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TOPICAL REPORT WIN-53
REMOVAL OF MOLYBDENUM FROM ACID LEACH LIQUORS BY
ACTIVATED CARBON

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TOPICAL REPORT WIN-53

REMOVAL OF MOLYBDENUM FROM ACID LEACH LIQUORS BY ACTIVATED CARBON

by

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July 29, 1958

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ABSTRACT

Data are presented on the adsorption of molybdenum on activated carbon. The effect of retention time and linear flow on adsorption, the use of sodium hydroxide as an eluant, and the possibility of recovering molybdenum from the caustic eluate are discussed.

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INTRODUCTION

Molybdenum is preferentially adsorbed by strong base anion resins resulting in a decrease in the adsorption rate of uranium. Since adsorbed molybdenum is not completely removed from the resin by a normal elution procedure, cyclic operation results in a cumulative poisoning of the resin. Eventually the molybdenum concentration on the resin becomes such that uranium ion exchange is very inefficient.

Molybdenum is also troublesome in solvent extraction. It reacts with some of the amines to form insoluble precipitates and cannot be stripped completely from amine solvents with acidified chloride or nitrate solutions. If an amine solvent is used to recover uranium from leach liquors containing molybdenum, part or all of the solvent stream must be treated with carbonate or hydroxide to strip the molybdenum, thereby adding to the cost of uranium recovery. Molybdenum is also extracted by the alkyl phosphates and is stripped along with the uranium by carbonate solutions.

The first instance of serious ion exchange difficulties that could be traced to molybdenum was experienced on a sample of Vitro leach liquor. Schiff (1,2), discussed the effect of molybdenum and the use of either a periodic caustic regeneration of fouled resin, or the use of a charcoal scavenger column.

In a later report issued by this laboratory, Quinlan (3) shows that small quantities of either chloride or nitrate in dilute solution of either sodium or ammonium hydroxide are excellent eluants for molybdenum on strong base anion resins.

There are essentially three approaches to solving the problem of resin poisoning from molybdenum adsorption:

1. The uranium ore may be leached under such conditions that only a small fraction of the molybdenum will report in the pregnant solution. A discussion of a leaching procedure which will accomplish this is presented by Magno in WIN-48 (4). The effect of various modifications of two-stage leaching procedures on the distribution of molybdenum between pregnant solution and residue is also discussed in WIN-54 (5), WIN-81 (6), and WIN-105 (7).

2. The molybdenum may be removed from the pregnant leach liquor by chemical precipitation. The simplest method is to precipitate the molybdenum as a sulfide but the relatively low concentration of molybdenum present as well as the cost of the operation have weighed against its use.

3. A more promising approach is the use of activated carbon to selectively adsorb molybdenum ahead of the uranium recovery circuit. Solutions of four to six per cent NaOH are used for carbon regeneration.

The results of the study on the third system is the subject of this report. Considerable work was done with activated carbon in conjunction with the laboratory investigation of lignite ores. The data in WIN-54 show that either agitation with carbon powder or the use of granular char in columns will effectively remove both molybdenum and soluble organic materials from acid leach liquors.

SUMMARY AND CONCLUSIONS

An investigation into the use of activated vegetable char to remove molybdenum from uranium leach liquors prior to the recovery of uranium by ion exchange or solvent extraction was conducted. Such a step could be useful as molybdenum interferes with the efficiency of uranium recovery by either procedure.

Both batch contacts and tests in columns were made and it may be concluded that a practical process involving the repeated use of char is possible. Although due to slow adsorption rates rather large inventories of adsorbents would be required.

Elution of the molybdenum was obtained with various strength of NaOH solution, but concentrations above four per cent were unnecessary. By separating the first ten of the total twenty bed volumes, an eluant assaying 18 grams Mo per liter was obtained. When two times the stoichiometric amount of CaCl_2 necessary to form calcium molybdate was added, a precipitate assaying 36 per cent Mo was produced. Precipitates were made at various hydrogen ion concentrations by adjusting with HCl. Results were 99+ per cent precipitation over the range pH 6 to 10.

