Results of continuous coal charring operations
by John W Goodenbour

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 retort for continuous charring of non-coking coal and the by-product recovery system to work in conjunction with it were investigated. Work had already been done on the retort by PDP Processing, Inc., at Melstone, Montana. This previous work indicated the necessity for using 18-8 stainless steel as the material of construction of the retort built at Montana State College.

Coals from Roundup, Red Lodge, Colstrip, and Great Falls, Montana; and from Minot, and New England, North Dakota; Price, Utah, and Sheridan, Wyoming, were utilized in running the plant. All coals investigated, with the exception of slack coal from the Brophy Mine in Red Lodge, Montana, and coal from the Surmi Mine at Great Falls, Montana, could be used to produce char which would meet American Smelting and Refining Company specifications, namely: not more than 5 percent volatile matter and at least 75 percent fixed carbon.

While investigating the coals mentioned above, many improvements were made on the retort and the original by-product recovery system.

INTRODUCTION

Among Montana's varied wealth of natural resources are the tremendous reserves of bituminous and sub-bituminous coal. Recoverable reserves of Montana coal on January 1, 1950 (assuming 50 percent recovery) were 110,866,222 thousand short tons. This includes bituminous, sub-bituminous, and lignite coal. Montana's reserves are surpassed only by the 299,932,144 thousand short tons of lignite in North Dakota (1). Mining of this coal has long been carried out in Montana. At the turn of the century Montana coal was being utilized not only in its native state, but also to produce metalurgical coke for the smelters in Butte, Anaconda, and East Helena, Montana. The coke was produced in four localities, namely Cokedale and Electric in Park County, Storrs in Gallatin County, and Belt in Cascade County (3). Labor trouble caused a shutdown of these beehive coking operations in 1911 and coke has not been produced in Montana since then.

Coal continued to "hold its own" as a major industry in Montana up to and through the period including World War II. Then, in Montana as in the rest of the country, coal production dropped off. Figure 1 shows coal production in Montana from 1883 through 1951. All data are from the Mineral Yearbook for the years covered. The major cause of this slump in Montana was dieselization of railroad locomotives. Several of the largest mines in the state were operated mainly for the railroads. Another cause was the advent of cheap natural gas. Whatever the cause, it has become increasingly evident that Montana's coal industry needs a "shot in the arm".

In October of 1952, the Engineering Experiment Station at Montana State College instituted a research program to investigate the possibility of commencing coking operations in Montana again. The program was active until June of 1954 when it was temporarily abandoned. At the present time, it is being reactivated. The results of the program (3) (5) indicated that beehive coking of coal from the Cokedale mines would be possible if an efficient method to mine the pitching vein at a reasonable cost could be found.

Unfortunately, most of Montana's coal is of a non-coking variety. In the Northwest area of the United States there is a demand for carbon which is causing considerable concern. Phosphorus plants in Silver Bow, Montana, Pocatello, Idaho, and Soda Springs, Idaho, use approximately 400,000 tons of coke annually. Smelters in East Helena, Anaconda, and Butte, Montana, use a like amount of coke, coke breeze, and coal. Much of this carbon is shipped long distances inflicting excessive freight costs. When the steel industry's demand for coke increases, carbon for Montana's smelters becomes more difficult to obtain. In general, the situation is difficult to cope with.

For these reasons, an economical way for benefication of non-coking coal has been sought. In 1950, PDP Processing, Inc., was organized to promote a retort, developed by a retired mining engineer, Frank Hobson of Missoula, Montana, for charring (benefication of non-coking coal) coal. One such retort with a rated capacity of 25 tons of coal a day was constructed at Melstone, Montana, for development purposes. After several short trial runs, it became obvious that there were shortcomings in the original design, although the basic principles of the retort were very satisfactory. The retort was dismantled and modified. Upon re-erecting the retort, some of the shortcomings still had not been eliminated. A completely new retort was fabricated at this point. This retort proved satisfactory in nearly all respects. A gravity flow system previously used for the removal of the char from the retort had the inherent disadvantage of poor heat transfer in cooling the char and this was overcome by using water-cooled augers to remove the char. The main difficulty encountered with this retort was in material of construction. The company had constructed the retort of mild steel to learn how long it would withstand normal operating conditions. It failed after approximately three days of continuous operation. This happened early in 1954. The company made plans to construct another retort using 18-8 stainless steel. While these plans were being formulated, the company contacted Dr. Lloyd Berg, Head of the Chemical Engineering Department at Montana State College, in an effort to learn some efficient method of condensing the by-products driven off during the charring operations. It was during these consultations that the decision was reached to bring the plant to Montana State College and erect it here for research both on the retort and on a by-product recovery system. The plant was moved during the summer of 1954. It was completed in October of 1954 and has since been operated in such a manner as to demonstrate the feasibility of charring coal from several Montana coal fields. During these operations many improvements were accomplished. This thesis covers the plant operations during the past year and the improvements made, based on the findings of these runs. Complete details of the plant are given in a thesis by R. L. Quesenberry (4).

EQUIPMENT AND PROCEDURE

Retort -

For a complete and detailed description of the retort and the by-product recovery system refer to the thesis written by R. L. Quesenberry (4). Figure 2 shows a simplified flow diagram of the retort. After the mild steel used in the third retort at Melstone failed, the company decided to construct the entire retort of 18-8 stainless steel. The retort at Montana State College was so constructed.

As is shown in Figure 2, coal is transported to a coal bin at the top of the retort. The coal flows from this bin down through the annular space between cylinder 1 and cylinder 2. Cylinder 1 is revolved slowly to provide agitation and prevent channeling of the coal. Two stainless steel augers at the base of the retort remove the char. The rate of throughput of coal is regulated by controlling the speed of these augers. The char is taken from the retort augers by another auger mechanism consisting of two jacketed 6-in. augers. Cooling water is circulated through the jackets to cool the char to a temperature low enough to prevent combustion upon exposure to air. Heat for retorting is supplied by burning natural gas in the firebrick furnace. On a commercial unit of this type, the dry, non-condensable gases from the by-product recovery system will be recycled to the furnace and it is expected that these gases will supply all or at least the major portion of the heat required for the operation of the retort. The combustion gases from the furnace pass upward through cylinder 1 and through the annular space between cylinder 2 and cylinder 3. Thus, the flowing bed of coal is heated from both walls. The combustion gases are then drawn by the combustion gas return blower through the combustion gas manifold and duct and back down to the furnace. There are baffles in the front of the furnace which are so arranged to mix thoroughly the return gases and the freshly burned gases. Spent gases are removed by a flue gas stack on the furnace. The estimated mean life of the gas in the furnace is seven cycles through the system.

