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RESEARCH AND DEVELOPMENT DIVISION

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THE DEVELOPMENT OF EQUIPMENT FOR THE CONTINUOUS BURNING

AND LEACHING OF GROUND CARBON

ABSTRACT

Equipment was developed for the continuous burning and leaching of ground carbon in order to recover uranium for the proposed Closed Cycle Beta Process. The burning apparatus consisted of a vertical tube with a grate to support the carbon. An updraft of air was used to support combustion. The burning rate of the apparatus was 500 grams of carbon per hour; combustion averaged over 98 percent complete. The leacher consisted of a heated nitric acid bath divided into four compartments through which ground carbon was pushed by rotating paddles. The acid flowed, by gravity, countercurrent to the carbon.

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Oak Ridge, Tennessee
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THE DEVELOPMENT OF EQUIPMENT FOR THE CONTINUOUS BURNING
AND LEACHING OF GROUND CARBON

INTRODUCTION

Background

In our effort to make the electromagnetic process more economical, one objective was to perform most of the uranium recovery in the beta buildings. This was to be done continuously rather than by batch operation in order to reduce the number of operating personnel required. It was planned that 99 percent of the uranium would be salvaged in each beta building; only residues containing less than 1 percent of the original uranium per cycle would be sent elsewhere for subsequent processing.

Purpose

This new conception of beta recycle meant that new processes and equipment must be developed to recover the uranium more efficiently and at a smaller cost than ever before. To attain this goal the problem was presented to various research groups, each one of which was assigned a specific task. The portion of the problem assigned to this group was the pilot plant development of equipment for the continuous burning and leaching of ground carbon salvage for the recovery of uranium. Besides being continuous, another specification for the process was that the burning be done in air rather than the more expensive pure oxygen that had previously been used in plant operations.

EXPERIMENTAL
(Continuous Burner)

Approach

Preliminary Tests. Early experiments were performed using a horizontal tube furnace and later a conventional, batch, downdraft burner of the type previously used for salvage operations in this plant. The work with the horizontal tube showed that the ground carbon as a powder would not sustain combustion in air without an external supply of heat. The batch burner indicated the possibility of burning carbon pellets in air with no addition of extra oxygen or external heat.

Tests on Characteristics of Continuous Burner. In view of experience gained from the preliminary tests, a continuous updraft burner was designed. During the operation of this burner, the following characteristics and conditions were determined:

1. Completeness of combustion
2. Maximum rate of air flow
3. Maximum rate of combustion of carbon
4. Most suitable binder for pellets
5. Most suitable conditions for extrusion feed
6. Effect of preheating air
7. Efficiency of exit gas scrubbing system.

Apparatus and Procedure

Tube Furnace. Ground carbon was placed in a vycor tube which fitted inside a one-inch horizontal tube furnace. The temperature

of the tube was raised to 900 to 1000°C, and air was passed over the carbon. When the electrical power was turned off, it was found that the combustion of the powdered carbon was not self sustaining.

Downdraft Batch Burner. Valuable information was obtained by operating a downdraft batch burner of the type previously used for production salvage operation in this plant. The burner was constructed of 4-inch nickel tubing approximately 12 inches high with a carbon grate near the bottom. A side piece was attached at the bottom through which exhaust fumes passed. Pellets made from the ground carbon were placed on the grate, and air was passed through the bed from the top. Use of this burner showed that combustion could be supported by air alone with no supplementary pure oxygen. It was necessary to pelletize the ground carbon in order to hold it on the grate and allow a sufficient flow of air. From observations made it was believed that an updraft burner would lend itself more readily to continuous operation. Since the carbon could be fed more readily at the top of the burner, an updraft would allow the flame to progress easily to fresh carbon; a downdraft would slow the burning rate since the flame would have to work its way back against the draft in order to ignite fresh carbon.

Updraft Continuous Burner. This apparatus as designed and built is shown in Figure 1. The burner was made of two sections of 4-inch diameter R-monel tubing. The top and bottom sections were 12 and 14 inches long, respectively, and were separated by a nickel grate which could be shaken. Air entered through an inlet pipe below the grate, passed through the carbon bed, and left the top of the burner as carbon

FIGURE 1
CONTINUOUS CARBON BURNER

dioxide and excess air. The bottom of the burner rested in a water bath which continuously overflowed into a Buchner funnel. The bath was provided with an agitator to prevent ash that passed through the grate from settling to the bottom of the container. In actual operation, when only one stage of leaching of ash was required, nitric acid could be continuously added to the overflow container. This was done during only one of the test runs since it was not a major problem of the process. For experimental testing of the burner it was not desirable to accumulate large volumes of acid solutions. The top section of the burner was wrapped completely with 1/4-inch copper tubing which could be used for water or air cooling of the hot portion of the burner. A small, removable window was located at the top of the burner through which the burning operation could be observed. Carbon pellets were screw fed into the top of the burner.

