



Charring of coals from Montana and neighboring states
by Darold E Skerritt

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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Abstract:

A continuous process for carbonization of non-coking coals has been developed at Montana State College. The process will produce char which meets coke specifications set by industries in the surrounding area and creosote which meets American Wood Preservers' specifications from certain bituminous coals.

The Montana State College char process employs a stainless-steel retort which is made up of four concentric vertical cylinders. The coal flows by gravity through a two-inch annular space. It is heated to a temperature of 1200 to 1400 degrees Fahrenheit by hot flue gases from a gas-fired furnace. The coal is agitated by means of a lift which gives the inner cylinder an up-and-down motion.

The char plant operated for extended periods .of time without deterioration of equipment.

Coals from Montana, Wyoming, and Utah were tested in the char plant. Those which performed satisfactorily were evaluated economically to determine the desirability of building a commercial plant.

Estimates show that it would be profitable to build a commercial char plant in Red Lodge, Montana; Superior, Wyoming; Rock Springs, Wyoming; and Hanna, Wyoming. Of these proposed sites, Superior, Wyoming appears to offer the highest return on investment.

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Approved:

Lloyd Berg

Head, Major Department

Lloyd Berg

Chairman, Examining Committee

Leon H. Johnson

Dean, Graduate Division

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ABSTRACT

A continuous process for carbonization of non-coking coals has been developed at Montana State College. The process will produce char which meets coke specifications set by industries in the surrounding area and creosote which meets American Wood Preservers' specifications from certain bituminous coals.

The Montana State College char process employs a stainless-steel retort which is made up of four concentric vertical cylinders. The coal flows by gravity through a two-inch annular space. It is heated to a temperature of 1200 to 1400 degrees Fahrenheit by hot flue gases from a gas-fired furnace. The coal is agitated by means of a lift which gives the inner cylinder an up-and-down motion.

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INTRODUCTION

Other fuels have taken much of the market away from the coal industry. Since there are large deposits of coal in Montana and neighboring states, development of new markets would be a big boost for the economy of the area.

There is a market for about 900,000 tons of carbon per year in this area (5). With this in mind, the Engineering Experiment Station of Montana State College sponsors research in the carbonization of coal.

There have been several previous attempts at low-temperature carbonization of coals (4, 7, 8, 9). None of them were completely successful. The research at Montana State College, however, has developed a process which is successful to date on a pilot plant scale. This process turns out a low-volatile product, which we call char, and by-product liquids from which, in many cases, a specification grade creosote can be made.

The char produced from certain bituminous coals has a physical strength and hardness which make it equivalent to coke for some uses, such as in the production of elemental phosphorus. It is impossible to predict which coals will give the char with the best physical properties. A test in the pilot plant is required.

This past year coals from Montana, Wyoming, and Utah were tested in the Montana State College char plant. These coals were tested to determine the quality of char produced, the quantity and quality of by-product oils produced, and any possible operational difficulties peculiar to the coals.

The coals which performed satisfactorily in the charring tests were then evaluated economically to determine the desirability of building a commercial char plant.

EQUIPMENT AND PROCEDURE

The Montana State College char plant is a semi-commercial pilot plant with a capacity of from 2 to 3 tons of coal per day. Figure 2 is a simplified flow diagram of this plant. The three principal parts of the char plant are the retort, the by-product recovery system, and the furnace.

The retort consists of four upright, concentric stainless-steel cylinders which are 12, 20, 24, and 38 inches in diameter. Coal is gravity fed from hoppers above the retort into the two-inch annular space between the second and third cylinders. The annular space is about 34 inches high. The inner cylinder is given an up-and-down motion by a mechanical lift. This keeps the coal agitated, preventing bridging between the two cylinders, thus preventing channeling and insuring a more uniform product. Air is prevented from entering the annular space by water seals at both the top and bottom. The retort is insulated by a layer of loose insulation contained in a mild steel shell which houses the retort.

The charred coal is removed from the bottom of the retort by two variable-speed stainless-steel screw conveyors. By controlling the speed of these conveyors, the throughput, and therefore the volatile content of the char, can be fixed at any desired level. The char is allowed to fall into water-sealed barrels which are removable when they become full. The barrels are weighed when they are removed.

This weight is compared to the weight of coal charged to the retort to determine char yields.