The by-product gases are driven off the coal through the effluent gas off-take tubes. These tubes extend from cylinder 2 through cylinder 3 into the annular space between cylinders 3 and 4 at an angle of 50°. The annular space between cylinders 3 and 4 serves as a by-product collection chamber. The by-product gases are removed from this chamber by the effluent gas blower. By throttling this blower the pressure within the retort can be maintained at just a slight vacuum. Care must be exercised in controlling the vacuum since when the pressure drop from the atmosphere to the retort becomes sufficient, air is forced back through the augers into the retort causing combustion of the char and coal. Air is excluded from the top of the retort by a water seal. There are two actual water seals. The upper one seals the combustion gas manifold where the supporting shaft passes through. The lower seal excludes air from the top of the retort as is shown in Figure 5.

By-Product Recovery System -

The original by-product recovery system is shown in Figure 3. This system was based on one mentioned in Bureau of Mines Bulletin 412. No sulfuric acid scrubber is included because the cost of the necessary equipment was excessive in comparison to the ammonium sulfate that could be recovered.

The effluent gases from the retort enter the recovery system through a cyclone separator. It was thought that by proper control of cyclone temperature, the tar would condense out and both tar and dust could be removed by the separator. The gases then went through two absorption columns countercurrent to a spray of straw oil. The first column, which is 10 in. in diameter and 10 ft high, was to be maintained at around 160° C so that the creosote would condense but the light oils would pass on to the second column. This column, which had a diameter of 7 in. and was 13 ft high, was to be operated at room temperature. This would remove the remaining condensable oils and dry gas would come off the top of the second column. In a plant operated commercially, this dry gas would be recycled to the furnace and used to supply heat for retorting. For convenience, the dry gas obtained during experimental runs was burned with natural gas in a flare. The creosote column and the light oil column each had a collection system where any water that condensed could be separated by gravity. These reservoirs were equipped with copper cooling coils to be used in controlling the temperature of the absorption oil. Straw oil, a petroleum fraction boiling between 160° C and 225° C was used to start the system. As soon as enough creosote and light oils were collected these were used as the absorption oils in their respective columns. This procedure was followed in an effort to separate the by-products into two rough fractions which could then be sold without further separation. The inlet to the cyclone on the first system was 7 in. by 7 in. square. The line between the cyclone and the first absorption column was a 3-in. standard pipe. The remaining pipe in the system was 2-in. standard pipe. The flare line was a 4-in. diameter pipe.

For the purpose of this thesis the term shakedown run shall be considered to be the operation of the new equipment of the plant to find and eliminate any major mechanical flaws. The term trial run shall be considered to be the operation of the plant to determine if specification char could be produced. A run in which the plant was operated so that mine owners and other interested persons could witness it in operation shall be termed a demonstration run.

On October 24, 1954, the initial shakedown run of the plant was started. The coal used was lignite from the Truax-Traer mine in Minot, North Dakota. As the temperature of the retort increased, expansion of the retort caused the rotating cylinder, cylinder 1, to come into contact with some stationary part of the retort. The lower water seal mechanism was re-designed as shown in Figure 5, because there was a slight contact between the rotating cylinder and part of the seal. This, however, did not eliminate the binding. The only other place the cylinder could possibly bind was at the base of the retort. It would have been very difficult to reach this portion of the retort, so heating was resumed in an effort to determine if the binding could be overcome. When the retorting temperature had been reached, cylinder 1 appeared to be turning freely. The only method of ascertaining if the cylinder was turning was to observe the drive mechanism. On October 26, the coal bin, directly over the retort and combustion gas manifold, became overheated. This caused the charring process to start in the coal bin. The by-products driven off in the bin could not be recovered. Although the loss of this small amount of by-products was not considered serious to any material balance that might be accomplished, working conditions became intolerable so the unit was again shutdown. Spun glass insulation was suspended 3 in. below the bottom of the bin and a small blower installed to circulate air between the bin and the insulation. The heating operations were started again. On October 27, Truax-Traer lignite was charged and brought up to temperature. The volume of effluent gases given off by this operation proved to be more than the effluent gas blower could handle. A positive pressure within the retort resulted,necessitating a cease in operations. The pulley on the blower was replaced with another pulley that doubled the revolutions per minute of the blower. Heating was started once again. An excessive pressure drop through the condensation equipment caused a positive pressure within the retort and the unit was again shutdown on October 29, ending the first shakedown run. Much had been learned about the shortcomings of the by-product recovery system. One important shortcoming of the original system was the inadequate temperature control available with the reservoir cooling coils. Because of the lack of adequate temperature control, it was impossible to run the two columns at widely separated temperatures as had been planned. The second column temperature ran just slightly lower than the first so many of the light ends were not condensed. Although no accurate weight balance was attained during this run, it was possible to ascertain the inadequacy of the system by the color of the flare flame. As the temperature of the column increased, the flame became a brighter yellow. Observation of the columns in operation through sight glasses provided at the top of the columns led to the conclusions that a fine mist of straw oil was being carried over from the first to the second column and from the second column out through the flare. Only a small amount of tar came out in the cyclone separator. In fact, the tar was present in just enough quantifies to make a solid mass with the dust.

The analyses of the coal used for the first shakedown run and the resulting char are given in Tables I and II in the appendix.

In order to reduce the pressure drop across the by-product recovery system, the 3-in. pipe between the effluent gas blower and the cyclone, the 2-in. pipe between columns and between the second column and the flare were replaced with 7-in. rolled steel pipe. The 4-in. flare line was replaced by 7-in. galvanized steel pipe. This flare line was provided with a retractable orifice and sample tap to be used in finding the amount and composition of gas going up the flare. Using this information, it would be possible to calculate the amount of heat available from these dry gases. The second column was replaced by one the same size as the first, 10 in. in diameter and 10 ft high. The pipe between columns was provided with a water jacket 7 ft high in an effort to cool the by-products further, thereby increasing condensation efficiency (the percent of the total condensable by-products that were condensed). A small cyclone separator, the cylindrical portion of which is 14 in. in diameter, was installed at the outlet of the second column in an effort to knock the mist out of the non-condensed gases going to the flare.

Second Shakedown Run -

While preparing for a second shakedown run, it was discovered that the 1.5-in. stainless steel shaft which supported and turned cylinder 1 was sheared. This probably occurred during the first shakedown run when cylinder 1 was binding. When the shaft parted, the cylinder dropped approximately one inch. In so doing it broke the water seal mechanism. This occurrence allowed water to run freely into the coal chamber of the retort. The shaft extended through the combustion gas manifold and was therefore subjected to much heat. The shaft was replaced by a 2-in.

stainless steel shaft. This shaft was provided with a water jacket to keep it cool.

