CANADA

EFFECT ON REAGENT CONSUMPTION OF RECYCLING SOLUTIONS IN THE WEAK ACID LEACHING OF A URANIUM ORE

by

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V. M. McNamara* and W. A. Gow**

ABSTRACT

An investigation was carried out to study the possibility of reducing the acid requirements in the leaching of uranium ores at controlled pH, by recycling a portion of the leach liquor as make-up solution with fresh ore. The work was carried out on a laboratory scale on a siliceous ore. Ore fineness, and quantity of oxidizing agent (sodium chlorate) added, were the two variables investigated. Acid consumption at pH 1.8 was reduced from 44.2 pounds per ton for the standard leach without recycling to 38.7 pounds per ton with recycling when the ore was ground to 75-80 percent minus 200 mesh, and, in the same comparison, from 37.3 pounds per ton to 29.7 pounds per ton when the ore was ground to 40-50 percent minus 200 mesh. Recycling also permitted a reduction of the amount of sodium chlorate required, for satisfactory leaching, from 3.0 to 1.5 pounds per ton. However, reducing the sodium chlorate reduced the amount of acid saved by recycling. Recycling had no significant effect on the amount of uranium extracted.

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(20 pages, 6 tables, 6 figures)

INTRODUCTION

In the treatment of brannerite-bearing uranium ores from the Blind River area[1], pilot plant studies have shown that, by employing a recycling type of leach circuit, it is possible to obtain a reduction in acid consumption in the order of 40 pounds of sulphuric acid per ton of ore. For brannerite ores, a higher acidity is required than in the sulphuric acid leaching of pitchblende and uraninite ores. Also, the free acidity of the solution leaving the leach circuit, under Blind River conditions, is in the range of 30 to 50 grams of sulphuric acid per litre.

The recycle flowsheet used on these brannerite ores, as shown in Figure 1, is based on the filtering of the leach pulp and the return of all of the filtrate to the leach circuit. The only solution leaving the leach circuit is that which is present as moisture in the filter cake. This is removed as pregnant solution after repulping the filter cake and then performing a conventional type of liquid-solid separation with washing of the solids.

The results obtained on Blind River ores raised the question of how this recycling system might work out if applied to the treatment of an ore which can be treated by acid leaching at controlled pH. This type of leach results in a leach solution which contains 5 grams of sulphuric acid or less per litre at the end of the leach.

