



The details of construction of the char plant at Montana State College
by Robert L Quesenberry

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

Presented in this thesis are the details of construction of the continuous coal charring plant located at Montana State College . Twelve drawings are included—the first is a simplified flow diagram of the entire plant and the other eleven are specific diagrams of the various parts of the plant.

The coal was transported to the top of a retort by an auger and traveled through the retort by gravity flow. The retort was constructed of four concentric vertical cylinders, The coal traveled through the annular space between the two inner cylinders and the innermost cylinder was revolved in order to agitate the coal to insure its flow through the retort. The rate at which the coal traveled through the retort was governed by the speed at which discharge augers were driven. The resulting char was ground to 3/8-in. minus and was then stockpiled in a storing shed.

The retort received the required heat from a gas-fired furnace and the heat traveled through the annular space between the second and third cylinders and the center of the innermost cylinder of the retort.

The volatile gases were drawn off from the annular space between the two outer cylinders by a blower mounted near the top of the retort and were blown to a cyclone separator which removed any dust particles. The gases then passed to a tar knockout drum in which the temperature was maintained at such a level that the tar (or any high boiling materials) was condensed. Two absorption columns were used to separate the creosote and light oils through the use of a straw oil solvent in a counter-current absorption process. The dry gases were flared.

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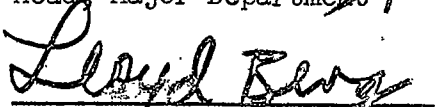
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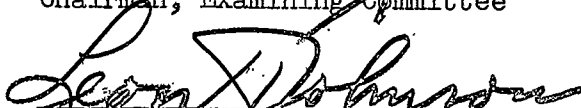
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Montana State College

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Head, Major Department


Chairman, Examining Committee


Dean, Graduate Division

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July, 1955

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ABSTRACT

Presented in this thesis are the details of construction of the continuous coal charring plant located at Montana State College. Twelve drawings are included--the first is a simplified flow diagram of the entire plant and the other eleven are specific diagrams of the various parts of the plant.

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INTRODUCTION

Montana, with vast and varied coal resources, today finds that its coal industry is being faced with a decreasing market for its products. The coal industry of Montana has problems which reflect the general nationwide trend of economic difficulties within this major industry. Increased railroad dieselization coupled with decreased use of coal for domestic heating are the prominent reasons for decreased coal consumption in Montana.

This problem certainly warrants profound thought and consideration by anyone interested in the economic welfare of Montana. An answer to this problem would simply be to find a process which would transform the coal into a more usable form.

In 1921, a retired civil engineer from Oregon State by the name of Frank E. Hobson began the development of a charring process which utilized a continuous operation. He organized a corporation to finance this development and built a 6-ft, vertical retort with a rotating center cylinder. The initial work on this process was applied to the charring of walnuts. The walnuts were to pass through an annular space in the retort, being heated from both walls, and the effluent gases were to be drawn off and condensed. To help finance this work, he sold the char for chicken feed and the condensed oils for a roofing tar. During the beginning of the depression in 1929, the corporation became entangled with financial difficulties and all progress was delayed.

In 1935, Hobson built a 25-tons per day plant to retort mercury ore. The retort functioned well for about a week and then the cast iron of which it was constructed, failed. It could not stand up under the 1200° F to 1400° F temperatures at which the retort was operated. Progress was again halted due to a lack of financing.

Later, several private business men became interested in the economic possibilities of charring non-coking coals. R. A. Porter, J. H. Dillon, and E. W. Pringle organized the P. D. P. Processing Inc., a corporation which would finance development on the process. During the summer of 1952, cost estimates and drawings were begun. In December of the same year, a plant was built from Hobson's specifications at Melstone, Montana. This plant, built of mild steel and cast iron, was not capable of standing up under the operating temperatures and vital portions of the retort oxidized. The plant was rebuilt with a heat recycle blower and mild steel was substituted for all of the cast iron. This plant also failed after 100 hours of operation due to the high temperatures involved. A third plant was built at Melstone with many improvements in the design and operated successfully from July, 1953 until December of the same year when it failed. Many changes were made in the design and the process was brought to Montana State College in July, 1954.

