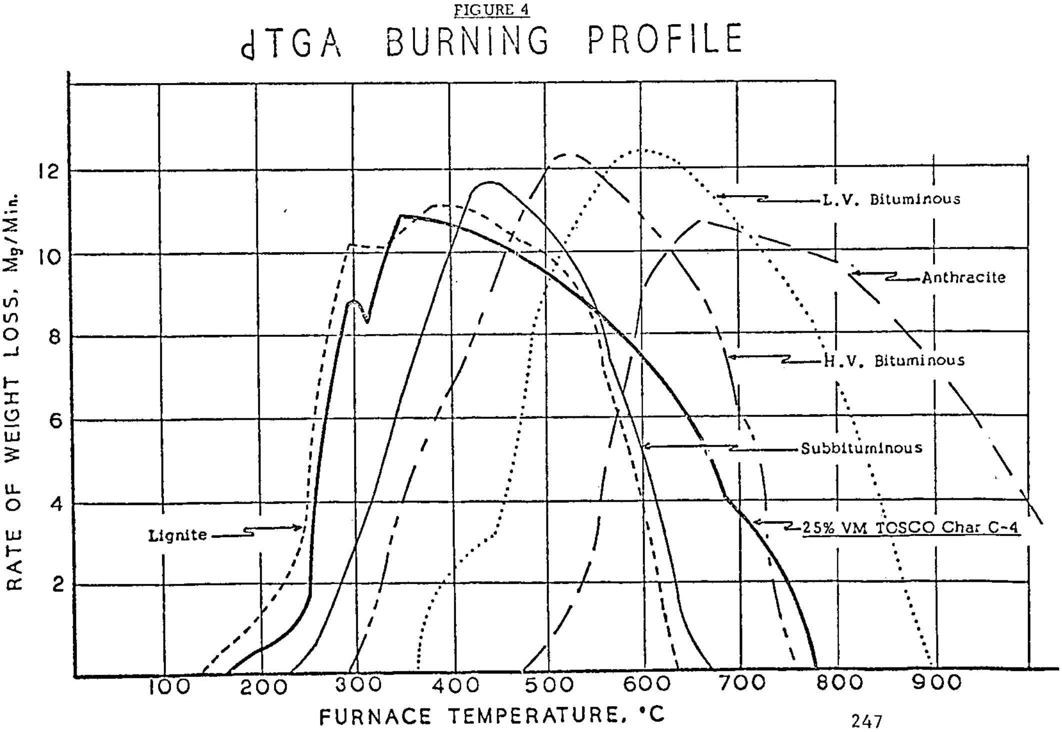


FIGURE 4



problems in heat recovery, in recovery of particulate solids and in water purification. Gasification of TOSCOAL char produces a synthesis gas free of tars and very low in methane, as illustrated in Table 9. Such a gas can be converted to high purity hydrogen or used as synthesis gas feed for methanol production.

Gasification of char has been investigated previously by FMC and others in the consortium called COGAS Development Company (19,20,21).

TABLE 9

GASIFICATION OF TOSCOAL CHAR FROM ILLINOIS NO. 6 COAL

Conditions	
Reactor Temperature (^oF)	1525
Fluidizing Gas	Steam (no air or O_2)
Product Gas Composition (Mole %)	
H_2	59.5
CO	18.3
CO_2	19.9
H_2S	0.1
CH_4	2.3
Total	100.1

UTILIZATION OF OIL

Oil from low temperature carbonization, 800-1000^oF, of coal differs from that produced in a coke oven (1600^oF) in that it contains a larger amount of oxygen and hydrogen and lower levels of pure compounds such as benzene and naphthalene.

Use of oil from TOSCOAL processing as a fuel oil is reasonable. Oils from Western coals and lignites generally have low-sulfur contents.

The oil from Run C-3, 970^oF retorting of Wyodak coal (Table 4) yielded, by distillation, an IBP to 446^oF fraction having a cresylic acid content of 65 volume percent. These acids are used in the manufacture of phenolic resins and phosphate ester plasticizers.