The scrubber system consisted of a gas cooling chamber followed by a steam aspirator which wetted solid particles in the gas stream. The aspirator emptied into a condenser which in turn was followed by a scrubber tower packed with 1/2-inch Raschig rings. Water passing through the scrubber tower was recirculated by a small pump. Condensate from the steam aspirator emptied into the overflow container in which the burner was set.

To operate the burner, cooling water was circulated through the coils of the burner and condensers of the scrubber system. A water seal was made at the bottom of the burner. Carbon pellets with

linseed oil binder were intermixed with wood chips and placed on the grate, half filling the burner. Oxygen was fed slowly through the bottom of the burner as a lighted splint was dropped through the window opening in the top of the burner. A draft was started by turning on the steam ejector; the scrubber pump was started to circulate water through the packing rings. Ordinarily, much smoke was emitted from the exhaust vent after starting up due to the burning of wood. For a few minutes oxygen was kept flowing slowly through the burner until the carbon was heated sufficiently to keep burning; air was then substituted for oxygen. The feed mechanism was set by a variable transmission to feed carbon to the burner continuously at the desired rate.

As the run continued, condensate collecting in the burner overflow was filtered on a Buchner funnel. Some unburnt linseed oil was carried over to the scrubber system and was eventually collected in the burner bath. Occasionally, the grate was shaken to remove ash and aid the combustion inside the burner.

Usually, when the run was completed, there were several small chunks of unburnt carbon mixed with ash and clinkers remaining on the grate. The bulk of the ash had fallen through the grate although some ash was carried into the scrubber system by the flow of air passing through the burner. To determine the amount of residue a run produced, the equipment was cleaned and all solids were combined and weighed. The amount of overflow solution filtered depended upon the length of the run and the rate of the steam ejector. A four-hour run

would yield approximately 12 liters of solution.

Two types of feed mechanisms were used. For feeding pellets, a straight $3/4$ -inch screw with $1/2$ -inch pitch was used. For extruded sticks, a convergent screw from an ordinary meat grinder was used; this was connected to a $3/8$ -inch straight screw inside a $3/8$ -inch pipe. A comparison of the two methods will be given in the discussion of results.

EXPERIMENTAL (Continuous Leacher)

Approach

From laboratory studies on leaching reported in Y-352, it was apparent that a large portion of the uranium in the ground carbon could be put in solution by direct leaching. Still better recovery of uranium could be achieved by leaching precoked carbon. Since the laboratory studies showed that multiple leaching was required to give maximum removal of uranium, it was decided to build and test a continuous countercurrent leacher of the Kennedy type. Although this leacher was of very unconventional design, it could be built and tested rather easily; an evaluation could be made at very little cost and in a short time. Three runs were made (two using ground, precoked carbon and one using ground, untreated carbon, from the calutron units).

Apparatus and Procedure

The countercurrent leacher is shown in Figure 2. The apparatus was built by splitting two pieces of 4-inch stainless steel tubing

FIGURE 2
COUNTERCURRENT LEACHER

lengthwise and welding the edges together to form four troughs, 2 inches deep and 4 inches wide. In each trough a rotating paddle wheel kept solids moving forward; the four paddle wheels were driven in the same direction by a chain and sprocket connection to a variable speed motor. The entire leacher was mounted on a hot plate and held at about 80°C. A slurry of ground carbon was screw fed to the second trough of the leacher. Thus, the first trough acted as a settling section and reduced the amount of solids carried out with the leachings. Nitric acid (35 percent) was pumped into the fourth trough (at the solids overflow end) and passed by gravity through all the troughs and overflowed through a filter (the assembly was tilted so that it was slightly higher on the acid inlet end). Leached solids were pushed out of the leacher at the acid inlet end and collected in a tray.