On December 18, a second shakedown run was started. When coal had been charged and retorting temperature reached, the binding of cylinder 1 occurred again. Because of the difficulty in reaching the base of the retort to overcome this constriction, it was decided to remove the coal from the retort and continue to turn cylinder 1 until it had worn itself free from its constriction. On December 19, this operation was carried out while gradually cooling the furnace and retort. On December 20, while reheating the furnace in an attempt to retard the cooling of the retort, the natural gas in the furnace exploded. Evidently, the combustion gas return blower, designed to operate at higher temperatures, momentarily blew out the flame. A small flame burning through a peephole in the furnace then ignited the collection of natural gas, causing the explosion which did extensive damage to the furnace. Only the portion of the furnace under the retort could be salvaged.

After clearing away the ruins of the front of the furnace, it was possible to reach the base of the retort. The binding of cylinder 1 was remedied by cutting 1 in. from the circumference of the jack-shaft over which the cylinder was suspended. This eliminated the binding. The furnace was then reconstructed.

Third Shakedown Run -

A third shakedown run was undertaken on January 24, 1955, using

Montana Coal & Iron Company coal from the Red Lodge, Montana area. After 12 hours of operation, the 7-in. pipe between the cyclone separator and the first absorption column became plugged with tar, resulting in a positive pressure in the retort. The run was discontinued. This run indicated, as did the first run, that very little tar came out in the cyclone separator. Because the tar was going beyond the cyclone, it was decided to add a third column to the by-product recovery system to remove the tar. This tar knock-out drum, as it is called, was constructed by welding three 55-gal oil drums together. The by-product gases that leave the cyclone enter the tar knock-out drum tangentially through a 7-in. square inlet. The outlet is a 7-in. rolled steel pipe which extends about one-third of the way down the column from the top. Water, which is used to condense the tar, is sprayed into the column through two small spray heads at the top of the column. Two high pressure steam (70 psig) spargers were provided near the bottom of the column for use in the event that the temperature of the column reached a point low enough to condense any of the creosote fraction. The condensed tar and water are removed through a liquid seal at the bottom of the column which discharges into a 20-gal tank. This tank is used to separate the tar from the water by gravity. A steam coil was placed near the bottom of the column to provide heat to keep the tar in the liquid state.

A simplified flow diagram of the present by-product recovery system is shown in Figure 4. In addition to the original equipment, this system includes the small cyclone separator at the outlet of the second absorption column and the tar knock-out drum.

Another run was attempted on February 3. Just enough tar condensed in the line between the effluent gas blower and the cyclone to collect fine dust and solidify, plugging the line. To prevent such condensation, the pipe from the blower to the cyclone was jacketed. Using 6-in. rolled steel pipe, waste combustion gases are taken from the flue gas stack on the furnace and passed through this jacket. This keeps the pipe hot enough to prevent tar condensation. Any dust that has a tendency to settle out will eventually be blown into the cyclone.

First Trial Run -

One of the major outlets for char produced by this process is sale to the American Smelting and Refining Company in East Helena, Montana, to be used as a reducing agent in the smelting of lead ore. American Smelting and Refining specifications are: not more than 5 percent volatile matter and at least 75 percent fixed carbon. The only other specification is that the char be 3/8 in. or less in size. On February 6, a trial run was conducted to find if char which would meet these specifications could be produced from slack coal from the Brophy mine in Red Lodge, Montana. The run lasted 12 hours. The unit functioned well except that the temperature of the second column could not be held low enough to condense the light ends. In an effort to effect better contacting of the absorption oil and the by-product gases, 1/4-in. mesh screens were placed in the columns, spaced 18 in. apart. The jacketed line between the two columns provided only enough heat transfer to reduce the temperature approximately 10° F. Because the absorption oil became hot during the run, there was only about a 10° F drop across the second column.

To enable operation of the second column at lower temperatures, a large heat exchanger was installed to cool the absorption oil before it was sprayed into the column. Using water as the coolant, the oil could be cooled to around 50° F.

Second Trial Run -

Another trial run was undertaken on March 4, using coal from the Northern Pacific Railway strip mine at Colstrip, Montana. The coal from this mine was loaded directly without sizing. It ranged in size from fine particles to lumps as large as 3 ft long. When this run was conducted, no crusher was available. The coal had to be reduced in size manually, using a sledge hammer. For this reason, only one truck load was run during the March 4th run. A crusher capable of reducing this coal to 1.5 in. or less has been constructed and will be used on Colstrip coal in the future. The by-product recovery system functioned much better with the heat exchanger in operation. During this run, there was approximately a 70° F temperature drop from the outlet of the first column to the outlet of the second column.

Third Trial Run -

Brophy stoker coal was used for the next trial run. This run was started on March 11. After several hours of operation, a positive pressure developed within the retort. The unit was shutdown and all the lines in the recovery system inspected. None was found to be plugged. The run was started once more on March 14th, but the vacuum was lost again after several hours. It was then discovered that the pipe which drains the first absorption column into its collection system was partially plugged with tar, resulting in a collection of absorption oil in the column. High pressure steam lines were connected into this line and others of the by-product recovery system. These steam lines were used periodically during the remaining runs to clear the system's piping.

First Demonstration Run -

Coal from the Big Horn Coal Company of Sheridan, Wyoming, was used for the first demonstration run on March 24. The company requested that the truck load of coal sent to Montana State College be used to produce char of varying composition. This run lasted until all of the coal had been utilized. The analyses for the run are listed in Table III.

Starting on April 18th, a series of demonstration runs lasting from eight to twelve hours were made on the following schedule:

April 18 - Surmi Mine, Great Falls, Montana

April 20 - New England Coal Company, New England, North Dakota

April 22 - Truax-Traer Coal Company, Minot, North Dakota

April 27 - Independent Coal & Coke Company, Salt Lake City, Utah.

Analyses of the coals and the chars produced can be found in Tables I and II.

On May 17, a run was conducted using coal from Roundup, Montana, and washed stoker coal from the Brophy mine at Red Lodge, Montana. This was a demonstration run, the purpose of which was the production of a sample of char from these coals. Therefore, the run only lasted about eight hours, although the equipment functioned well.

During all of the preceding runs, the char was stockpiled at the end of the water-cooled auger system. The char displayed a tendency to burn when it was handled in this manner. For this reason a char storage bin was constructed and another water-jacketed auger added to the system to carry the char to the top of the bin. In order to meet the American Smelting and Refining Company size specification, a small crusher was constructed at the end of this auger to reduce the char to 3/8 in. or less in size.