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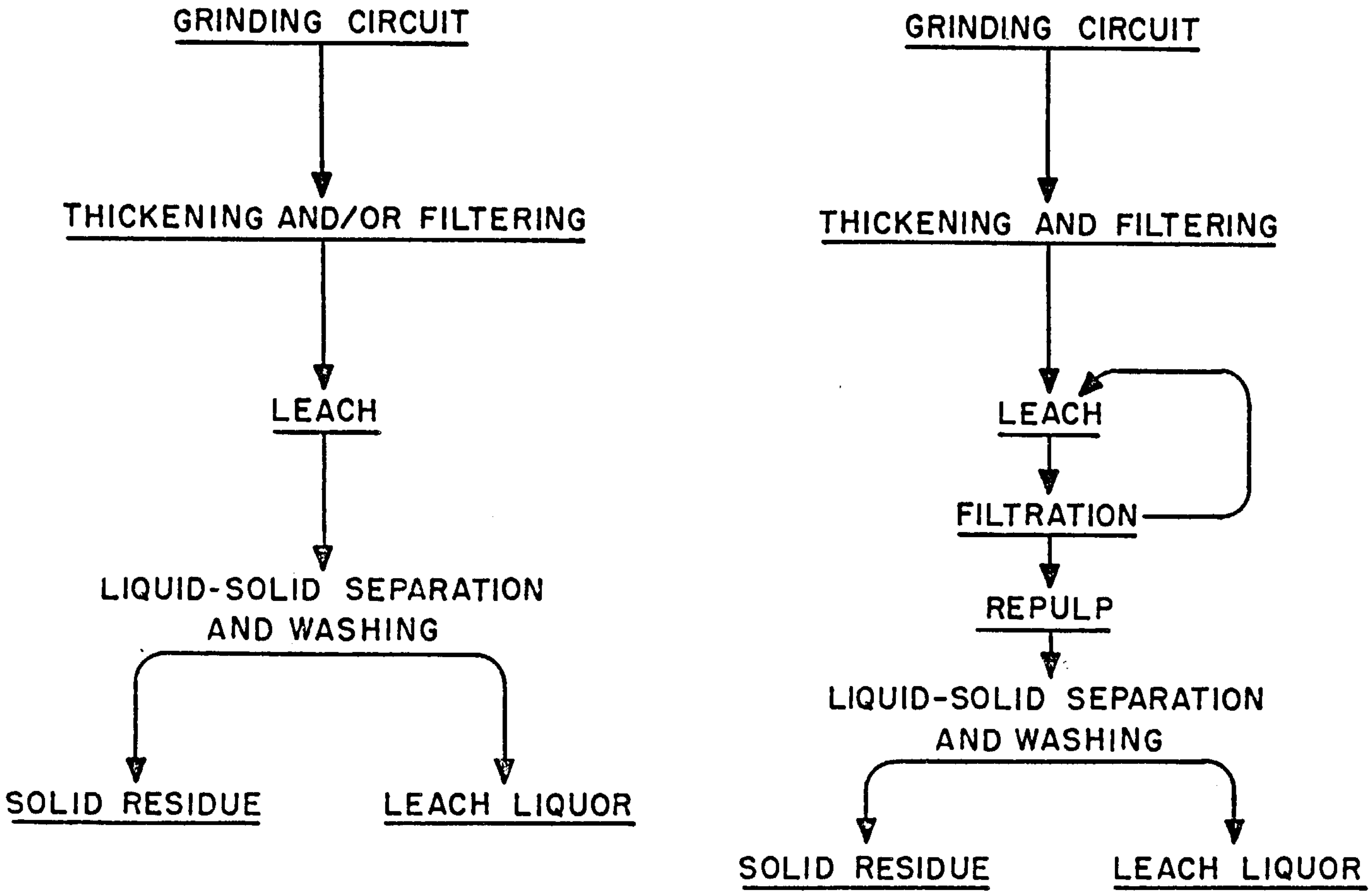
(1) See references on page 17.

FIGURE I



STRAIGHT LEACH FLOWSHEET

RECYCLE FLOWSHEET

Consequently, laboratory tests were made on an ore from a plant where acid leaching at controlled pH is employed and where the cost of acid is comparatively high due to high transportation costs. The material treated (Radioactivity Division Sample No. 8/56-4) was a fine-grained siliceous rock, composed mainly of quartz with some feldspar, containing finely disseminated pitchblende as well as hematite, calcite, chlorite, epidote, and pyroxene.

The highlights of this report were presented to the 1958 United Nations International Conference on the Peaceful Uses of Atomic Energy[2].

TEST PROCEDURE

The leach tests, in this investigation, were done using 1000-gram (dry basis) batches of ore. Immediately prior to leaching, 1150 grams of dry ore, crushed to minus 10 mesh, was ground in an Abbe porcelain mill with 500 millilitres of water and 20 pounds of steel balls. After grinding, the pulp from the mill was filtered, and 150 grams (dry basis) of the filter cake was then taken for screen analysis, leach feed assay and moisture determination. The remaining 1000 grams of ground sample was leached.

Leaching was carried out at room temperature, in a 1500-millilitre glass beaker, with mechanical stirring, using a glass, marine-type impeller. All the recycle solution from the previous leach was added to the moist, ground sample. Additional water was added to the leach so that, when the acid required for the leach was introduced, the final pulp density would be 57 percent solids (solids/liquid=4/3).

Solid sodium chlorate was added in the required quantity at the beginning of the leach. The pH was recorded, automatically, by a Beckman pH meter with a Brown "Electronik" panel which controlled the sulphuric acid addition to maintain the pH constant at 1.8. Sulphuric acid was added as a solution containing 1 gram H_2SO_4 per millilitre. Sampling was kept to a minimum.

Each leach was filtered after 48 hours and the leach filtrate retained for recycling. The residue filter cake was then washed and the wash filtrate formed the pregnant solution. The wash consisted of two 250-millilitre volumes of 1/4 percent H_2SO_4, followed by one 250-millilitre water wash. Since there seemed to be some possibility of inadequate washing when metal values in the solution became high, an extra 250-millilitre water wash was put through the residue filter cake. The uranium assays of this extra wash have been recorded. In this work the fourth filter cake wash was not added to the pregnant solution. This could be done to give a total wash equal to the weight of the dry ore.