The present retort is constructed with 18-8, type 304 stainless steel which is holding up very well under operation with no apparent damage. A by-products system has been added to the retort to extract and separate the tar, creosote, and light oils from the effluent gases.

THE CHAR PLANT

A simplified flow diagram of the char plant at Montana State College is illustrated in Figure 1, page 25. The retort is constructed of four concentric cylinders numbered from one to four from the inside out. The coal is delivered to the top of the retort by an auger and travels through the annular space between cylinders 1 and 2. Cylinder 1 is driven at a rate of approximately 3 rpm by a gear reducer to agitate the coal and to insure its flow through the retort. The coal is heated from both walls as heat from a gas-fired furnace travels through the center of cylinder 1 and the annular space between cylinders 2 and 3. The combustion gases are drawn from the gas manifold back to the furnace by the combustion gas return blower. The baffles in the furnace thoroughly mix the return gases and the freshly burned gases. The estimated mean life of the gas in the furnace is seven cycles through the system. A variable gear reducer regulates the speed of the char augers from one to four rpm and this speed in turn regulates the rate at which the coal flows through the retort.

The effluent gases are driven off the coal through effluent gas off-take tubes; the tubes extend from cylinder 2 through cylinder 3 into the annular space between cylinders 3 and 4 at an angle of 50° . The gases are then drawn from this annular space by the effluent gas blower. This blower maintains the retort at slight vacuum to prevent the effluent gases from escaping through the descending coal to the coal bin and through the discharge augers. Air is excluded from the retort by two water seals to prevent combustion of the char.

The effluent gases are blown to a dust cyclone. The line from the gas blower to the cyclone and the cyclone is jacketed; heat from the waste gas stack is circulated through the jacket to maintain temperatures such that tar will not condense and solidify with fine dust particles. The gas enters the cyclone tangentially and the dust particles settle out at the bottom.

The gases now pass through a tar knockout column. A pair of water sprays were installed at the top of this column and a pair of steam spargers (70 psig) were installed near the bottom of the column in order to have a positive temperature control. The tar is removed from the bottom of the column through a liquid seal. The liquid seal is traced by a $\frac{1}{2}$ -in. steam line which was coiled in the bottom of the knockout drum to insure the fluid state of the tar.

The effluent gases now travel to two straw oil absorption columns which are for the separation of the creosote and light oils in the by-product gases. The gases flow upward through the columns counter-current to a spray of straw oil, a petroleum fraction boiling between 160° C and 225° C. The first column was designed to operate at 160° C. This temperature is below the boiling point of the creosote--therefore the creosote should condense and the light oils should pass on to the second column. The line between the columns was provided with a 7-ft water jacket to cool the by-products and to increase the condensation efficiency (the percent of the total condensable by-products that were condensed). The second column was designed to operate at room temperature and the remaining condensable gases should condense in this column.

In order to obtain better gas-liquid contact, $\frac{1}{8}$ -in. galvanized screens supported on 5/16-in. threaded rod were placed at 18-in. intervals throughout the height of each column. Both columns are equipped with 120-gal straw oil reservoirs; cooling coils are provided in each reservoir. Two internal gear pumps pump the straw oil through heat exchangers to cool the absorption oil before it is sprayed into the columns. The straw oil and absorbed creosote (or light oils) flow from the bottom of each column to one of two 55-gal barrels connected in series for separation. The feed and straw oil lines from these barrels have steam piped to them to remedy any plugging that may occur. The enriched creosote (or light oils) is then forced to a 300-gal storage tank by approximately 10 psig air pressure.

The uncondensable gases pass to a cyclone for the removal of any straw oil mist which is carried over. The dry gas is then burned with natural gas in a flare. A sparker was installed at the gas outlet in the flare to ignite the gas. In a commercial plant, the dry gas will be burned as fuel in the furnace and should supply most if not all the required heat.

THE FURNACE

The char plant at Montana State College was built in a large room in the northeast corner of Ryon Laboratory. Because of the height of the unit, it was necessary to build the floor of the furnace approximately 3 ft below the floor level of this room. A hole, 14 ft x 8½ ft was broken in the concrete floor and this hole was lined with concrete, forming a solid base for the furnace.