ACTIVATED CARBON

Activated carbon may be visualized as a solid foam, that is, a large surface within a rigid granular structure of relatively small volume. Such a structure may be achieved by heating or chemically treating organic matter, preferably of cellular structure such as woody products or bone. Activation by means of heat is essentially a process of destructive distillation whereby a portion of the material is driven off in the form of volatile products leaving a carbonaceous residue with a large volume of internal voids. Chemical activation may be accomplished by treatment of suitable chars with zinc chloride or phosphoric acid. Chemical activation is usually supplemented by heat treatment.

Classified as to type of raw material used in their production, carbons suitable for adsorption from solution may be divided into carbons of animal origin, commonly designated as bone char, and carbons of vegetable origin. Vegetable chars are usually made from lignite, wood charcoal, or the black ash residue which is a by-product of paper manufacture. Vegetable chars were the only type used in this investigation.

Charcoal has been applied to many processes involving the adsorption of materials from solution. Activated carbon has found extensive usage in the sugar, alcohol, and electroplating industries. Its application to the recovery of gold and silver values from dilute cyanide solutions is probably the best known adaptation to hydrometallurgy.

A. Column Adsorption of Molybdenum from Edgemont Leach Liquors with Activated Carbon

Encouraging results were obtained on the removal of molybdenum from acid leach liquors by adsorption on an activated carbon bed. Test work was done using an Edgemont leach solution which was "spiked" with molybdenum. The leach liquor used in the test work assayed as follows:

<u>Constituent</u>	<u>Grams/Liter</u>
U ₃ O ₈	0.62
Mo ⁺⁺⁺	0.133
Fe ⁺⁺⁺	0.22
Total Fe	0.46
SO ₄	8.1
V ₂ O ₅	0.29

The investigation was carried out on both untreated and reduced liquor. The leach liquor was run through a one-half inch diameter column containing 25 ml of Permutit Carbo-Dur, an activated charcoal, at an exhaustion retention time of three minutes. The columns were operated to a cut-off point of 0.01 gram molybdenum per liter in the effluent on the assumption that molybdenum concentrations below 0.01 gram per liter would not influence uranium ion exchange to any great extent. Elution of the partially loaded charcoal was accomplished with six per cent NaOH followed by an acid wash. Approximately 95 per cent of the molybdenum was eluted in five bed volumes.

It was felt that reducing the liquor to an emf of minus 180 mv (pt. vs SCE), or below, with metallic iron and forming colloidal molybdenum blue might complex the molybdenum in such a manner that it would be more readily adsorbed on the charcoal. The results presented in Tables 1 and 2 indicate that to some extent this is true. Breakthrough occurred at approximately 135 bed volumes using unreduced liquor and 185 bed volumes with the reduced solution. After 195 bed volumes, molybdenum adsorptions were 80.5 per cent and 90.3 per cent for the untreated and the reduced liquors, respectively, based on effluent assays. Total uranium adsorption is negligible when considered over an entire loading cycle. Approximately three per cent of the uranium is adsorbed from the first few bed volumes with little or no adsorption taking place after passing 10 bed volumes through the column.

B. Column Adsorption of Molybdenum from North Dakota Lignite Leach Liquors with Activated Carbon

A test was made on Peter Kiewit Lignite leach solution (WIN-54-Sample 185-8). The pregnant liquor had a pH of 1.25, an emf of minus 295 mv (pt. vs SCE), and assayed as follows:

<u>Constituent</u>	<u>Grams/Liter</u>
U ₃ O ₈	1.12
Mo ⁼	0.141
SO ₄ ⁼	140.6
Total Fe	22.4