The progress of the recycle leaching was followed by obtaining solution assays for uranium and iron in the recycled first filtrate and in the pregnant solution (wash filtrate). With each change in variables, sufficient recycling leaches were run in series to indicate that a reasonably constant operation was obtained, as evidenced by a levelling off of solution assays.

The variables that were studied in order to obtain the most efficient leaching conditions were the ore fineness and the quantity of sodium chlorate added to the leach. A number of standard batch leaches without recycling were run to give an adequate basis for comparison with usual leach practice. A total of 82 leaches, including the control leaches, was done.

RESULTS AND DISCUSSION

In treating ore that was ground to 75-80 percent minus 200 mesh, and using 3 pounds of sodium chlorate per ton as oxidizing agent, a standard leach, without recycling, averaged 44.2 pounds of sulphuric acid consumed per ton ore. The same leaching conditions, along with the recycling technique, resulted in an acid consumption averaging 38.7 pounds per ton. The acid saving is 12.5 percent, with no appreciable difference in uranium extraction (Table 1).

When the ore grind was coarser (40 to 50 percent minus 200 mesh) and 3 pounds of sodium chlorate per ton was added, a standard leach without recycle consumed 37.3 pounds of acid per ton of ore. The recycle series settled down to 29.7 pounds per ton, a saving of about 20.5 percent of the acid; again with no appreciable difference in extraction. Similarly, the acid saving due to recycling, when using 2.25 pound sodium chlorate, is 17 percent, and when using 1.5 pound sodium chlorate, is 18 percent.

Table 1 also indicates that in the recycling system it was possible to reduce the amount of oxidizing agent required by 50 percent

TABLE 1

Averaged Test Data
Acid Consumption:Percent Extraction

	Test Number	Ore Grind (%-200 M)	$NaClO_3$ (lb/ton)	Acid Consumption (lb H_2SO_4/ton ore)	Residue Assay (% U_3O_8)	U_3O_8 Extraction (%)
Control Batches	1, 2	75-80	3	44.2	0.013	97.0
Recycle System	9-14, 21-28	"	3	38.7	0.010	97.6
	30-34	"	1.5	40.4	0.010	97.4
	16-19	"	Nil	46.6	0.079	80.1
	19	"	Nil	46.3	0.10	75.0
Control Batches	41, 64, 65	50-55	3	41.1	0.012	97.4
Control Batches	66-70	40-50	3	37.3	0.016	96.6
	71-79	"	2.25	39.3	0.014	96.4
	80-82	"	1.5	40.5	0.018	95.4
Recycle System	36-40, 42-45	"	3	29.7	0.015	96.4
	57-63	"	2.25	32.6	0.015	96.6
	49-55	"	1.5	33.2	0.016	96.2

Notes:

(a) The results of the test immediately following a change in a variable are excluded.

(b) Grinding times: 75-80% minus 200 m = 35 min
50-55% minus 200 m = 21 min
40-50% minus 200 m = 19 min

with no apparent adverse effect on extraction. Recycling did not eliminate the need for oxidizing agent. When the oxidizing agent was omitted, extraction dropped off from 97.6 percent to 75 percent, in five cycles, as shown in Table 1.

It is evident from this work that a recycle system would permit a saving of either 5 1/2 to 7 1/2 pounds of acid per ton, or a saving of 4 to 5 pounds of acid and 1.5 pounds of sodium chlorate per ton.

Although the ore used in this study was from an area where reagent cost is relatively high, the saving made possible by recycling would be largely offset by the cost of an added filtration step and would be of borderline interest.

However, the recycle system may show to better advantage if applied to the treatment of an ore which involves higher acid consumption.

Figures 2, 3, and 4 indicate the trend of the recycle leaching as the two variables (i.e. ore fineness and sodium chlorate addition) were changed. The results of two standard control leaches, at fine and coarse grinds (Cycles 1 and 41 respectively), are also shown by these figures. Tables 5 and 6 (Appendix) present all test data in detail. It may be noted that the uranium concentration increased gradually, during 60 recycling leaches, to a value of almost 30 g/1 in the recycle solution.