The furnace was constructed with Denver Fire Clay brick using Milled Fire Clay as a sealer between the bricks. Fire brick laid on edge and directly on the concrete base forms the furnace floor. The arches were constructed with No. 1 arch brick using La Tite, a heat resistant cement and were leveled with No. 28 Hi Cast cement. Baffles were constructed in the furnace and were so arranged as to thoroughly mix the combustion gases; the spent gases are removed by a flue gas stack.

Two rows of red brick were laid 1½ in. from the outside of the fire brick; this space and the space between the fire brick arch and red brick ceiling was filled with Zonolite insulation. Approximately 1 in. of mortar was put on top of the Zonolite to support the red brick ceiling. The portion of the roof under the retort was leveled with No. 28 Hi Cast, and the rest of the roof was leveled with mortar. Ideal Masonry Cement admixed with three volumes of sand was used as the mortar for the red brick.

A door and burner block sealed with La Tite, were placed in the west end of the furnace and a right angle Denver Fire Clay Burner No. 784 was

attached to the burner block. A gas line with two valves was installed to the burner with one valve placed near the burner for adjustment and the other in the basement in case of emergency. The entire inner surface of the furnace is covered with La Tite and the outer surface of the walls is covered with $\frac{1}{2}$ -in. Denver Fire Clay No. 89 Insulating Cement over chicken wire. Dimensions and details of construction of the furnace are shown in Figure 2, page 26.

THE RETORT

Figures 3 and 4, pages 27 and 28 respectively, include the dimensions and details of the retort construction. A mild steel shell was constructed around cylinder 4 leaving an annular space of 18 in. which was filled with Zonolite insulation.

Steam jets were installed near the bottom of the retort as shown in Figure 5, page 29. A swirling motion is provided by these jets to dislodge and remove the fine particles of char or coal which settle into piles and clog the lower gas off-take tubes.

Cylinder 1 is mounted on a stainless steel shaft equipped with a water jacket; the shaft extends into a 3-ton capacity storage bin over the retort. The shaft and water jacket are shown in Figure 5. A cross member was mounted to the top of the shaft and 4 log chains attached to 7-in. rings were suspended from it to drag the coal into inlets placed in the bottom of the bin. A 3000-lb capacity thrust bearing was placed under the bin to support cylinder 1. The bottom of the bin was insulated with 1 in. of spun glass and a strip of aluminum foil.

Illustrated in Figure 6, page 30, is a 10-ton capacity storage tank placed on concrete footings which is being used as an exterior coal storage bin. A conveyor belt delivers the coal to this bin and a 6-in. auger carries the coal from it to the top of the retort.

A description of the discharge augers may be found in Figure 7, page 31. These water-cooled augers, driven by a gear reducer at a rate of approximately 10 rpm, were constructed to cool the char and to prevent

it from burning upon exposure to the atmosphere. From the outlet of these augers a 16-ft water-cooled auger transports the char to a stock-pile shed. This auger is projected into the char shed at an angle of 45° and a chain-driven grinder which grinds the char to $3/8$ -in. minus is mounted at the exit end. This grinder is illustrated in Figure 8, page 32. The grinder is spring-loaded to allow for any scrap metal which may have been mixed with the feed coal. The finely ground char is discharged into the char shed, a building 9 ft x 9 ft x 9 ft, utilizing a 2-in. x 4-in. frame work and an inside lining of corrugated steel.

Shown in Figure 9, page 33, is the heat return blower which is mounted on the roof of the furnace. This blower, powered by a 1-hp motor is operated at temperatures up to 800° F. An auxilliary blower was installed to circulate the air around the bearings and to keep them from overheating. The heat return manifold, heat recycle blower, and the lower 3 ft of the waste gas stack for the furnace were covered with 1 in. of No. 89 insulation over chicken wire.

The effluent gas blower, powered by a 10-hp motor, is mounted near the top of the retort at the outlet of the effluent gases and was designed to operate at temperatures up to 800° F and to maintain an outlet pressure of 3 psig. Directly over this blower, a platform was constructed on the retort to facilitate its operation. The blower and platform are illustrated in Figure 9, page 33.

BY-PRODUCT RECOVERY SYSTEM

Included in the by-product recovery system is a dust removal cyclone, a tar knockout drum, a pair of absorption towers, and a demisting cyclone.

