Market development survey for continuous coal charring process

by Robert A Lengemann

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering
Montana State University

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The char used in the Anaconda test and in the American Chrome test was derived from Red Lodge coal as this coal is being used in the first commercial plant at Red Lodge, Montana. Colorado Fuel and Iron Corporation furnished their own coal since this is the coal they intend to use, should they decide to build a char plant for their use.

The estimated capacity of the Red Lodge plant is 2000 lb. of char per hour per retort. The by-product yield is 20 gallons per ton of coal.

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ABSTRACT

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INTRODUCTION

Montana coal deposits may once again be regarded as valuable assets since the advent of the new charring process at Red Lodge, Montana. Until now, the users of coke and char in Montana have had to go elsewhere for their supply of carbon. The principal users in and around Montana are the Anaconda Company at Anaconda, Montana; American Smelting and Refining Company at East Helena, Montana; Victor Chemical Company at Butte, Montana; Westvaco Chemical Company at Pocatello, Idaho; and Monsanto Chemical Company at Soda Springs, Idaho. The annual carbon requirements of these companies are as follows:

Anaconda Company	500,000 tons
Victor Chemical Company	100,000
Westvaco Chemical Company	200,000
American Smelting & Refining Company	25,000
Monsanto Chemical Company	75,000
Total	900,000

This would require approximately 1,400,000 tons of coal per year.

The above estimate covers only those existing markets and does not take into consideration any industries which might be attracted by a low priced, reliable source of carbon. One such industry is the American Chrome Company at Nye, Montana. They are considering the installation of a smelter to be used in smelting the chromium-bearing ores which they are mining at the present time. This smelter would use electric furnaces and utilize char from Red Lodge.

The companies previously mentioned can and probably will be supplied from the plant at Red Lodge, not only because of locational advantages, but also because the elemental phosphorus producing companies (Westvaco Chemical Company and Victor Chemical Company) require an agglomerated char of the type produced from Red Lodge coal. The possibility exists, of course, that these companies, excluding the phosphorus companies, may be supplied by future plants in other locations. This, however, depends on future economic studies and goes beyond the scope of this report.

The present supply of coke for Northwestern industries is supplied largely by an excess from the steel industry. The disadvantages of this arrangement can be seen immediately. The steel companies are in business primarily to produce steel, and coke is a necessary raw material in the production of steel. When steel production is low, coke is in excess and the resulting price is low, but when steel production is high, the price of coke follows. The freight rates from the distant steel companies also aid in raising the price of the coke. These fluctuations in coke price and supply place the phosphorus and non-ferrous metal refiners of Montana and adjoining states in a difficult situation. They are only too glad to replace coke with char provided the char will work satisfactorily in their respective operations.

The P. D. P. char process can alleviate this situation and at the same time revive the coal industry in Montana.

It would be possible to build a coking operation to serve Montana industries were it not for the fact that there is no source of coking coal in Montana which can be mined economically with existing mining methods. The coking properties of coals depend upon the amount and nature of certain bitumens present in the coal. These bitumens will melt on heating and give up their volatile constituents. They then harden into a hard, coherent mass. Most of our western coals do not contain these bitumens in sufficient amounts to produce a high-grade coke. This lack of coking coal coupled with the fact that char can be produced at a much lower cost than coke, accounts for the lack of coking operations in Montana and makes the charring process so attractive. This lower cost is achieved through a much lower initial investment plus the fact that the char process is more economical to operate. A coking operation capable of producing 110,000 tons of coke per year would cost about $4,700,000 (3) while a char process of equal capacity would only involve an initial investment of about $625,000 (1). From these figures it can be seen that the char process is definitely more economical provided the char is acceptable as a substitute for coke.

At the present time, work is being carried out which may lead to a new char plant in Colorado for the conversion of high-volatile coals to high-volatile chars (V.M. 17-19%). These chars will be blended with more high-volatile coals to produce a metallurgical grade coke (4), thus producing an acceptable grade coke from inferior coal. This experimentation is being carried out by the Colorado Fuel and Iron Corporation at Pueblo, Colorado. Originally, low-volatile coal was used in place of char in the blending, but due to the great distances between low-volatile coal deposits in eastern Oklahoma and the coking operations in Colorado and California, char from local high-volatile coals is being substituted with very good results. The char being used contains between 17-19% volatile matter.

EQUIPMENT AND PROCEDURE

The equipment used in producing the char for this market development was (1) a pilot plant retort (Fig. 1), and (2) a commercial scale retort (Fig. 2). A bench scale retort was used to test all coals before they were fed to the larger retorts.