A thermocouple indicates the temperature of the char leaving the retort. It was found that at char temperatures below 1200 degrees Fahrenheit, the char produced contained more volatile matter than desired. Therefore, the plant was operated so that the temperature of the char outlet was between 1200 and 1400 degrees Fahrenheit. The upper temperature is limited by throughput.

Hot combustion gases from the furnace enter the outermost annular space near the bottom and travel upward and then down through the innermost annular space. They are then pulled by a blower up through the inner tube, and are recycled to the furnace. The coal is therefore heated on both sides as it is retorted.

The moisture and volatile matter which are driven from the coal in the charring operation escape from the coal zone through louvers into four vertical slots which bridge the outer heat zone. These gases, which are under a slight vacuum caused by a blower in the by-product recovery system, are sucked up through a V-shaped manifold. Next, they travel through a cyclone which removes any dust which may become entrained in the gas stream. Both the manifold and cyclone are heat-jacketed to prevent volatiles from condensing out.

The gases then pass to the by-product recovery system. This consists of three condenser columns in series in which the gases are

scrubbed with a water spray. The water and volatiles which are condensed are pumped by a centrifugal pump to a decanting drum where the by-product oils are decanted off. The water is pumped through a heat exchanger which cools it, and it is recycled to the scrubber columns. The permanent gases produced in the process are discharged from the third condenser through a stack and are burned. In a commercial plant, these gases could be compressed and used to heat the furnace.

The furnace is fired with natural gas. An automatic controller regulates the amount of gas fired to the furnace, keeping the temperature of the combustion gases entering the retort constant.

The furnace is equipped with a draft so that part of the hot combustion gases returning from the retort may be recycled, and the excess may be vented to the atmosphere.

RESULTS AND CONCLUSIONS

Several coals from Montana and neighboring states were retorted in the Montana State College char plant. The char plant was operated for two sustained runs. The first run lasted 28 days, and the second lasted 42 days. These runs caused no visible damage to the retort or auxiliary equipment.

Four of the coals tested were from the Red Lodge, Montana area. These coals were from the Brophy, Montana Coal and Iron, Janskovich, and Burns mines.

Five tons of Brophy coal was run through the college retort. The char was produced at an average rate of 2540 pounds per day. As shown in Table I, the char produced had a fixed-carbon content of 86.7 percent. This meets the specifications which are set by the phosphorus and non-ferrous metals industries in this area. The char produced from Brophy coal agglomerated, giving it a hardness suitable for use in the phosphorus industry.

Phosphorus manufacturers require a char with physical strength to resist break-up during handling. The char must have a size range between $1/8$ and $3/4$ inches. The char must also contain less than 5 percent volatile matter and have a fixed-carbon content of approximately 85 percent or greater.

Each ton of Brophy coal yielded 1080 pounds of char and 19.1 gallons of by-product oils. These yield figures, along with yields from

other coals are tabulated in Table II.

A creosote which meets specifications set by the American Wood Preservers Association was produced. The oil produced from charring Brophy coal was distilled into three fractions. A gasoline cut accounted for 11.3 percent of the oil by volume. The creosote fraction was 68.4 percent of the total volume of oil. The remainder was pitch. Table III shows a comparison of the creosote fraction with American Wood Preservers' specifications (2).

Coal from the Red Lodge mine owned by Montana Coal and Iron Company produced a char which is very similar to the char produced from Brophy coal. The char had a fixed-carbon content of 84.0 percent. Each ton of Montana Coal and Iron coal produced 1068 pounds of char and 20.4 gallons of oils.

Since the analysis, hardness, and yields of char produced from Montana Coal and Iron coal is so similar to that produced from Brophy coal, it is assumed that the two coals are equally suited for charring.

Over two tons of coal from the Janskovich mine near Red Lodge was tested in the char plant. The char produced was high in ash with a fixed-carbon content of only 71.4 percent. This char is not suitable for use in the elemental phosphorus industry.

Char produced from the Burns mine near Red Lodge was also of inferior quality. The fixed-carbon content was only 70.0 percent.

Four high-coking coals from Utah were tested in the Montana State College char plant. The coals tested were from mines owned by Independent Coal and Coke, Knight-Ideal, Kennelworth, and Western Aniline and Chemical Company. These coals coked up inside the retort, proving themselves unsatisfactory for charring in a plant of this design.