The dust cyclone is a truncated cone which tapers from 3 ft in diameter to 6 in. in diameter over a height of 4 ft. The gas enters the cyclone tangentially through a 7-in. x 7-in. opening, 3 in. from the top of the cylinder. A 10-in. diameter riser, $2\frac{1}{2}$ ft long, was placed in the cylindrical portion of the cyclone with 6 in. extending above the surface of the cyclone. The cyclone is illustrated in Figure 10, page 34. The heat jacket for the cyclone and the line from the gas blower to the cyclone was insulated with Denver Fire Clay No. 89 Insulating Cement over chicken wire.

The tar knockout column was constructed by welding three 55-gal oil drums together. The by-product gases enter the top of this column tangentially through a 7-in. square outlet from the dust cyclone and leave through a 7-in. diameter line which extends downward from the top of the column about $\frac{1}{3}$ the height of the column. The details of construction of this column may be found in Figure 11, page 35.

The effluent gases travel through 7-in. rolled steel pipe to the two straw oil absorption columns. These columns are illustrated in Figure 12, page 36. The first column is 10 in. in diameter and $10\frac{1}{2}$ ft high. The light oils pass on to the second column through a 7-in. rolled steel pipe which is cooled by a 9-in. water jacket, 7 ft high. The second straw oil absorption column is 10 in. in diameter and 10 ft high. Each column is

equipped with a 120-gal straw oil reservoir and a sight glass is provided near the top of each column for observation.

The cylindrical portion of the demisting cyclone is 14 in. in diameter and 28 in. high and the truncated cone portion tapers from a diameter of 14 in. to 6 in. over a height of 16 in. The gas and mist enter the cyclone through a 3 $\frac{1}{2}$ -in. x 7-in. rectangular pipe. A 6-in. diameter rolled steel riser extends 9 in. into the cyclone. A flare line constructed of 6-in. galvanized stove pipe is connected to the riser of the cyclone and extends 20 ft above the building. A retractable 1-in. orifice was installed in the flare line for the purpose of measuring the flow rate of the dry gas. The sparker, which ignites the gas in the flare, consists of a spark plug, wiring to a Model-T ignition coil, and a pair of dry cells. The spark plug was constructed so that it could be withdrawn from the flame after ignition of the gas.

POWER REQUIREMENT

The electrical power required for the plant is approximately 16.5 kw per hr. This figure excludes the lighting requirements.

SPECIFICATIONS

Estimated Material Required for the Construction of the Char Plant:

725 sq ft 1/8-in. mild steel (16 sheets 5 ft x 10 ft)

70 sq ft 1/8-in. 18-8, type 304 stainless steel
(2 sheets 5 ft x 10 ft)

550 sq ft 3/16-in. mild steel (12 sheets 5 ft x 10 ft)

280 sq ft 3/16-in. 18-8, type 304 stainless steel
(6 sheets 5 ft x 10 ft)

50 sq ft 3/8-in. 18-8, type 304 stainless
(1 sheet 5 ft x 10 ft)

6 sq ft 1/2-in. mild steel (1 sheet 1 ft x 6 ft)

35 sq ft 1/2-in. 18-8, type 304 stainless steel (1 sheet 6 ft x 6 ft)

355 ft 4-in. x 4-in. x 1/4-in. angle

480 ft 2-in. x 2-in. x 3/16-in. angle iron

2 ft 1 1/2-in. x 1 1/2-in. x 1/8-in. angle iron

900 2 1/2-in. x 4 1/2-in. x 9 1/2-in. Denver Fire Clay fire brick

600 #1 Denver Fire Clay arch brick

4000 2 3/8-in. x 3 3/4-in. x 8-in. red brick

100 lb La Tite cement

300 lb Denver Fire Clay Milled Fire Clay

200 lb Hi Cast cement

18 sacks masonry cement

800 lb Denver Fire Clay #89 Insulating Cement

40 sacks Zonolite insulation

200 sq ft 1-in. chicken wire

1 Denver Fire Clay burner block 11 1/2-in. x 11 1/2-in. x 13 1/2-in.

1 Denver Fire Clay Burner #784

120 lb 18-8 stainless Steel welding rod

200 lb mild steel welding rod

10 55-gal oil drums, 12 gage

2 68-in. augers, 6-in. diameter, 2.76-in. 1 1/8-in. diameter 18-8, type 304 stainless steel shafts, 1/2-in. 18-8, type 304 stainless steel blades