Despite the addition of the heat exchanger to the by-product recovery system, the temperature at the outlet of the second column was still too high during most of the demonstration runs to condense the light ends. Therefore, another heat exchanger was placed into the system to cool the absorption oil for the first column. This exchanger was constructed by a research fellow and was much smaller than the one used in conjunction with the second column. However, no larger one was available.

When the demonstration runs were finished the cyclone was inspected. The cyclone and the pipe between it and the tar knock-out drum were found to be coated with tar and dust. Since the heat jacket constructed for the pipe connecting the blower and the cyclone eliminated the same problem there, a similar jacket was constructed for the cyclone and the pipe connecting the cyclone and the tar knock-out drum.

Trial Run For Drying -

Because it was desired to operate the retort using dry coal, a test run was made on coal from the Big Horn Coal Company on May 24, to determine the feasibility of drying the coal in the retort. The drying process proved to be too time-consuming and was abandoned.

All the preceding short runs were performed for two primary reasons. First, to find and eliminate any "bugs" in either the retort or the by-product recovery system and second, to demonstrate the ability of the retort to produce usable char. No material balance was ever accomplished because of the length of the runs. All of the runs were so short that the by-product recovery system never reached temperature equilibrium.

On June 6, a run was started using Big Horn coal. This run was to be used in attaining a material balance. After 16 hr of operation, the insulation on the wires in a conduit leading to the motor driving the combustion gas return blower melted, causing a short circuit. The conduit had been placed directly on the furnace roof. The unit was shutdown, the conduit was moved and the wires replaced. The motor was located very near to the flue gas stack and therefore was operating at elevated temperatures. While the unit was cool, the motor was moved to a cooler location. The run was resumed on June 8. On the 9th, one of a pair of matched belts in the variable speed drive for the retort discharge augers wore out. It was necessary to order a set of belts from Akron, Ohio. On June 17, the run was started once more. After 24 hours, equilibrium was reached and a weighed amount of coal was charged to the system. At this point, the temperature within the retort began to climb, although the natural gas flame in the furnace was at a minimum. The retort temperature continued to increase and it became necessary to shutdown to protect the effluent gas blower from overheating. When the retort had cooled the combustion gas manifold was cut open to inspect the top and inside of the retort. It had been suspected that a hopper at the top of the retort, which was constructed of mild steel, had failed. This was not, however, the case. Cylinder 1 was originally fabricated in three sections. This necessitated welding around the circumference of the cylinder in two places. Some time during the run, one of these welds failed. The bottom section of the cylinder fell to one side. This allowed the coal being fed to the retort to fall directly into the furnace. At this time, the cylinder is being repaired. When the repairs are completed, the material-balance-run will be conducted.

RESULTS

All the data referred to in this section are tabulated in Tables I, II, and III of the appendix.

First Shakedown Run -

As stated previously, the principal results of the first shakedown run served to point out several major shortcomings of the by-product recovery system. These "bugs" were eliminated before the second shakedown run. Analysis of the char produced during the first run seemed to be highly unfavorable. There was still 3.3 percent moisture and 17.7 percent volatile matter in this char. The reason for these poor results are clear. It was during the first shakedown run that the shaft supporting cylinder 1 sheared, dropping the cylinder, which in turn broke the water seal. For the remainder of that run, water was continuously drained into the coal chamber. The coal itself was high in moisture. Therefore, much of the heat applied to the coal was used to drive off the water and only part of the volatile matter was removed. In addition to flooding the coal, cylinder 1 was not turning so the coal did not receive proper agitation.

Even though the by-product recovery system was not functioning properly, some by-products were condensed. A.S.T.M. distillations were run on the absorption oil from both columns. Material in the creosote range was found in the oil from the first column and the oil from the second column yielded a fraction in the light oil range. It was impossible to calculate condensation efficiency since the exact amount of gases handled by the system was not known.

Third Shakedown Run -

Char produced during the third shakedown run was still higher in volatile matter than was desired, although the retort functioned properly. The retort temperature was held at approximately 1000° F during this run. The rate of throughput was around 800 pounds of coal per hour. This run was discontinued because tar plugged the line from the cyclone to the first absorption column. The tar knock-out drum described in the equipment section of this thesis was added to the system at this point.

First Trial Run -

The first trial run using Brophy slack coal was discontinued because of a dust buildup in the line from the retort to the cyclone. A heat jacket was constructed and the run continued. The temperature of the retort was maintained at 1000° F and approximately 500 pounds of coal per hour were charged to the retort. Analysis of the char produced showed that less than 5 percent volatile matter char could be produced by the retort. The ash content of Brophy slack coal was so high, however, that the material produced was not high enough in fixed carbon to meet American Smelting and Refining Company specifications.

Second Trial Run -

During the second trial run, coal from Colstrip, Montana, was charged to the retort at a rate of 800 pounds of coal per hour. The retort temperature was approximately 1000° F. Because of the high moisture content of the coal, the volatile matter of the char was not low enough. However, from the ratio of fixed carbon to ash in the char it can be seen that if the volatile matter content was less than 5 percent, the fixed carbon would be over 75 percent. This could be accomplished by a slower throughput, as was used in the first trial run.

Third Trial Run -

Brophy stoker coal was used for the third trial run. During the first eight-hour portion of this run the rate of throughput was approximately 700 pounds of coal per hour. Retort temperature was 1000° F. Char from this part of the run had 6.4 percent volatile matter. The run was temporarily discontinued when it became impossible to maintain a vacuum within the retort. After inspecting the equipment for plugged lines, the run was continued at the rate of 400 pounds per hour. The char produced during this last portion of the run was the first that met American Smelting and Refining Company specifications, having only 3.8 percent volatile matter and 78 percent fixed carbon. Loss of the retort vacuum again necessitated a shutdown.

First Demonstration Run -

After installing steam lines to by-product recovery system pipes as described in the previous section of this thesis, the first demonstration run was undertaken using coal from the Big Horn Coal Company of

Sheridan, Wyoming. Table III gives the results of this run. The Big Horn Coal Company desired samples of char with composition ranging from the lowest possible volatile matter content to 20 percent volatile matter. The run produced very good char, some as low as 3.5 percent volatile matter which had almost 90 percent fixed carbon.