Table 1

Charcoal Adsorption of Molybdenum-Untreated Liquor

<u>Bed Volume</u>	<u>Effluent Assay</u>		<u>% Adsorption</u>	
	<u>Grams/Liter</u>			
	<u>U₃O₈</u>	<u>Mo</u>	<u>U₃O₈</u>	<u>Mo</u>
5	0.51	0.001	17.8	99.2 ⁺
10	0.61	0.001	1.6	99.2 ⁺
11 thru 60	0.62	0.001	Nil	99.2 ⁺
65	0.62	0.004	Nil	97.0
80	0.62	0.005	Nil	96.3
130	0.62	0.006	Nil	95.5
135	0.62	0.009	Nil	93.3
180	0.62	0.014	Nil	89.5
195	0.62	0.026	Nil	80.5

Table 2

Charcoal Adsorption of Molybdenum-Reduced Liquor

<u>Bed Volume</u>	<u>Effluent Assay</u>		<u>% Adsorption</u>	
	<u>Grams/Liter</u>			
	<u>U₃O₈</u>	<u>Mo</u>	<u>U₃O₈</u>	<u>Mo</u>
5	0.48	0.001	22.6	99.2 ⁺
10	0.62	0.001	Nil	99.2 ⁺
11 thru 60	0.62	0.001	Nil	99.2 ⁺
65	0.62	0.002	Nil	99.5 ⁺
110	0.62	0.003	Nil	97.7
165	0.62	0.005	Nil	96.3
180	0.62	0.006	Nil	95.5
195	0.62	0.013	Nil	90.3

The leach liquor was run through two, one-half inch diameter glass columns connected in series. Each column contained 25 ml of wet-settled Permutit Carbo-Dur, an activated carbon. A total of 185 bed volumes of solution was passed through the system at a six-minute retention time before the cut-off value of 0.01 gram per liter of molybdenum was reached in the second column effluent. The first column was eluted with six per cent NaOH followed by an acid wash. Loadings on this column were 20.7 grams of Mo per liter of wet-settled carbon. Higher loadings have been obtained on other leach liquors. In this instance, however, the high iron content of the liquor appears to be responsible for the lower molybdenum values since both ions are adsorbed by the carbon.

In order to obtain uranium loading and elution characteristics of a molybdenum-free Dakota Lignite leach liquor, two cycles were run on IRA-400 resin using the effluent from the carbon columns. The results are presented in Table 3. Uranium breakthrough occurred after 20 bed volumes in the first cycle and approximately at the same point in the second cycle. Saturation loadings were respectively 46.2 and 50.3 grams of U_3O_8 per liter of wet-settled resin. Rapid breakthrough and low loadings were probably due to the high concentration of SO_4 in the feed.

Table 3

Ion Exchange of Treated Lignite Leach Liquor

Cycle	Bed Volumes To:			Loading at Uranium Saturation g U_3O_8 /l WSR
	<u>Breakthrough</u>	<u>Exhaustion</u>	<u>Elution</u>	
1	20	80	7	46.2
2	18	76	7	50.3

C. Column Adsorption of Molybdenum from Hidden Splendor Leach Liquor

Fifteen kilograms of ore from the Hidden Splendor mine were leached at ambient temperature, 50 per cent solids, and 300 pounds of H_2SO_4 per ton of feed for 18 hours. The pregnant liquor was diluted four to one with water. A partial chemical analysis of the feed is shown in Table 4.

Table 4

Chemical Analysis
Hidden Splendor Leach Liquor

<u>Constituent</u>	<u>Grams/Liter</u>
U ₃ O ₈	0.79
Mo	0.15
Al ₂ O ₃	0.10
Total Fe	1.48
Fe ⁺⁺	1.06
Fe ⁺⁺⁺	0.42
SO ₄ ⁼	25.3
pH	0.5
Emf (mv)	-400

The pregnant solution was run through a series of two, one-half inch diameter glass columns containing 25 ml of wet-settled Columbia brand activated carbon. Retention times in the carbon bed were three minutes and 10 minutes on exhaustion and elution, respectively. Linear flow of pregnant leach liquor was about 0.6 gallon per square foot per minute. Six per cent NaOH was used as an eluant for the carbon columns. Leach liquor was passed through the columns until the effluent from the second column reached a cut-off value of approximately 10 per cent of the molybdenum in the pregnant liquor. Column No. 1 was then eluted and placed at the end of the circuit. The data are presented in Table 5.