2 6-in. augers on a 1-in. mild steel shaft, 21 ft long

1 6-in. auger on a 1-in. mild steel shaft, 16 ft long

1 8-in. auger on a 1 1/16-in. mild steel shaft, 6 ft long

2 3-in. hinges

3 sq ft heavy safety glass

1 3 1/2-in diameter, 3000-lb thrust bearing

1 4 1/2-in. bearing holder

6 ft 1/8-in. chain

32 in. 2 1/16-in. mild steel shaft

2 1/2 ft 2-in. stainless steel shaft

Note; All pipe and Fittings are Standard Black

2 ft 1/4-in. pipe

2 1/4-in. elbows

1 1/4-in. union

1 1/4-in. globe valve

50 ft 1/2-in. pipe

12 1/2-in. tees

16 1/2-in. unions

14 1/2-in. globe valves

18 $\frac{1}{2}$ -in. elbows
4 ft $\frac{3}{4}$ -in. pipe
80 ft 1-in. pipe
14 1-in. globe valves
20 1-in. unions
10 1-in. elbows
2 1-in. plugs
23 1-in. tees
4 reducing couplings 1-in. x $\frac{1}{2}$ -in.
2 ft $1\frac{1}{4}$ -in. pipe
1 $1\frac{1}{4}$ -in globe valve
1 $1\frac{1}{4}$ -in. union
1 $1\frac{1}{4}$ -in. elbow
105 ft 2-in. pipe
2 2-in. globe valves
3 2-in. unions
12 2-in. elbows
1 2-in. tee
1 reducing coupling 2-in. x 1-in.
7 ft 3-in. pipe
3 3-in. elbows
1 2-in. tee
1 3-in. butterfly valve
3 ft 4-in. pipe
18 $\frac{1}{8}$ -in. pet cocks, brass

1 pressure gage, air (0 to 15 psig)
22 ft galvanized stove pipe
300 ft $\frac{1}{2}$ -in. thin walled electrical conduit
30 ft $\frac{5}{16}$ -in. threaded rod
14 sq ft $\frac{1}{2}$ -in. galvanized screen
32 ft $\frac{3}{4}$ -in. copper tubing
20 ft $\frac{1}{2}$ -in. copper tubing
8 ft $\frac{3}{8}$ -in 18-8, type 304 stainless steel pipe
8 ft $\frac{1}{2}$ -in. 18-8, type 304 stainless steel pipe
120 ft 2-in. OD. 18-8, type 304 stainless steel pipe, $\frac{1}{4}$ -in thick
9 switch boxes, 575 AC volts, 30 amps, 3 poles, $7\frac{1}{2}$ hp
9 circuit breakers, 440 volts, 60 cycle, max motor rating $7\frac{1}{2}$ hp,
440 volts

Main Drive Unit (Figure 5, page 29)

1 Link Belt Worm Gear Drive, size HWV 7D-35, input rpm 1750, 2.8 hp
1 Link Belt Gear Motor, size DM-20, output rpm 45, 1 hp
1 Link Belt Electric Motor, model #5K203L911, 1 hp, 3 phase,
voltage 220/440, amperage 3.18/1.59
1 Mount for Worm Gear Drive, Gear Motor and Electric Motor
1 sprocket, 1-ft diameter, 12 teeth
1 Link Belt Chain #140, 26 links
1 sprocket, 7-in. diameter, 11 teeth
1 sprocket, $5\frac{1}{2}$ -in. diameter, 21 teeth
1 Link Belt Chain, #60, 28 links
1 sprocket, 4-in. diameter, 15 teeth

Heat Recycle Blower (Figure 9, page 33)

- 1 blower, 20-in. blade
- 1 electric motor, 1 hp, 3 phase, voltage 220/440, amperage 4.14/2.07
- 2 4½-in. pulleys
- 2 roller bearings, 1 3/16-in.
- 1 Gates Truflex 2440 Belt

Effluent Gas Blower (Figure 9, page 33)

- 1 blower, 20-in. blade
- 1 electric motor, 1800 rpm, 10 hp, 3 phase, voltage 220/440, amperage 25/12.5
- 1 pulley, 7-in. diameter
- 1 pulley, 9-in. diameter
- 3 belts, 93-in.