Second Demonstration Run -

The second demonstration run was on coal from the Surmi Mine at Great Falls, Montana. The throughput was 500 pounds of coal an hour at a temperature of 1000° F. The coal was extremely high is ash and therefore yielded char which, although only 5.1 percent volatile matter, would be unmarketable because of the 39.8 percent ash. However, this coal displayed coking tendencies in the retort, and for this reason a sample was sent to the Rochester and Pittsburgh Coal Company in Indiana, Pennsylvania, for coking tests. But after thorough testing in a beehive coking oven, no coke was formed.

Third Demonstration Run -

Using New England Coal Company lignite from New England, North Dakota, a third demonstration run was conducted at 500 pounds per hour and 1000° F. Because of the high moisture content of the lignite, 35 percent, the char produced by this run was high in volatile matter.

Fourth Demonstration Run -

The fourth demonstration run was conducted using lignite from the

Truax-Traer Coal Company of Minot, North Dakota. It was run at a rate of 500 pounds of coal per hour but at slightly higher temperatures, 1050° F to 1100° F. The higher temperature used seemed to have no ill effects on the effluent gas blower which was designed to operate at 800° F. The results were far more favorable at this temperature. The char contained only 7.4 percent volatile matter and had 78.6 percent fixed carbon.

Fifth Demonstration Run -

Coal from the Independent Coal & Coke Company, Salt Lake City, and shipped by Lilenquist Brothers of Trementon, Utah, was utilized in making the fifth demonstration run. The plant was operated at a throughput rate of 800 pounds of coal per hour and at retort temperatures of between 1150° F and 1200° F. The volatile matter content of the char was high, 11.1 percent, despite the high temperatures used. This fact can be accounted for by the relatively high rate of throughput and the high volatile matter content of the coal, 42.4 percent.

A sample of screened coal called "bug dust" from Roundup, Montana, and a sample of washed stoker coal from Brophy mine in Red Lodge, Montana, were run at approximately 700 pounds of coal per hour in an effort to determine if these coals could be used to produce char that would meet American Smelting and Refining Company specifications. Char from the Roundup coal had 7.8 percent volatile matter and 77.6 percent fixed carbon, while char from the Red Lodge coal had 12.0 percent volatile matter and 75.2 percent fixed carbon. It is evident from these data that both coals could be used to produce char for American Smelting and Refining Company.

Material-Balance-Run -

During the attempted material-balance-run coal from the Big Horn Coal Company was charged at a rate of approximately 500 pounds per hour. Retort temperature was maintained at between 1200° F and 1250° F. Char with a volatile matter content of 3 percent or less was produced consistently during this run.

CONCLUSIONS AND RECOMMENDATIONS

The data collected to this date lead to only a few general conclusions. The project will be carried on during the coming year during which time the plant will be operated in such a matter to obtain material balance data on a number of coals. Such data can then be used in an economic study of each coal. A study such as this has to be based on estimates now. None of the runs conducted during the past year was long enough to get any such data.

The most obvious conclusion to be reached from the data reported in this thesis is that a retort of the dimensions shown in Figure 2 has a throughput capacity of about 12 tons per day. Most of the coals under consideration contained relatively high amounts of moisture. However, in a commercial plant the retort could be supplemented with a rotary drier.

Spent gases from the furnace could be used to dry the coal in such a drier before it was charged to the retort. The diameters of cylinders 1, 2, and 3 could be increased enough to double the capacity of the retort. By increasing all the diameters by the same amount, the thickness of the coal bed could be maintained the same as it is now. Such an increase in cylinder size would yield a retort of approximately the same outside dimensions as the present one and would not entail a very large extra outlay of capital.

The retort was originally designed for low temperature carbonization not to exceed 1000° F. However, the data collected during the demonstration run and on the attempted material-balance-run indicate that operation at 1200° F or more may be needed to produce specification char consistently. If the effluent gas blower were placed between the cyclone separator and the tar knock-out drum, it is probable that temperatures approaching 1400° F could be used. This estimate is based on operational records which show up to a 400° F temperature drop between the effluent gas blower and the outlet of the cyclone separator.

If the normal operating temperature of the retort were to be increased, additional cooling capacity for the by-product recovery system would be necessary. Better use could be made of the present heat exchangers by replacing the present circulating pumps, which are now used at maximum capacity, with larger pumps. This would allow a larger volume of absorption oil to be sprayed into the columns.

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To the Chemical Engineering Staff, the author extends his gratitude for much helpful advice.

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APPENDIX

Table I

ANALYSES OF COAL USED

Source	Type	%FCM	%VM	%FC	%ash
Big Horn Coal Co.	stoker	22.3	33.8	39.8	4.1
Brophy Mine	slack	10.2	31.7	42.7	15.4
Brophy Mine	stoker	9.9	31.9	47.5	10.7
Colstrip	run of mine	14.2	36.1	40.5	9.2
Independent Coal & Coke Co.	stoker	3.7	42.4	49.8	4.1
Montana Coal & Iron Co.	stoker	6.2	35.2	46.1	12.5
New England Coal Co.	lignite	35.0	27.2	27.6	10.2
Roundup Coal	"bug dust"	12.1	31.3	47.0	9.6
Surmi Mine	stoker	1.8	30.0	44.9	23.3
Truax-Traer Coal Co.	lignite	31.5	29.6	32.1	6.8

Table II

ANALYSES OF CHAR PRODUCED

Run	Coal used	%FCM	%VM	%FC	%ash
1st shakedown	Truax-Traer lignite	3.3	17.7	60.6	18.4
3rd shakedown	Montana-Coal & Iron stoker	0.0	14.0	72.0	14.0
1st trial	Brophy slack	0.0	3.8	65.5	30.7
2nd trial	Colstrip	0.0	13.2	71.2	15.6
3rd trial					
1st part	Brophy stoker	0.0	6.5	76.2	17.3
2nd part	Brophy stoker	0.0	3.8	78.0	18.2
1st demonstration	Big Horn Coal Co. stoker	see Table III			
2nd demonstration	Surmi Mine stoker	0.0	5.1	55.1	39.8
3rd demonstration	New England Coal Co. lignite	0.0	26.4	61.8	11.8
4th demonstration	Truax-Traer Coal Co. lignite	0.0	7.4	78.6	14.0
5th demonstration	Independent Coal & Coke Co. stoker	0.0	11.1	78.3	10.6
Run to produce samples	Roundup "bug dust"	0.0	7.8	77.6	14.6
	Brophy washed stoker	0.0	12.0	75.2	12.8

Table III

ANALYSES OF CHAR FROM FIRST DEMONSTRATION RUN

Sample No.	%VM	%FC	%ash
3	18.5	74.3	7.2
4	19.6	73.3	7.1
10	21.6	71.6	6.8
16	4.6	88.0	7.4
17	3.9	88.7	7.4
19	3.5	89.7	6.8