Table 5

Molybdenum Loading and Elution of Carbon Columns

<u>Cycle</u>	<u>Bed Volumes</u>		<u>Loading</u>	<u>Equivalent</u>
	<u>Cut-off</u>	<u>Elution^{1/}</u>	<u>g Mo/l</u> <u>W.S. Carbon</u>	
1	452	10	52.5	4.5
2	448	10	51.9	4.5
3	448	10	56.4	4.5

^{1/} Better than 90 per cent elution of molybdenum was obtained in three bed volumes.

RETENTION TIME VERSUS LINEAR FLOW

It has been common practice in this laboratory when conducting columnar ion exchange tests for uranium recovery to use a solution retention time with the resin of from three to five minutes regardless of the bed dimensions. Scale-up from the bench column size of about one-half inch diameter containing 25 ml of wet-settled resin to the pilot plant column of two-inch diameter containing two liters of wet-settled resin usually results in no change in operating efficiency as a result of increased linear flow velocity. However, when this approach was adopted to test activated carbon for molybdenum recovery, very rapid breakthrough was experienced during the scale-up test at the same retention time used in the smaller and shallower bed.

It should be pointed out that no attempt was made to determine either the optimum volume of sodium hydroxide nor the number of contacts required for regeneration. Previous experience had shown that the volumes used were effective, but they are not necessarily the most economically efficient.

It was determined that five grams of dry carbon are equivalent to 13 ml of wet-settled carbon. At the conclusion of the test, the volume had been reduced to 11.25 ml of wet-settled carbon. This represents a loss of 13.5 per cent which is probably due to fines in the carbon.

At the same solution retention time, based on 40 per cent voids, a five-fold variation in the cross-sectional flowrate existed between the two columns tested.

This variation of linear flowrate had no effect at the retention times commonly used in uranium ion exchange, probably because of the rapid rate of the exchange reaction. In the carbon system the molybdenum is probably physically adsorbed and this requires a somewhat longer period for the active sites to participate.

Two tests were made on two-inch columns, each containing two liters of wet-settled activated carbon. The feed used was obtained by adding sodium molybdate to a sample of Lakeview leach liquor. The liquor, after being spiked, assayed about 0.1 gram Mo per liter.

Table 6Effect of Retention Time on Molybdenum Recovery in a Two-Inch
Diameter Column

<u>Column A</u>			<u>Column B</u>		
<u>Head</u> <u>g Mo/l</u>	<u>Bed</u> <u>Volumes</u>	<u>Effluent</u> <u>g Mo/l</u>	<u>Head</u> <u>g Mo/l</u>	<u>Bed</u> <u>Volumes</u>	<u>Effluent</u> <u>g Mo/l</u>
0.11	10.2	0.001	0.11	10.99	0.001
0.11	26.85	0.005	0.057	25.27	0.001
0.11	51.39	0.006	0.066	52.30	0.003
0.11	76.77	0.007	0.066	76.20	0.001
0.057	102.57	0.006	0.066	106.97	0.002
0.057	136.44	0.007	0.063	139.53	0.003
0.057	178.5	0.010	0.063	173.04	0.003
0.066	203.88	0.015		205.0	0.003
				246.0	0.008
				252.47	0.010

	<u>Column A</u>	<u>Column B</u>
Throughput, Liters	420.22	507.64
Average Flowrate, ml/min.	280	45.8
Retention Time, min.	2.86	17.45
GPM/ft. ²	3.39	0.56
Mo Tail, g/l (average)	0.007	0.003
Calc. Loading g/l WSC	20.975	28.66

In the first test, the data from which is shown in Table 6, Column A was operated at a retention time of about three minutes, giving a cross-sectional flowrate of over three gallons per minute per square foot.

The second test was run on Column B at a cross-sectional flow-rate of about 0.6 gallons per minute per square foot which is that flow required in a one-half inch column for a three-minute retention time.

The data indicate that leakage occurs from Column A even though the cut-off value of 0.01 gram of Mo per liter was not reached until 178 bed volumes of solution had passed through the column.