Three coals from Wyoming were retorted in the char plant. Wyoming coals tested were Union Pacific coal from Superior; Rainbow coal from Rock Springs; and Monolith coal from Hanna.

Coal from the Union Pacific Coal Company mine in Superior, Wyoming produced agglomerated char which had a fixed-carbon content of 91.2 percent. The physical strength of this char was tested by Westvaco Chemical Company of Pocatello, Idaho. The char had a tumbling strength of 92.5. A tumbling strength above 90 meets specifications for coke in elemental phosphorus production.

Each ton of coal from Superior yielded 1082 pounds of char and 27.1 gallons of oils. A creosote was made by distilling off 80.5 volume percent of the oils. The remainder of the oils was pitch. No gasoline cut was taken. Table IV is a comparison of the distillate with American Wood Preservers' specifications (2).

Coal from the Rainbow mine in Rock Springs, Wyoming, owned by Kemmerer Coal Company, also produced an agglomerated char. The tumbling strength of the Rainbow char was 91.1. The fixed-carbon content was 92.7 percent. The Rainbow coal yielded 1080 pounds of char and 20.1

gallons of by-product oils per ton.

Coal from a Hanna, Wyoming mine owned by the Monolith Coal Company produced a soft char when retorted in the Montana State College char plant. The char contained 86.0 percent fixed carbon. This char will not meet the specifications of the elemental phosphorus industry, but will meet the specifications of non-ferrous metal producers.

An economic comparison was made for coal charring operations in Red Lodge, Montana; Superior, Wyoming; Rock Springs, Wyoming, and Hanna, Wyoming. The factors which influence the economics are the yields of char and liquid by-products, the price obtainable for the char, the distance from markets, and the price of the coal.

Phosphorus grade char will bring \$22 per ton delivered to the phosphorus producer. Char breeze, used in lead and zinc roasting operations, on the other hand, will only bring \$11.50 per ton delivered to the smelter.

Superior and Rock Springs chars are only about one-third fines since sized coal is available, while Red Lodge char yields about 50 percent breeze. All of the Hanna char must be sold as breeze because it will not meet phosphorus producers' specifications.

The char prices listed for economic comparison in Table V are an average prices including both coarse char and breeze. They are net prices f.o.b. plant site. In calculating these values, freight rates were taken from a plot of freight cost per ton of coke breeze versus

rail miles (6). This plot may be seen in Figure 1.

Markets for char in Montana are Victor Chemical Works at Silver Bow, and American Smelting and Refining Company at East Helena. Other char markets in the area are Westvaco Chemical Company at Pocatello, Idaho; Monsanto Chemical Company at Soda Springs, Idaho; and U. S. Smelting and Refining Company at Garfield, Utah.

Freight rates for Red Lodge char are based on marketing the fines at East Helena, and the coarse material at Silver Bow.

The price of coarse char from Superior and Rock Springs are figured using Soda Springs, Idaho as the market. Garfield, Utah is the intended market for the char breeze from Superior and Rock Springs and all of the Hanna char.

The average price of the liquid by-products produced was taken as 22 cents per gallon (1).

The operating expenses are calculated to be about \$3.52 per ton of coal charged. A breakdown of the operating expenses may be seen in Table VI. The cost of the coal was obtained from the mine owners.

An economic comparison for various chars has been made based on both a 100-ton of char per day plant, and a 500-ton per day plant. The results are tabulated in Table VII.

A charring operation at any of the sites mentioned would be profitable. Superior, Wyoming appears to be the location which will yield the highest return on investment.

In every case, a plant capable of producing 500 tons of char per day gave a slightly higher return on investment than a 100-ton per day plant. The investment required for a 500-ton per day plant was, of course, much higher.

The economic calculations are based on building a new plant at prevailing costs. No consideration was given the present charring facilities at Red Lodge, Montana.

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Without the guidance and help of Dr. Lloyd Berg and Mr. D. E. Atkinson, much of the work accomplished would have been impossible.