The bench scale retort consisted of a $1\frac{1}{2}$-in. stainless steel pipe closed at both ends except for a gas off-take tube at the top. It was operated as a batch operation and it was heated by means of electrical windings around the outside of the pipe. The capacity of this retort was about 100 grams of coal per batch. The coal gases were withdrawn through the tube at the top and all condensable gases were condensed in a receiver flask. The non-condensable dry gases were put through a wet test meter. In this way, each coal could be analyzed for dry gas, creosote, water, and char yield.

After first proving that the process was feasible, the pilot plant retort was then used to produce char for tests in the plants of prospective consumers until the first commercial plant went into operation. It also produced creosote and tar in sufficient quantities for further research on the uses and properties of these oils.

The pilot plant retort with a capacity of 10 tons of coal per day consists of four concentric upright stainless steel cylinders (Fig. 1). The center or innermost cylinder is a heat duct conducting heat from the furnace through the retort. The first annular space out from the center or that space between cylinders 1 and 2 is the coal zone. The width of the coal zone is two inches. Coal is gravity-fed into the top of this space and is withdrawn from the bottom by two variable speed stainless steel augers. The annular space between cylinders 2 and 3 is the outside heat zone. Thus, the coal is heated on both sides. The combustion gases from both heat zones are collected in the heat manifold at the top of the retort and recycled to the furnace. The outside annular space between cylinders 3 and 4 is the gas off-take zone. The coal gases are conducted from the coal zone through the outside heat zone by eighty 2-in. stainless steel tubes. From the coal gas zone, they are picked up by the by-product blower and forced through the gas condensing system. The coal is kept in constant agitation by rotating the No. 1 cylinder back and forth through a thirty-degree arc.

After the coal gas leaves the retort, it passes through a cyclone where all the dust is removed. It was found necessary to heat-jacket the coal duct up to the cyclone to prevent the gas from condensing. The condensed tars, when combined with the coal dust which they carried, would plug the system. After the dust is removed, the gas proceeds through three condensing columns where it is scrubbed with a recycled cool creosote-water liquor. The noncondensable gases are flared.

During the operation of the pilot plant, trouble was encountered in the separation of the creosote from the water. Decantation was tried but as the density of the creosote was very close to that of water (about 1.03), this proved inefficient. As centrifuges are used to separate certain immiscible liquids, a centrifuge was installed to see if this method of separation could be used. It was found that the separator worked well on creosote-water mixtures of about 80% creosote and 20% water but did not have enough adjustment to separate mixtures which varied from this composition. Since the mixture to be separated contained about 30% creosote and 70% water, the machine in use was unacceptable. The centrifuge worked well enough, however, to merit further investigation, so a sample of the mixture to be separated was sent to The De Laval Centrifuge Company to be tested. Not only did their analysis show that the separation could be made but it also greatly reduced the benzene insolubles in the creosote.

The commercial retort (Fig. 2) was finished and put into operation by the Atkinson-Berg Company at Red Lodge, Montana on July 15, 1957. The Red Lodge plant will consist of six such retorts but this first one will be operated for a period of three to four months before construction will begin on the remaining five retorts. Although the commercial retort operates on the same principle as the pilot plant retort, several important improvements have been made.

The heat passes up through the outside heat zone and passes down through the inside heat zone. It is then exhausted through the annular space between cylinders 0 and 1. By eliminating the fresh combustion gas entrance into the inner heat zone, the seal at the bottom of the coal zone between the coal and combustion gases has been eliminated. A great deal of burning was taking place at this spot in the pilot plant retort.

The coal is agitated in the commercial retort by raising and lowering cylinder 2 hydraulically about $1\frac{1}{2}$-in. every minute. This movement of the inner wall of the coal zone prevents the coal from bridging between the two walls. This up and down movement seems to prevent channeling more effectively than in the case of the pilot plant retort where the tube is rotated back and forth about thirty degrees.

The coal gas is drawn from the coal through louvers into a square duct between cylinders 3 and 4. From here it travels downward to the bottom of the retort where it passes into cylinder 0 and is taken upward again to the top of the retort and withdrawn. The space between the louver ducts is the outside heat zone.

The cylinders of the retort which are being heated are suspended from the top and are supported at the bottom by a spring and lever system, thus allowing the cylinders to expand downward against the tension of the spring.

The first char cooler to be installed at Red Lodge was a water-cooled vibrating plate which the char traveled across. The coarse material traveled a great deal faster than the fines, so the coarse material was not cooled sufficiently. This vibrator cooler was replaced by a trommel cooler and classifier. The cooling was effected by water sprays on the outside of the trommel. In addition, sprays were also added directly into the char augers. The water to these sprays was regulated so that the heat from the char would just vaporize the water.