In contrast, Column B exhibits a fairly steady adsorption of molybdenum and then a sharp rise to the cut-off value. The data from Column B are what would be expected from a one-half inch bench column operating at a three-minute retention time or a cross-sectional flow rate of 0.6 gallons per minute per square foot. Linear flow is therefore a more critical factor in carbon column design than the solution retention time.

CARBON ELUTION STUDIES

A two-inch column containing two liters of Columbia Brand activated carbon was operated to saturation with respect to a molybdenum solution containing about 0.1 gram Mo per liter. The carbon was removed from the column and reserved for elution studies.

The test work was done by introducing 25 ml of wet-settled carbon into a half-inch glass column and then eluting with solutions of sodium hydroxide of variable concentration. The retention time used for elution was 10 minutes. Composite samples of the effluent were taken every bed volume (25 ml) and assayed for molybdenum. The elution was considered complete when a molybdenum spot test* showed negligible molybdenum in the effluent. As an added precaution several more bed volumes of sodium hydroxide were passed over the bed and assayed as a composite sample. The carbon was then dried at 110°C and assayed for molybdenum. The dry carbon averaged about 10 grams in weight and averaged about 0.1 per cent molybdenum.

The test results from four elutions performed, as described above, are shown in Table 7. Four similar tests in which 0.3M Cl^- was added to the caustic gave the same results, indicating that the presence of chloride ion is not beneficial at the caustic concentrations used. A plot of the elution is shown in Figure 1.

The data indicate that, for practical purposes, it is not worthwhile to use a higher caustic concentration than four per cent.

A separate test was made in which a two-inch column containing two liters of carbon was loaded to saturation with respect to a solution containing 0.1 gram per liter Mo.

*Place a drop of sample on a porcelain spot plate. Add a drop or two of 10 per cent hydrochloric acid solution, a drop of ferric sulfate solution (50 g $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ /liter) followed by a drop of potassium thiocyanate solution (50 g KSCN /liter). A blood red color will develop. A drop or two of stannous chloride (350 g $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ /liter), will reduce the iron and destroy the iron thiocyanate color. The color remaining is due to the presence of the molybdenum thiocyanate complex. Standard molybdenum solutions may be used for comparison.

Table 7

Elution of Molybdenum from Columbia Activated Carbon with
Varying Concentrations of Sodium Hydroxide

Bed Volumes	<u>1% NaOH</u>		<u>2% NaOH</u>		<u>4% NaOH</u>		<u>6% NaOH</u>	
	<u>%</u> Eluted	<u>g Mo/l</u>	<u>%</u> Eluted	<u>g Mo/l</u>	<u>%</u> Eluted	<u>g Mo/l</u>	<u>%</u> Eluted	<u>g Mo/l</u>
1	0.73	0.624	1.22	1.09	1.67	1.45	7.67	6.44
2	6.34	4.74	18.72	15.6	33.55	27.6	59.34	43.4
3	18.90	10.6	41.94	20.7	67.97	29.8	94.58	29.6
4	31.57	10.7	65.15	20.7	92.11	20.9	97.16	2.17
5	44.48	10.9	84.78	17.5	95.97	3.34	98.10	0.785
6	57.27	10.8	93.59	7.85	97.44	1.27	98.56	0.388
7	70.09	10.8	95.99	2.15	98.04	0.542	98.84	0.238
8	80.87	9.1	96.85	0.76	98.44	0.327	99.06	0.181
9	89.11	6.96	97.50	0.58				
10	93.50	3.7	97.98	0.429				
11	95.46	1.66	98.34	0.318				
12	96.49	0.873	98.63	0.255				
13	97.19	0.588	98.86	0.217				
14	97.72	0.446	99.06	0.171				
15	98.14	0.357	99.23	0.155				

Loading, 84.44
g Mo/l
WSC

89.16

86.58

83.99

Average - 86.04 g Mo/l WSC

The two-inch column was then eluted with 10 bed volumes of 4 per cent NaOH with the first five bed volumes and second five bed volumes composited separately. The first composite assayed 17.9 grams Mo per liter and the second fraction assayed 1.03 gram Mo per liter.