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TABLE I

ANALYSIS OF VARIOUS CHARS

<u>Mine</u>	<u>Volatiles</u>	<u>Fixed Carbon</u>	<u>Ash</u>
Brophy	3.0%	86.7%	10.3%
Mont. Coal & Iron	4.0	84.0	12.0
Janskovich	4.6	71.4	24.0
Union Pacific	3.2	91.2	5.5
Rainbow	3.0	92.7	4.3
Monolith	3.0	86.0	11.0
Burns	4.0	70.0	26.0

TABLE II

DATA ON VARIOUS COALS

Mine	Char Yield % by Wt.	Oil Yield gal/ton	Production Rate lb. char/day
Brophy	54.0	19.1	2540
Mont, Coal & Iron	53.4	20.4	2290
Janskovich	51.6	9.4	2210
Burns	53.8	12.8	1650
Union Pacific	54.2	27.1	1610
Rainbow	52.0	20.1	2100
Monolith	54.3	26.0	1695

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TABLE III

COMPARISON OF CREOSOTE FROM BROPHY COAL
WITH AMERICAN WOOD PRESERVERS' SPECIFICATIONS

<u>Creosote Test</u>	<u>Specification</u>	<u>Brophy Tar</u>
S. G. at 38/15.5°C	1.03+	1.039
Distillation: up to 210°	5. - (wt.%)	3.36
210-235	5-25	14.34
235-270	20 +	36.83
270-355	60-85	70.18
355+	40 +	28.60
Coke Residue	2.0-	0.8
Water, Wt. %	3.0-	Pass
Benzene Insoluble Wt. %	0.5-	Pass

TABLE IV

COMPARISON OF CREOSOTE FROM UNION PACIFIC COAL
WITH AMERICAN WOOD PRESERVERS' SPECIFICATIONS.

<u>Creosote Test</u>	<u>Specification</u>	<u>U. P. Tar</u>
S. G. at 38/15.5°C	1.03+	1.023
Distillation: up to 210°C	5- (Wt. %)	0.91
210-235	5-25	7.09
235-270	20+	27.63
270-355	60-85	65.24
355+	40-	34.1
Coke Residue	2.0-	1.17
Water, Wt. %	3.0+	Pass
Benzene Insoluble	0.5-	Pass

TABLE V

COMPARATIVE ECONOMICS OF SEVERAL CHARS

<u>Revenue</u>	<u>Red Lodge, Montana</u>	<u>Superior, Wyoming</u>	<u>Rock Springs, Wyoming</u>	<u>Hanna, Wyoming</u>
Char Price - \$/ton	\$11.25	\$13.27	\$13.35	\$5.00
Char Yield - lbs/ton	1080	1084	1040	1086
Income from Char - \$/ton coal	6.08	7.18	6.95	2.71
Liquid by-product yield - gal/ton coal	20	27	20	26
Income from by-products - \$/ton coal	4.40	5.94	4.40	5.72
Total Income - \$/ton coal	10.48	13.12	11.35	8.43
<u>Expenses</u>				
Operating Expenses - \$/ton coal	3.52	3.52	3.52	3.52
Coal Cost - \$/ton	4.80	4.50	4.50	2.00
Total Cost - \$/ton coal	8.32	8.02	8.02	5.52
Net Income before Income tax - \$/ton coal	2.16	5.10	3.33	2.91

TABLE VI

ESTIMATED OPERATING EXPENSES

Charge -- 185 tons of coal/day yields 100 tons/day
of char, 350 days/year.

	<u>Per Ton of Coal</u>
Electricity	\$0.08 (1)
Plant Labor -- 5 men/shift; 3 shifts/day; at \$2.00/hr.	\$1.44
Plant Superintendent -- \$550/month	\$0.11
Utilities -- Steam, Gas, Water	\$0.09
Repair Materials	\$0.25
Payroll Taxes and Office Overhead	\$0.06
Property Tax and Insurance -- 3% of Plant Investment	\$0.28
Selling and Administrative Expenses	\$0.28
Plant Amortization -- 10% of \$600,000 Investment	\$0.93
	<hr/>
TOTAL EXPENSE	\$3.52