Outside Storage Bin (Figure 6, page 30)

- 1 15-in. sprocket, 60 teeth
- 4 11-in. sprockets, 20 teeth
- 1 Diamond Chain, #433S, 71 links
- 1 4-in. sprocket, 16 teeth
- 6 8-in. sprockets, 12 teeth
- 10 bearings, roller, 1-in.
- 1 Link Belt Chain #60, 47 links
- 1 Pacific Gear and Tool Works Motorized Speed Reducer, San Francisco, California, 2 hp, 160 rpm
- 1 GE Induction Motor, totally enclosed, 2 hp, 3 phase, model #5K224E818, voltage 220/440, amperage 5.36/2.68

Feed Auger (Figure 7, page 31)

- 1 electric motor, 3 hp, 3 phase, 1740 rpm, voltage 220/440, amperage 8.4/4.2
- 1 pulley, 4-in.
- 1 pulley, 12 3/4-in.
- 1 59 1/2-in. belt

Discharge Auger (Figure 7, page 31)

- 1 Link Belt Gear Motor, 3 hp, output rpm 84
- 1 Link Belt Electric Motor, 3 hp, 3 phase model #5K225E1982, voltage 220/440, amperage 9.8/4.9
- 2 45° beveled gears, 5-in. OD, 25 teeth
- 2 roller bearings, 1-in.
- 2 5 1/2-in. sprockets, 21 teeth
- 1 9-in. sprocket, 35 teeth
- 1 Link Belt Chain #60, 57 links
- 1 2-ft sprocket, 108 teeth
- 1 4-in. sprocket, 14 teeth
- 1 Link Belt Chain #60, 55 links

Circulating Pump (Figure 12, page 36)

- 1 electric motor, 3 hp, 3 phase, voltage 220/440, amperage 7.6/3.8
- 2 roller bearings, 1-in.
- 1 3-in. pulley
- 1 10-in. pulley
- 2 belts, 64-in.
- 2 gear pumps, 5 gal/min, internal gear

Final Auger Drive (Figure 8, page 32)

- 1 Link Belt Gear Motor, 2 hp, output rpm 155, ratio 11.4
- 1 Link Belt Electric Motor, 2 hp, 3 phase, Tri Glad Induction, model #5K224E923, voltage 220/440, amperage 13.6/6.8
- 1 electric motor, 3/4-hp, rpm 1725, 60 cycle, 1 phase, voltage 110/220, amperage 5.84/2.92
- 2 roller bearings, 1-in.
- 1 12-in. sprocket, 51 teeth
- 1 4-in. sprocket, 15 teeth
- 1 Link Belt Chain, #60, 57 links
- 1 2-in. pulley
- 1 19 $\frac{1}{2}$ -in. pulley
- 1 Gates Truflex belt #3690
- 1 shaft, 1-in. diameter, 12 in. long, mild steel

Drive for Retort Augers (Figure 7, page 31)

- 1 Link Belt Worm Gear Drive, 1.6 hp, ratio 50, input rpm 1750
- 1 GE Electric Motor, rpm 1725, $\frac{1}{2}$ hp, voltage 110/220, amperage 7.8/3.9
- 1 Speed Selector Variable Planetary, B. F. Goodrich, Akron, Ohio
- 2 sprockets, 4-in. diameter, 16 teeth
- 2 sprockets, 7 $\frac{1}{2}$ -in. diameter 30 teeth
- 1 Link Belt Chain #60, 112 links

ACKNOWLEDGEMENT

The author acknowledges with thanks the support of the Engineering Experiment Station of Montana State College which sponsored the author's participation on this project. The author acknowledges aid and suggestions supplied by the entire staff of the Chemical Engineering Department of Montana State College. Special thanks are extended to Bob Atkinson and Burton Andersen who accomplished most of the construction of the plant and also to John Goodenbour and Dick Waterman with whom the author worked on the project.

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FIGURE 1

SIMPLIFIED FLOW DIAGRAM OF THE CHAR PLANT