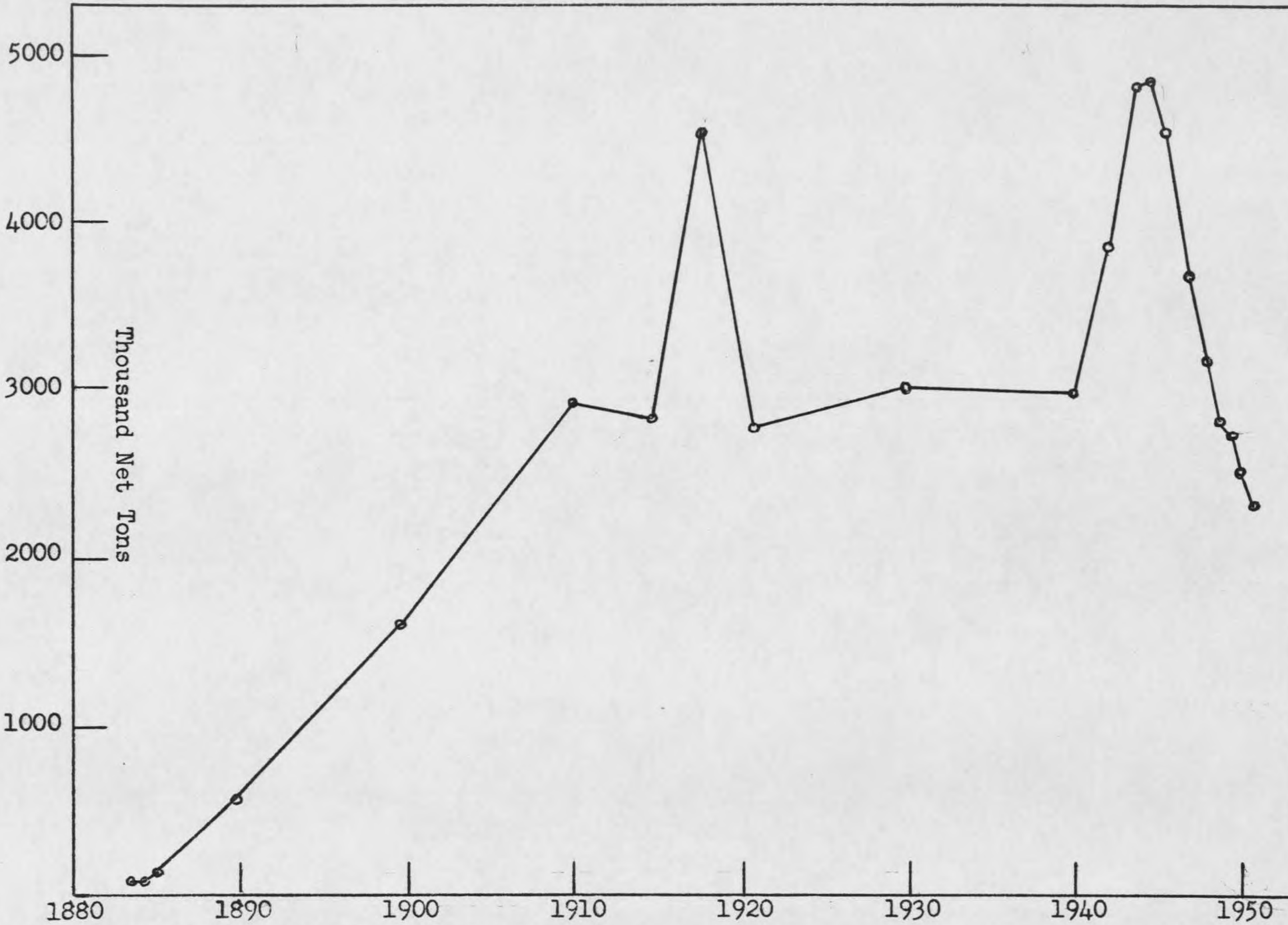

Figure 1. Montana Coal Production

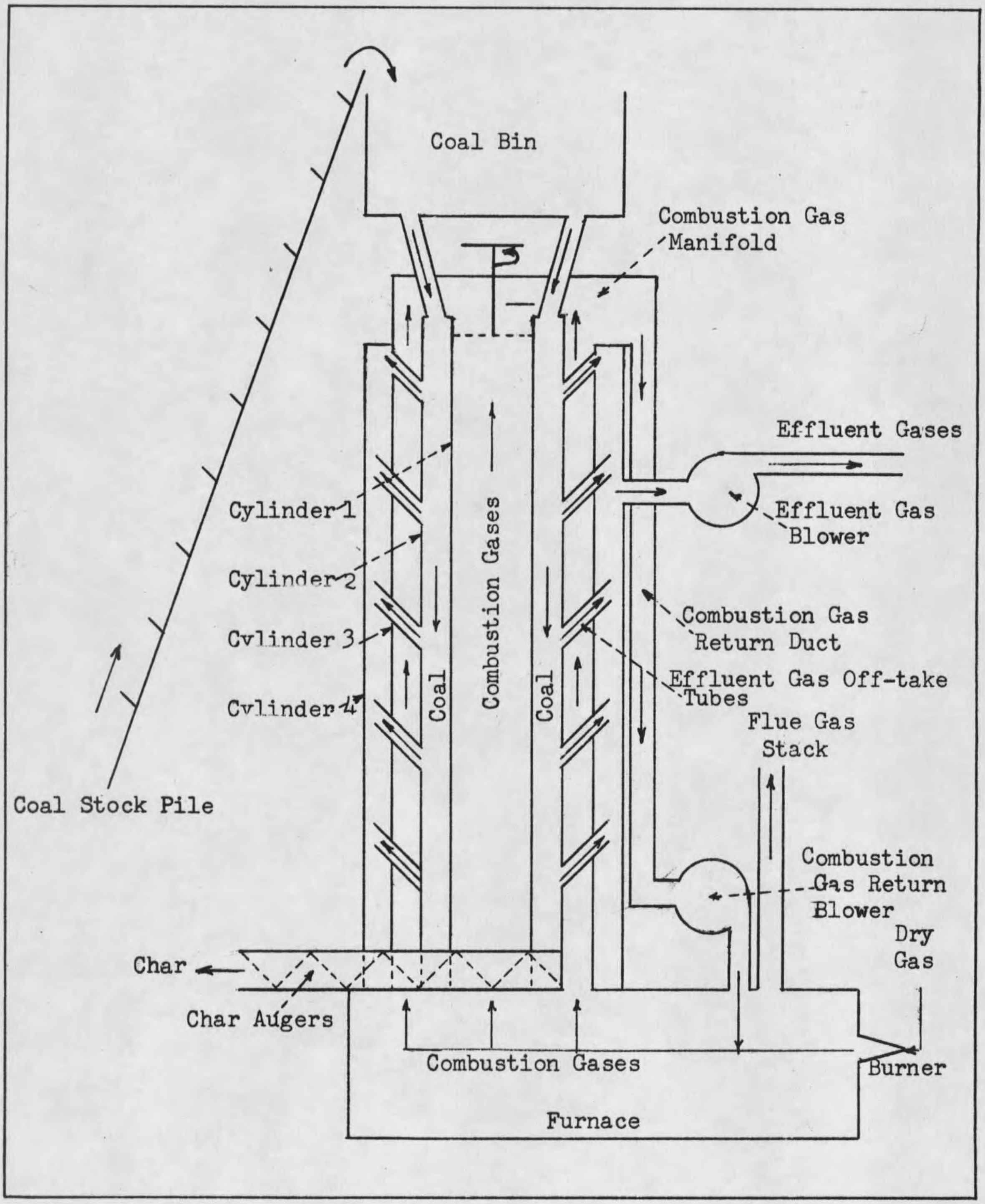

Figure 2. Retort Flow Diagram