TABLE VII

ECONOMIC COMPARISON

<u>100 ton/day Plant</u>	<u>Red Lodge, Montana</u>	<u>Superior, Wyoming</u>	<u>Rock Springs, Wyoming</u>	<u>Hanna, Wyoming</u>
Plant Investment	\$600,000 (3)	\$600,000	\$600,000	\$600,000
Net Income after Fed. Income Tax	67,500	159,000	108,000	90,000
Annual Return on Investment - %	11.2	26.5	18.0	15.0
Plant Payout Time - yrs.	8.9	3.8	5.6	6.7
<u>500 ton/day Plant</u>				
Plant Investment	\$2,900,000	\$2,900,000	\$2,900,000	\$2,900,000
Net Income after Fed. Income Tax	337,000	795,000	530,000	450,000
Annual Return on Investment - %	11.6	27.4	18.3	15.5
Plant Payout Time - yrs.	8.6	3.7	5.5	6.5

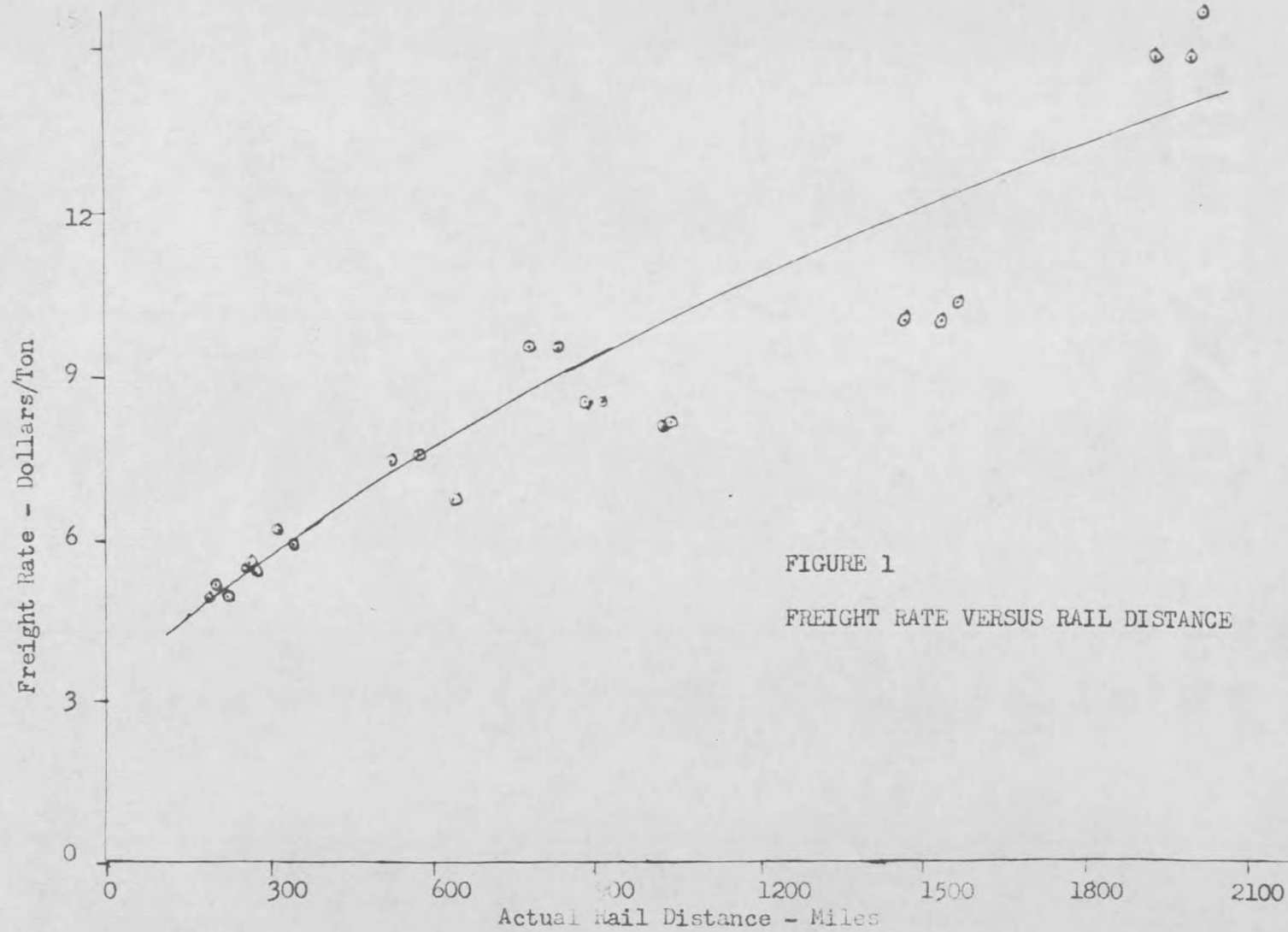


FIGURE 1

FREIGHT RATE VERSUS RAIL DISTANCE

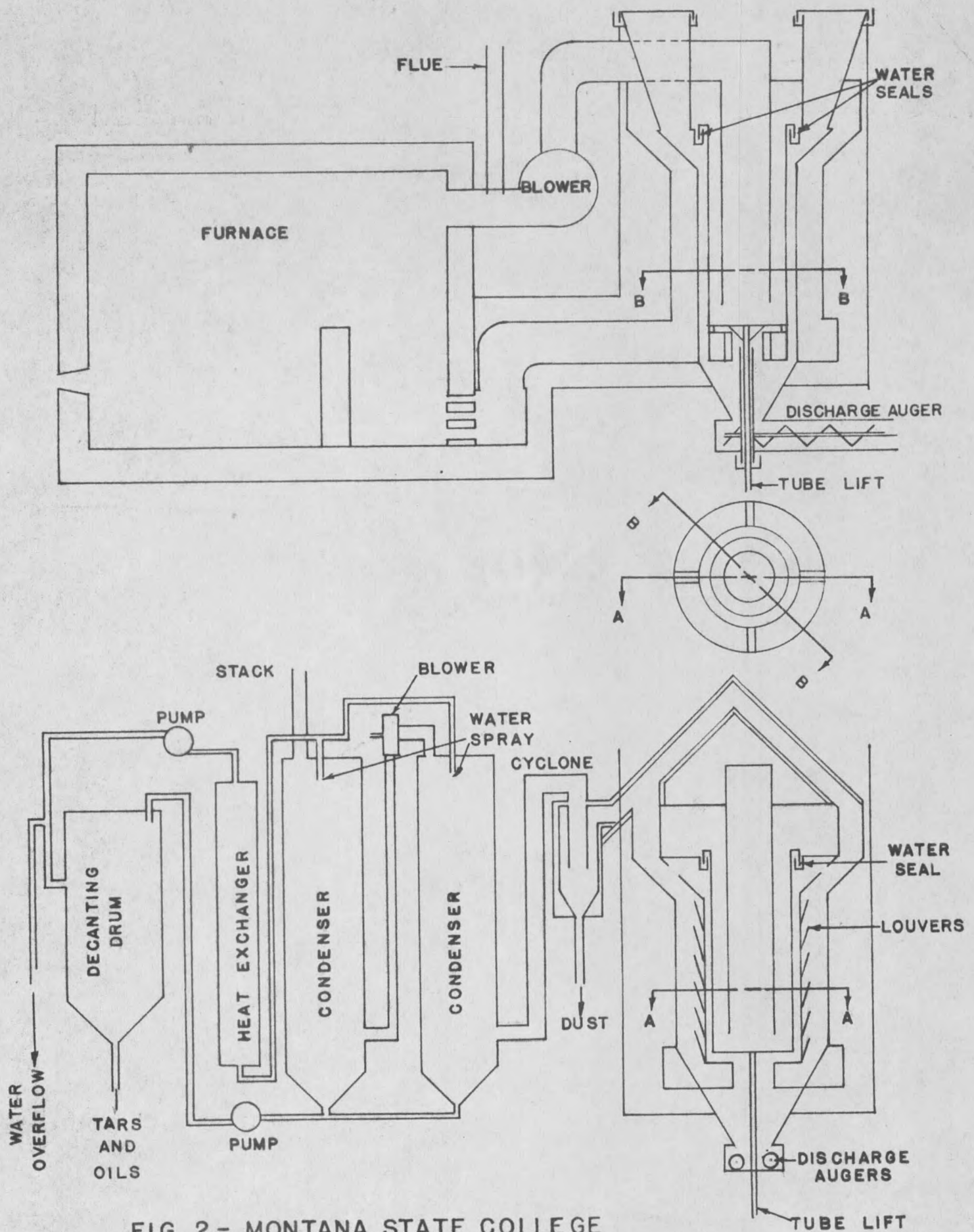


FIG. 2- MONTANA STATE COLLEGE
COAL- CHAR PROCESS PILOT PLANT

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