Some difficulty was encountered with the furnace when the plant first went into operation. When the gas to the burners was increased, smoke would issue from the stack. Dampers and a blower were placed in the stack to obtain more draft. The pressure on the burners was also lowered. This has not altogether solved the problem. It is estimated that the burners are still operating at less than 50% efficiency.

The condensing columns exploded twice during initial operation, blowing all the water seals. A small air leak was found in the by-product blower. A damper in the flare stack to maintain a back-pressure on the columns would probably eliminate the possibility of this in the future.

On continuous operation it was found that the by-product ducts became plugged with dust and condensed tars due to excessive heat loss from the ducts. Heat jackets around the ducts were installed using combustion gases from the furnace as a source of heat. A spray was also introduced to the by-product blower to flush any material which might condense in the blower. This is possible since the blower is located after the cyclone. It is not possible to use sprays between the retort and the cyclone as this would result in the condensing of some tars which would pick up the dust before it is removed.

At the present time, the retort is operating at about 50% of capacity (about 1000 lb. of char per hour) and yielding 20 gallons of by-products per ton of coal. The gases being flared are more than sufficient to heat the retort. As soon as the second retort is built, these gases will be used to fire the furnaces.

RESULTS AND CONCLUSIONS

A test of char made from Red Lodge coal in the pilot plant retort was run at Anaconda's Sponge Iron Plant at Anaconda, Montana. Anaconda uses sponge iron as a precipitant in its leech-precipitation-float process for refining oxides of copper. It requires 4 lb. of sponge iron to produce 1 lb. of copper and 1 lb. of char goes into making each pound of sponge iron (2). Anaconda produces 132,000 tons of copper by this method each year, so this is a potential market of 500,000 tons of char per year. They are, at the present time, using sub-bituminous coal from the Big Horn Coal Company at Sheridan, Wyoming successfully. This means that char must compete with coal on a fixed carbon basis. Anaconda is obtaining coal with 40% fixed carbon for $2.00 per ton. This sets the price of carbon at $5.00 per ton. Char with 85% fixed carbon would have to sell for $4.25 per ton plus the difference in freight rates. Char cannot be sold profitably at this price. The average price of the char produced must be about $15.00. At the present time, the Red Lodge plant is producing a product which is 75% breeze (¼-in. minus). The coarse material can be sold for $20.00 per ton, so this fixes the price of the breeze at $13.30 per ton. As can be seen from these figures, the price which must be had for the fines is dependent on the percentage of ¼-in. plus material in the product. The amount of coarse material in the product in turn is dependent on the percentage of coarse material in the feed coal. The screen analysis of the feed coal is very close to that of the product, so there is very little grinding taking place in the process. The overall picture indicates that the price of the fines will go down as the quality of the feed coal goes up. The one saving feature of the Anaconda market is that, should the char breeze market slump elsewhere, this market will provide a temporary outlet for the char breeze.

The prospective market for char breeze at the present time is in sintering sulfide ores of zinc and lead at American Smelting and Refining Company at East Helena. As soon as a sufficient quantity of char has been produced, a test will be run at East Helena.

A test of Red Lodge char produced with the pilot plant retort was made by the United States Bureau of Mines at Albany, Oregon for the American Chrome Company. The test was carried out in an electric furnace for smelting chromium-bearing ores. Sulfur is the critical constituent in the char used in smelting chrome-bearing ores. The maximum sulfur which the char may contain is 0.5%. Sixteen tons of char were used in the test but the test was not satisfactory because the sulfur content was too high. As can be seen by comparing Tables I and II, the commercial retort does a better job of carbonization than did the pilot plant retort. Possibly the char from the commercial retort will be lower in sulfur content.

A five-ton sample of high-volatile coal was obtained from the Edna Coal Company at Steamboat Springs, Colorado. The coal was processed in the pilot plant retort for testing by the Colorado Fuel and Iron Corporation. This char was to be blended with more high-volatile coal and fed to their coke ovens in an attempt to produce a metallurgical grade coke from inferior coking coals. Some work had been done previously blending low-volatile coals with high-volatile coals. Due to the fact that the nearest commercial source of low-volatile coals to the coke-producing operations in the west is in eastern Oklahoma and western Arkansas, it was decided to try to substitute char with a volatile matter content of 17-19% in place of the low-volatile coal.

The analysis of coke from 100% high-volatile coals and from a mixture of high-volatile and low-volatile coal is shown in Table III. Using the tumbler stability index as the criteria of improvement, it can be seen from Table III that there is a definite improvement in the coke produced from a mixture of high-volatile and low-volatile coal over that coke produced from 100% high-volatile coal.