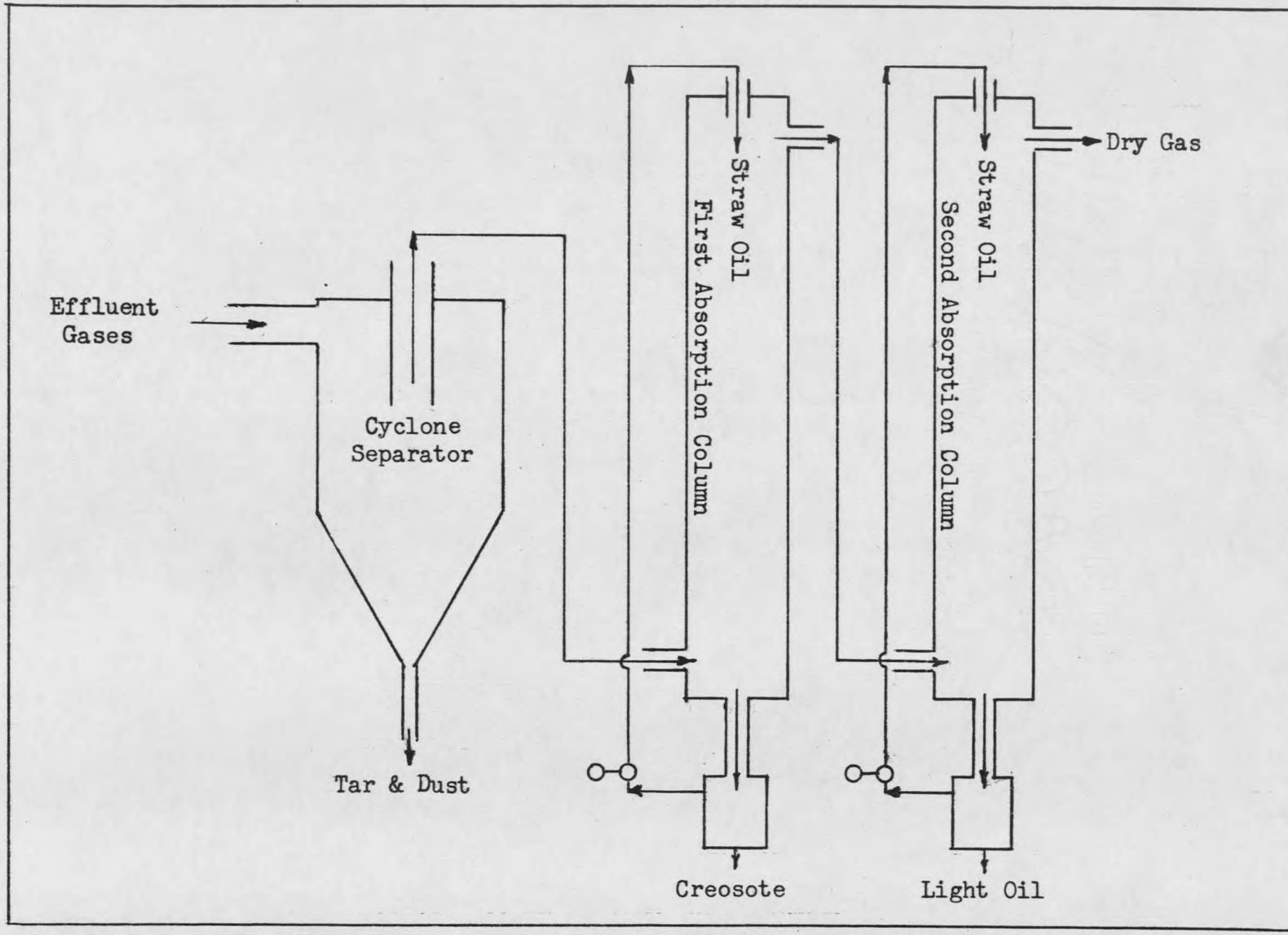

Figure 3. Original By-Product Recovery System Flow Diagram

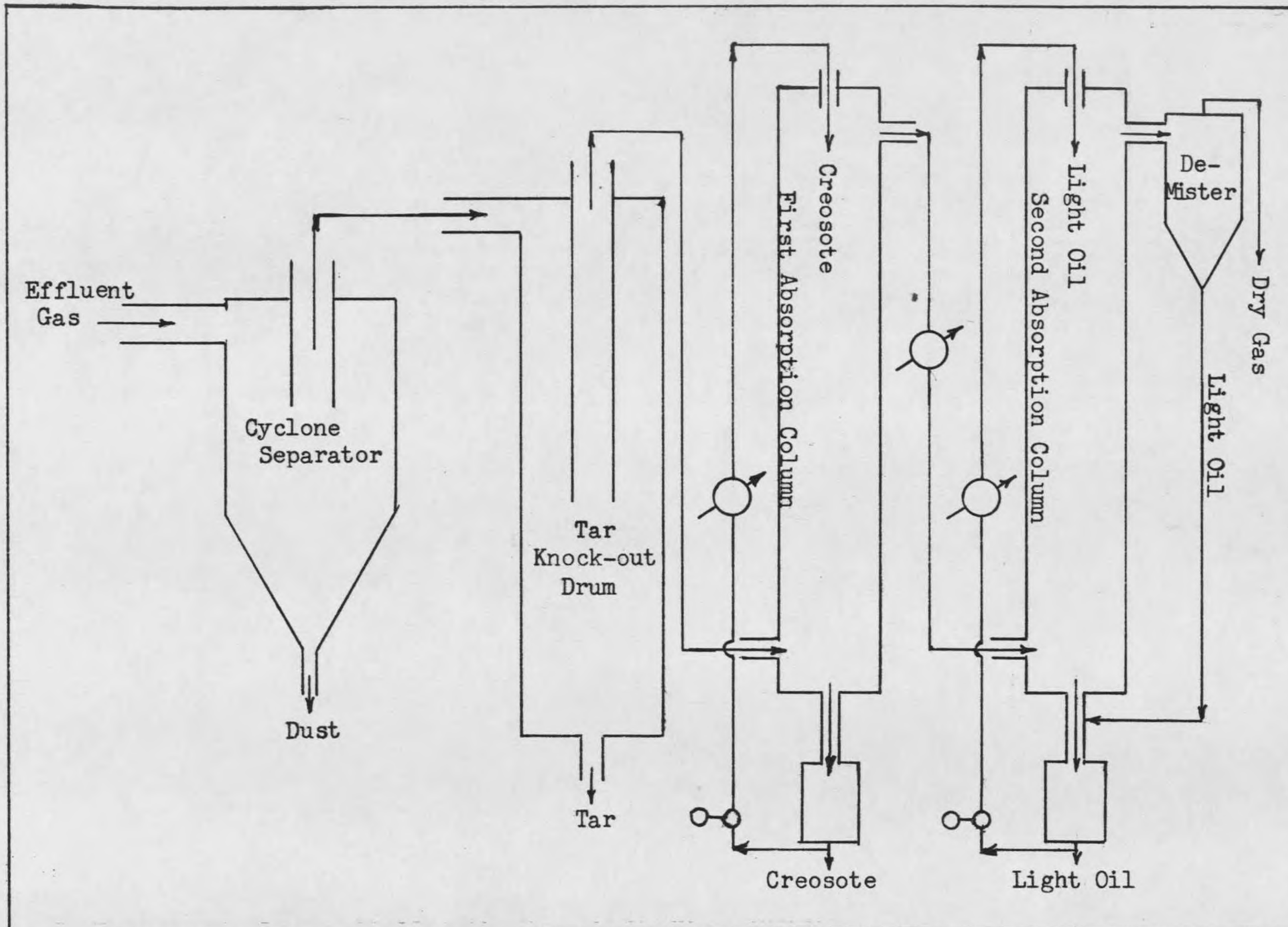