RESULTS (Continuous Burner)

Operating conditions and results of all burner runs are shown in Table 1. Combustion averaged better than 98 percent complete on all material balance runs. The maximum rate of burning was found to be 500 grams of carbon per hour when the burner was water cooled; this was at an air flow rate of 4 cubic feet per minute. At higher flow rates, large amounts of dust were carried over to the scrubbing system. When air was passed through the cooling coil instead of water, and this preheated air then fed to the burner, the rate of combustion was about 1.7 times that when water cooling and a similar cold air flow rate were

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Table 1

Carbon Burning Data

<u>Run</u>	<u>Weight Charge (g)</u>	<u>Weight Residue (g)</u>	<u>Burning Time (hr.)</u>	<u>Rate of Burning (g/hr.)</u>	<u>Rate of Air Flow (Ft.³/min)</u>	<u>Type and Wt. Ratio of Binder to Carbon</u>	<u>Remarks</u>
1	1200	60	2.5	376	3.0	5 carbon 1 sucrose	Much ash carried into scrubber system.
2	1200	47	2.7	346	2.7	5 carbon 1 sucrose	
3	1970	135	7.5	201	1.1	5 carbon 1 linseed oil	Burning 97.8 % complete.
4	1005	66	4.5	171	1.1	5 carbon 1 linseed oil	Burning 98.2 % complete.
5	1062	58	4.0	207	3.0	5 carbon 1 linseed oil	Burning 99.7 % complete.
6	704	103	0.8	480	See remarks	5 carbon 1 linseed oil	Rate = .6 ft ³ /min first 5 min., changed to 4.0 ft ³ /min.
7	1454	222	2.0	500	4.0	5 carbon 1 linseed oil	This is maximum rate of burning.
8	1113	184	2.0	372	2.0	5 carbon 1 linseed oil	Air was preheated.
9	1710	131	4.5	219	2.0	5 carbon 1 linseed oil	Air was not preheated.

used. However, the practice of air cooling the burner is not recommended since it leads to very high temperatures and considerable oxidation of the metal parts.

Pelletizing

In order to determine a satisfactory method of making pellets for burner feed, a qualitative experiment was made using several types of binding agents. The results are shown in Table 2. Of those binders tested, a linseed oil, water, and carbon mixture gave the best results. The 8 percent linseed oil, 12 percent water, and 80 percent carbon mixture resulted in satisfactory pellets of the lowest possible oil content. Below 8 percent linseed oil, the pellets did not hold together when heated.

Extrusion

Considerable work was done to devise a method of extruding sticks of the ground carbon directly to the burner. This was advantageous in that it eliminated the extra pellet making operation and lend itself more readily to continuous processing. The first test was made in a sand core-making machine in the Y-12 foundry. The same linseed oil, water, carbon mixture was used that gave the best results in pellet making. The sticks formed were very satisfactory for use in the burner. An extruder similar to the core machine was made from an ordinary meat grinder and was attached to the burner for further testing. The extruder consisted of a hopper which fed the ground mixture into a convergent screw which in turn forced the material into a straight screw housed

Table 2Observed Properties of Carbon PelletsUsing Various Binders

<u>Agent for Binding Carbon</u>	<u>Mixture Texture</u>	<u>Resistance to Heat Test*</u>
Water	Poor	Poor
Petroleum oil	Poor	Poor
Glycerine	Fair	Poor
Dextrin + water	Good	Poor
Sucrose + water	Good	Poor
Linseed oil + water	Good	Good
Shellac + water	Good	Poor

* Ability of pellets to withstand two-hour heat test at 900°C without falling apart.

inside a 3/8-inch pipe. A number of tests were made at various oil and water concentrations. The results are shown in Table 3. In general, the adapted meat grinder did not function as well as the core machine; it had a tendency to plug after several hours of operation. However, it is believed that with a standard core machine attached as the burner feed, no trouble would be encountered.

Scrubbing System

Tests made by the Health Physics Group showed that gases passing through the scrubbing system were washed efficiently. The uranium content of the exit gas was found to be essentially the same as that of the air in the room and well below the established chemical toxicity tolerance and radiation tolerance. Results of these tests and extrapolation of the values to enriched material are shown in Table 4. Extrapolated values (calculated by method given in report A-7.390.23) show that the scrubbing system could be used safely with product level material.