Another two-inch column was loaded as above and the elution was started using the second half of the eluate from the first test as a recycle. The last five bed volumes used were fresh four per cent sodium hydroxide. It is worth noting that the recycle fraction assayed 38 grams of NaOH per liter as against its original concentration of 41 grams of NaOH per liter.

The test data, as shown in Table 8, indicate very efficient elution. It can be seen that if it were desired a three-way split would result in a higher grade eluate than the 18 grams of Mo per liter obtained.

Table 8

Elution of Molybdenum from Carbon with Recycle Eluate

<u>Bed Volumes</u>	<u>Effluent</u>		<u>Total Grams Mo</u>	<u>% Elution</u>
	<u>g Mo/l</u>	<u>Grams Mo</u>		
1	12.3	24.6	24.6	14.2
2	36.9	73.8	98.4	56.8
3	30.0	60.0	158.4	91.4
4	2.80	5.6	164.0	94.6
5 ^{1/}	1.84	3.68	167.68	96.7
6 ^{1/}	0.841	1.68	169.36	97.7
7	0.361	0.72	170.08	98.1
8	0.322	0.64	170.7	98.5
9	1.23 ^{2/}	2.46	173.18	99.9
10	0.062	0.12	173.3	100

^{1/} Fresh eluate introduced.

^{2/} Column stood overnight.

First five bed volume composite	-	18.3 g Mo/l
Second five bed volume composite	-	0.609 g Mo/l

MOLYBDENUM PRECIPITATION FROM NaOH ELUATE

A preliminary investigation was made into the possibility of recovering molybdenum from an eluate obtained by a caustic elution of activated carbon. The carbon had been used to adsorb molybdenum from an acid leach liquor after which it was regenerated by a treatment with four per cent sodium hydroxide solution. Ten bed volumes of eluant were used with the first five bed volumes being composited and used in this study. The composite eluate assayed about 15 grams of NaOH per liter and 18 grams of Mo per liter.

The test work was performed by taking a 500-ml sample of the composite eluate, adjusting the pH to the desired value with HCl, and then adding calcium chloride as a solid to the solution. The suspension was stirred for one hour, filtered on a Buchner funnel, and the precipitate washed with 100 ml of a 0.75 per cent CaCl_2 solution. The filtrate was assayed in all cases, and the precipitates only as shown in the Table. The test data are shown in Table 9.

The reaction was assumed to be:

which indicates that the stoichiometric amount of CaCl_2 required to precipitate the 9 grams of Mo present in the sample was 13.8 grams.

Table 9

Effect of pH on the Precipitation of Molybdenum from NaOH Eluate with Varying Concentrations of CaCl_2

pH	% of Stoichiometric Amount of CaCl_2	g HCl/l	g CaCl_2 /l	Filtrate g Mo/l	% Ppt.	Ppt. % Mo
6	71	-	19.5	1.6	91.1	-
6	140	-	39.0	0.28	98.5	-
7	71	-	19.5	1.6	91.1	-
7	140	-	39.0	0.10	99.5	-
8	71	13.4	19.5	1.49	91.7	38.0
8	98	13.4	29.0	0.32	98.2	36.6
8	140	13.4	39.0	0.09	99.5	-
9	71	12.4	19.5	4.12	77.1	36.0
9	140	12.4	39.0	0.14	99.3	35.0
10	71	11.2	19.5	5.02	72.1	35.3
10	140	11.2	39.0	0.049	99.7	34.5

The data indicate that an excellent recovery of molybdenum from the test solution was possible, although the grade of the molybdenum precipitate is lower than what would be expected in a pure calcium molybdate (48 per cent Mo).

BATCH ADSORPTION STUDIES

A. Comparison of Powdered and Granular Carbons

The data shown in the column adsorption section indicate good molybdenum recovery and molybdenum loading. However, since the rate of molybdenum adsorption with carbon is low when compared to uranium adsorption on resin, a considerable inventory of carbon would be required to purify the feed for ion exchange or solvent extraction in a mill.