Oils from low temperature carbonization have been hydrogenated to a synthetic crude oil which has then been evaluated as a refinery charge stock (22), and as a carbon black feedstock (23).

After thermal treatment, oil from low temperature carbonization of lignite can be used as electrode pitch (24) and for the manufacture of coke (25).

Pitch, to be used in formcoke manufacture, can be made by air blowing the liquid product from low temperature carbonization (26).

ECONOMICS

The cost of a potential commercial TOSCOAL processing plant, using a subbituminous coal of the Big Horn type has been estimated. The design plant capacity yields are:

1) Feed rate, ton/day of "as mined" coal	7,230
2) Dry char product, ton/day	3,910
3) Oil product, bbl/day	4,130
4) Net product gas, MM Btu/day	2,261
5) Net gas, oil and dry char HHV values as a percent of wet feed HHV	94.7

Part of the hydrocarbon product mix is used internally as process fuel.

The plant envisioned is based on a maximum size single pyrolysis train operating at a retort temperature of 900°F. Operation at 800°F would increase plant capacity, but would produce somewhat less liquid product per ton of feed coal.

The investment, in June 1976 dollars, would be $73 million for the pyrolysis battery limits. The investment cost does not include the mine, feed preparation, product storage, land, buildings, rail siding and loading facilities and offsite utilities. Equipment for sulfur dioxide removal is also not included but may not be necessary.

Components of the operating cost are:

1) A total of 28 shift workers
2) Maintenance cost of $2.8 MM/year
3) Operating supplies of $0.5 MM/year
4) Power requirement of 37 MM KWH/year

Expenditure of these estimated investment and operating costs would produce a superior solid fuel which would offer cost savings in utility power generation. A recent study (27) compared investment costs and operating parameters for a 500 megawatt P.C. (pulverized coal) fired boiler to be fired, on the one hand, with Gillette, Wyoming coal and North Dakota lignite and, on the other hand, with chars from these coals. In the Gillette coal case an investment savings of nine dollars per installed KW can be realized, for the boiler island, in changing fuels from raw coal to char. These savings are mainly in reduced requirements for pulverizers and for boiler furnace size. Further, boiler efficiency would improve by 5.3% and internal power consumption, mainly for fans and pulverizers, would decrease by 2,500 KW.

Corresponding savings in the North Dakota lignite case were higher. The investment would be reduced by $17.5 per installed KW. Boiler efficiency would improve by 6.8%, and internal power consumption would decrease by 6,300 KW.

In addition to savings in power generation, an advantage of char over moist, "as mined" coal and lignite would be in lowered freight costs. Assuming a freight cost of 12 mills/ton mile, the cost of shipping a ton of Wyodak coal (Table 1) 1,000 miles would be $12.00 or $.74/MM Btu. On the same basis, the cost of shipping one ton of Wyodak char (C-8 run, Table 3) would be only $.51/MM Btu. This saving assumes there would be no offsetting cost in handling the more pyrophoric and dusty char.

Covered hopper cars have been manufactured by Thrall Car Manufacturing Company (Chicago Heights, Illinois) and perhaps could be used to haul char produced from low temperature carbonization. Currently, the "flip top" cars are being used to ship "as mined" lignite across North Dakota to the Big Stone Power project at Big Stone City, South Dakota. The covered car was needed to reduce dust loss and to prevent freezing during the winter.

SUMMATION

TOSCOAL processing of coal is based on technology acquired in twenty years of continuous work on the TOSCO II oil shale retorting process. Coals of low rank can be used directly. Those of higher rank may be retorted after treatment with air and steam to effect decaking.

Processing of Western coals and lignites is of interest in reducing the large freight costs currently involved in transporting moisture and non-combustible components. Use of chars rather than coal as utility boiler fuels offers investment and operating cost advantages. Chars produced may also be used in the manufacture of formcoke and as an improved feedstock in gasification.

Liquid products may be used as a fuel, and as a source of chemicals, coke and pitch binders.

High heating value gas is produced as a coproduct.

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