RESULTS (Continuous Leacher)

Table 5 shows a tabulation of results from the three runs made in the continuous leacher. The carbon used in runs 1 and 2 was pre-cooked at 1000°C for about two hours; untreated carbon was used for run 3. The amount of uranium put in solution in the first two runs was 96 percent of the total; in run 3 (untreated carbon) only 80 percent

Table 3
Extrusion Tests

<u>Run No.</u>	<u>% Carbon</u>	<u>% Linseed Oil</u>	<u>% Water</u>	<u>Resistance to Heat Test</u>	<u>Extrusion Rating</u>
1	80	8	12	Good	Good
2	67	13	20	Good	Fair
3	67	13	20	Good	Poor
4	65	16	19	Good	Fair
5	62	20	18	Good	Fair
6	84	8	8	Good	Fair
7	81	11	8	Good	Fair
8	71	7	22	Fair	Fair
9	70	0	30	Poor	Poor
10	70	8	22	Fair	Fair
11	69	8	23	Good	Fair

Table 4Samples of Exit Gas from Carbon Burner Scrubbing System

<u>Inlet Air Flow</u> <u>(Ft³/hr.)</u>	<u>Exit Gas Condition</u>		<u>Room Condition</u>	
	<u>Micrograms U</u> <u>per Meter³</u>	<u>Alpha Counts</u> <u>per Meter³</u> <u>per min.</u>	<u>Micrograms U</u> <u>per Meter³</u>	<u>Alpha Counts</u> <u>per Meter³</u> <u>per min.</u>
250	7	10	7	10
66	5	8	5	7

150 micrograms U/Meter³ is chemical toxicity tolerance
 1225 alpha counts/Meter³/min. is radiation tolerance.

Extrapolation to Enriched Material

<u>Material Type</u>	<u>Allowable Concentration</u> <u>in Exit Gases</u> <u>(micrograms U/meter³)</u>
700	150
1000	150
1300	150
1900 (high W)	75 (limited by radiation)

These values were calculated by method given in report A-7.390.23

Table 5

Leacher Data

	Run 1			Run 2			Run 3		
	<u>Wt. or Vol. Material</u>	<u>Wt. U (g)</u>	<u>% of Total U</u>	<u>Wt. or Vol. Material</u>	<u>Wt. U (g)</u>	<u>% of Total U</u>	<u>Wt. or Vol. Material</u>	<u>Wt. U (g)</u>	<u>% of Total U</u>
Carbon Input	2337 g	4.370	100.00	2877 g	5.466	100.00	3500 g	80.41	100.00
Carbon Throughput	533 g	0.046	1.11	1000 g	0.046	0.79	2022 g	13.14	12.79
Carbon Holdup	1799 g	0.108	2.62	1851 g	0.179	3.07	1378 g	5.59	5.44
Carbon Carryover	5 g	0.002	0.05	26 g	0.002	0.03	70 g	1.89	1.84
Acid Input	14200 ml	0.00	0.00	24000 ml	0.00	0.00	18500 ml	0.00	0.00
Acid Throughput	5620 ml	2.53	61.32	13980 ml	3.91	67.19	13000 ml	65.60	63.83
Acid Holdup	6400 ml	1.41	34.17	3940 ml	1.26	21.65	4000 ml	10.90	10.61
Acid Carryover	2160 ml	0.03	0.73	6045 ml	0.42	7.26	1300 ml	5.65	5.50

of the total uranium was put in solution. These values are in good agreement with those obtained from laboratory leaching studies reported in Y-352. The amount of uranium put in solution is interpreted as the sum of acid throughput, acid holdup, and acid carryover shown in Table 5. The amount of material holdup in the leacher was quite high for these short runs (4 to 6 hours), but it is to be understood that the amount would be essentially constant for longer runs and, therefore, a small percentage of the throughput. The main disadvantage encountered in operation of the leacher was the large amounts of liquid carried over with the solid discharge. If further development work were warranted, it would be necessary to redesign the solid discharge end so that the carbon would be thoroughly drained before leaving the leacher. An alternative would be to continuously filter the discharged solids and recycle the acid filtrate.

SUMMARY

The continuous burner was made to operate satisfactorily for the burning of ground carbon which had been pelletized with a linseed oil binder. Tests on extrusion feed indicated that by using a core machine, the ground carbon mixed with linseed oil and water could be continuously fed to the burner in stick form. Combustion in the burner was over 98 percent complete, and the maximum rate of burning was 500 grams of carbon per hour. The scrubbing system efficiently stripped the burner exit gases of uranium.

The continuous carbon leacher was able to remove 96 percent of the uranium from precoked carbon and 80 percent of the uranium from untreated carbon.

Approved

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