A cursory study of agitation methods to secure adsorption on carbon was made in order to determine if it would be possible to obtain a suitable feed for either a solvent extraction or ion exchange circuit. An agitation system could have the advantage of sharply reducing the carbon inventory required but might have the disadvantage of giving a low-grade eluate for molybdenum precipitation.

Plant operation was visualized as consisting of countercurrent contacts in tanks with the char being screened between tanks. The first test was made using a 15-minute contact time and varying the quantity of carbon. A liter of Mesa Top leach liquor containing 0.097 gram Mo per liter was used for each contact. Since a solid-liquid separation using a screen was anticipated, the powdered carbon was used as a base of comparison only. The data as shown in Table 10 indicate that if 0.01 gram Mo per liter is considered as a cut-off point that somewhat more than 4 grams of coarse carbon per liter are needed to clean up the liquor in a single 15-minute contact. Adsorption on the fine carbon was more rapid indicating that the rate depends on surface area and diffusion.

Table 10

Comparison of Coarse and Powdered Carbon

<u>Gram Carbon</u>	<u>Assays Gram Per Liter Mo in Solution</u>	
	<u>Darco S-51</u>	<u>Columbia Brand Carbon</u>
	<u>Powdered Carbon</u>	<u>20/48 mesh</u>
1	0.027	0.06
4	0.005	0.037
16	0.002	0.007

B. Effect of Time

The second test considered the effect of time on adsorption of molybdenum. Using 4 grams charcoal per liter of solution. The data shown in Table 11 indicate continual adsorption at a slow rate during the test period.

Table 11

Effect of Time on Molybdenum Adsorption Columbia Brand Carbon 20/48 Mesh

<u>Time</u>	<u>G/l Mo Solution</u>	<u>% Adsorbed</u>
0	0.097	0
15	0.039	59.8
30	0.034	64.9
60	0.025	74.2
120	0.013	86.6

C. Effect of Repeated Contacts

In another test sixteen grams of coarse carbon were contacted for 30 minutes with a liter of leach liquor containing 0.046 gram Mo per liter. The carbon and solution were separated by screening and the carbon recontacted with a fresh batch of liquor. The process was repeated six times. The data as shown in Table 12 indicate that under the test conditions it was possible to treat six batches of liquor with carbon before carbon regeneration was required.

Table 12

Effect of Repeated Batch Contacts of Carbon and Liquor Columbia Brand Carbon 20/48 Mesh

<u>Contact</u>	<u>Solution, g/l Mo</u>
1	0.003
2	0.004
3	0.005
4	0.007
5	0.008
6	0.011

Fig. 2. Successive Contacts on One Carbon Sample

D. Cyclic Testing

A cyclic test to determine if there is a loss of efficiency with repeated adsorption and regeneration procedures was made.

Five grams of dry carbon (Columbia Brand 20/48 mesh) was used in a contact with 1000 ml of solution which assayed 0.097 gram Mo per liter. Solid-liquid separation was made on a 65-mesh screen. During the day the contact time used was 30 minutes but occasional 16-hour contacts were made overnight. Regeneration was effected by three batch contacts with 100 ml of four per cent sodium hydroxide used in each contact. A fourth contact of 100 ml of 0.1N sulfuric acid was made before the carbon was used again in an adsorption cycle. The contact time during regeneration was 15 minutes for each contact.

The test data are plotted in Figure 2. The upper curve exhibits a sharp drop in efficiency over the first few cycles after which it tends to level out. The initial change in the curve is probably due to the loss of carbon which undoubtedly occurs at the start of the test.

The curve obtained for the 16-hour contacts which may be considered to be an equilibrium curve points out the poor adsorption rate obtained with carbon as compared to that when uranium is adsorbed on resin. Under comparable test conditions in a uranium system the two curves would be much closer together.

Figure 2 confirms the data obtained in the study of linear flowrate where it was shown that under the test conditions it was most important to allow ample contact time between carbon and solution.

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