Table IV shows the analysis of coal used in the charring process and the analysis of char produced. Due to the small size of the sample and the lack of experience in producing char with such a high-volatile matter content, the unit was never completely lined out during the run. Also, with the burning of coal gas within the retort, V. M. content was hard to regulate. In Table V, the analysis of coke is made where char has been substituted for low-volatile coal in blending. Comparing this analysis with that of the coke produced from 100% high-volatile coal in Table III, it can be seen that all chars produce a marked improvement in stability although none produce as much improvement as low-volatile coal. Note that the P. D. P. char is slightly below average in the + 1 in. tumbler test. As was previously mentioned, the pilot plant char is definitely inferior to that produced from the commercial retort. It is the author's opinion that this would warrant another test using the product of the commercial retort. The analysis of the char screen fractions is given in Table VI. The 7% difference in V. M. between the + $\frac{1}{2}$ in. and the -20 mesh is probably why the P. D. P. char does not quite measure up to the other chars. Colorado Fuel and Iron Corporation requested that this V. M. difference be kept below 3%. Due to better control of retention time in the commercial retort, this difference could probably be kept below 3%.

The creosote being produced at Red Lodge at the present time will be sold to local distributers as a wood preservative. The centrifuge at Red Lodge is producing creosote with 2% water and no benzene insolubles. See Table VII for the complete analysis of Red Lodge creosote.

The overall picture of the development of the P. D. P. Char Process seems to indicate that the process can be operated profitably to serve the industries of the northwest. The American Smelting and Refining Company seems to be a certain market for all the char breeze from Red Lodge. They have used both coke breeze and petroleum coke in their sintering process and there seems to be no reason why char will not work equally well although a test will be run before this is final. The market at Anaconda is definitely out as a steady market although if other markets fail for char breeze, it will provide an outlet to prevent a complete loss on these fines. Although the Colorado Fuel and Iron Corporation project is still in the development stages, this would be an excellent site for a new plant. At the present time the phosphorus market is the most attractive with prices ranging from $18.00 to $25.00 per ton of char ($\frac{1}{4}$ in. plus). Once the Red Lodge plant becomes an active industry rather than a development project, there are many possibilities of new markets for char and creosote.

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APPENDIX

TABLE I

Char Produced from Red Lodge Coal in the Pilot Plant Retort

Moisture	1.0%
Volatile Matter	5.2%
Fixed Carbon	74.5%
Ash	19.3%
	100.0%

TABLE II

Char Produced from Red Lodge Coal in the Commercial Retort

Moisture	1.00%
Volatile Matter	3.26%
Fixed Carbon	85.54%
Ash	10.30%
	99.8%

TABLE III

Analysis of Coke from Colorado Coal.

Material	Test	100% H.V. Coal	85% H.V. + 15% L.V. Coal
Coke	Screen +4	20.6	7.5
	Screen +2	71.3	71.3
	Shatter +2	53.3	60.0
	Tumbler +1	22.1	44.0
	Porosity	53.3	51.4
	P. F. V.	34.9	50.1

TABLE IV

Analysis of Coal and Char from Routt County, Colorado.

	Coal	Char
Moisture	0.7 %	0.0
Volatile Matter	42.2	19.0
Fixed Carbon	49.7	70.5
Ash	8.1	10.5
Sulfur	0.65	
Phosphorus	0.055	
F. S. I.	1.0	

TABLE V

Mixture -- 85% H.V. coal + 15% Char

Char made in Process	A	B	C	D	E	P.D.P.
Coke-Screen +4	23.4	14.0	27.6	11.1	16.3	30.7
Coke-Screen +2	84.3	80.4	86.6	79.5	77.9	84.2
Shatter +2	59.2	62.2	59.7	55.3	60.2	68.5
Shatter +1½	81.5	93.4	78.5	81.5	82.0	85.1
Tumbler +1	38.2	37.2	34.8	40.6	40.2	34.3
Tumbler +¼	54.9	58.1	58.0	57.0	58.6	59.7
Porosity	55.4	58.3	51.2	59.8	56.6	53.6
P. F. V.	46.3	47.5	44.2	48.6	48.3	45.5

TABLE VI

Analysis of Screen Fractions of Char from Routt County Coal.

Screen	Percent	Volatile Matter
+ ½	4.7	25.6
½ x 4m	59.0	19.6
4 x 6m	10.4	19.6
6 x 10m	12.3	18.7
10 x 20m	5.6	20.1
-20m	8.0	18.7

TABLE VII

Analysis of Creosote from Red Lodge Plant.

Water	2.055%
Material Insoluble in Benzene	- - -
Coke Residue	15.2
Specific Gravity	1.100
Distillation:	
up to 210°C	6.84%
up to 235°C	17.36
up to 315°C	45.86
up to 355°C	60.6
Distillation Residue Analysis:	
wt % Volatile Matter	60.6
wt % Fixed Carbon	39.4
wt % Ash	0.0