Figure 4. Present By-Product Recovery System Flow Diagram

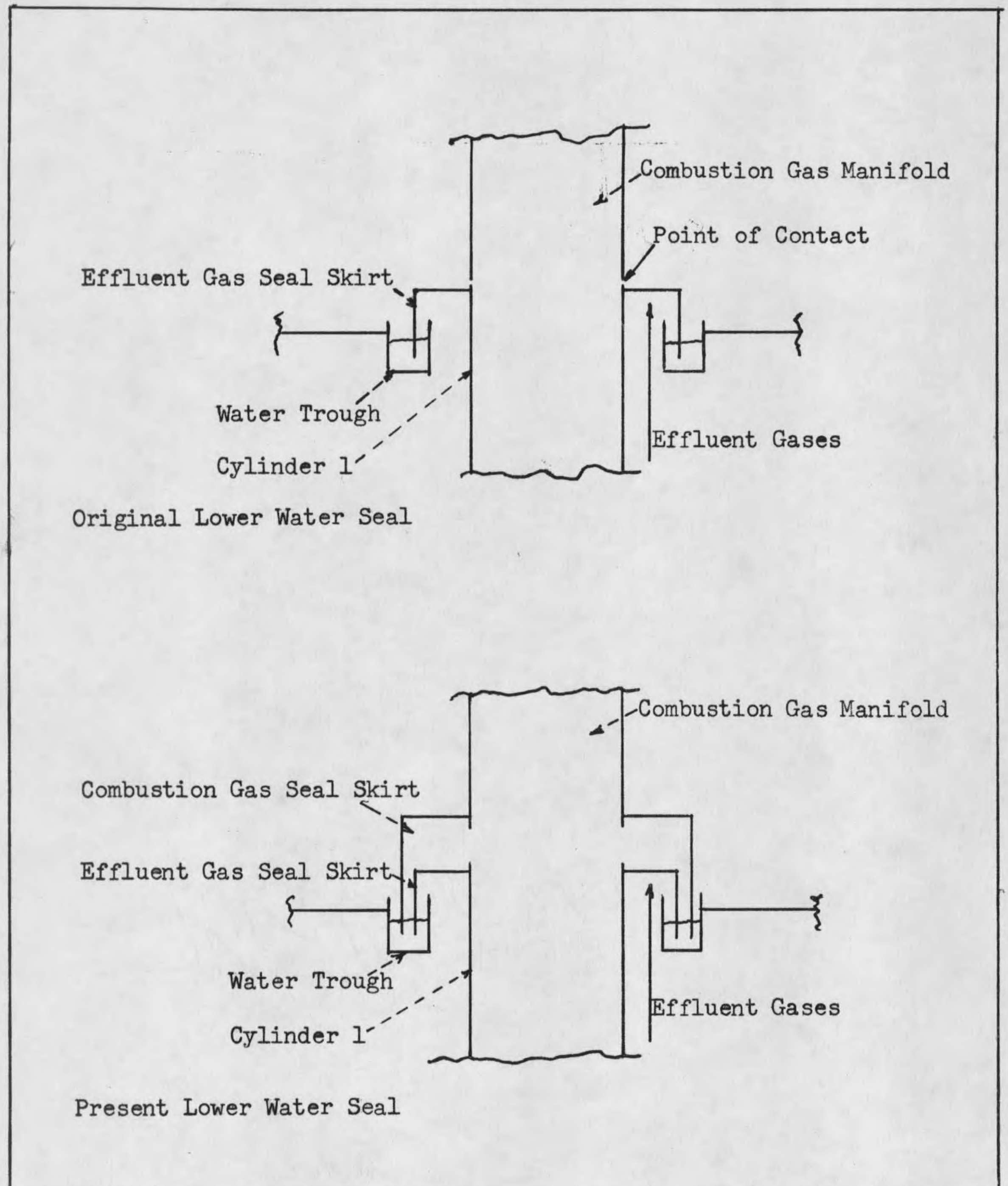

Figure 5. Lower Water Seal Re-design