Further study of the data shows that the finer grind (75-80 percent minus 200 mesh) allowed better extraction of the uranium at the

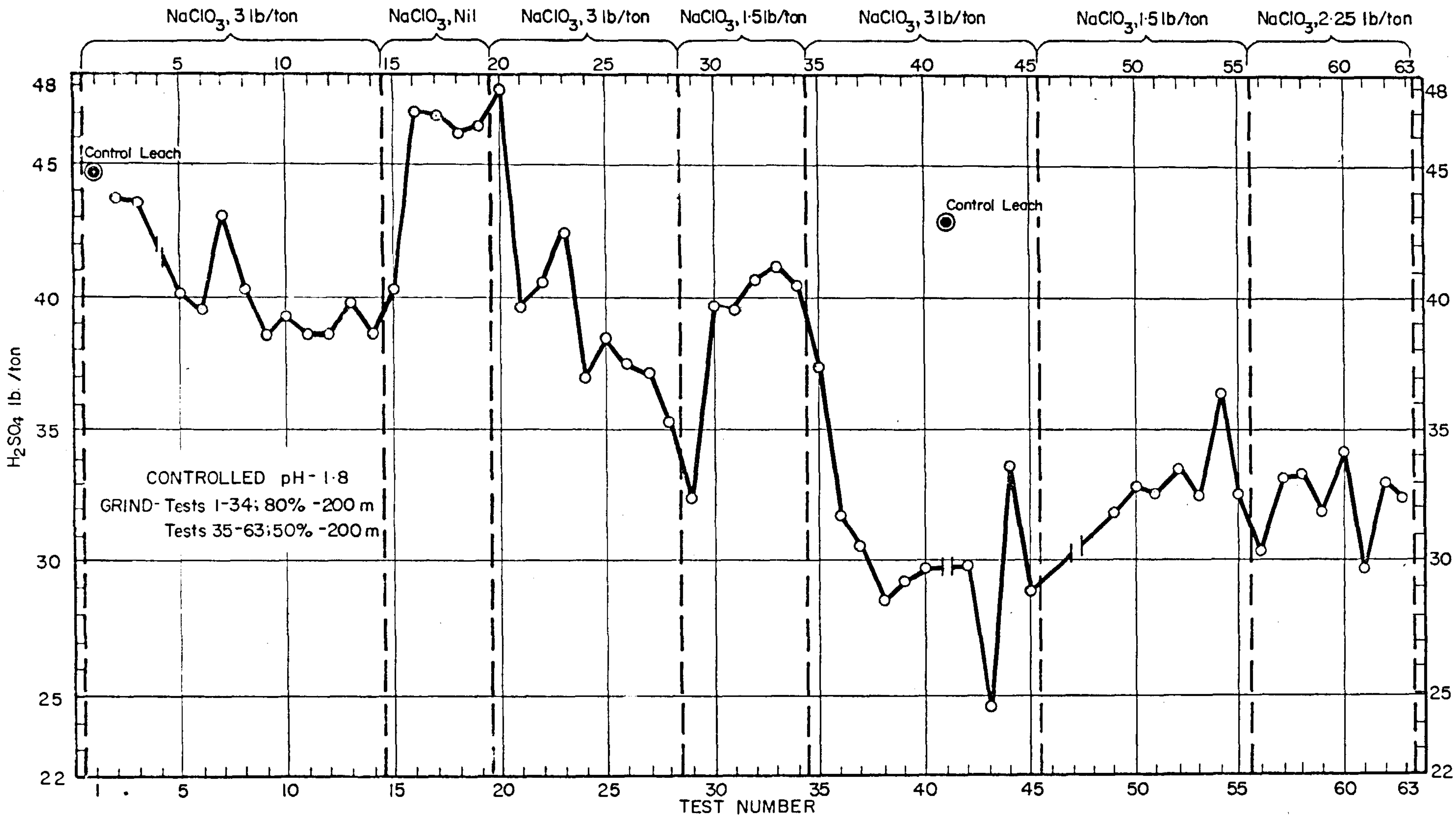


FIGURE 2

ACID CONSUMPTION - RECYCLE LEACHING

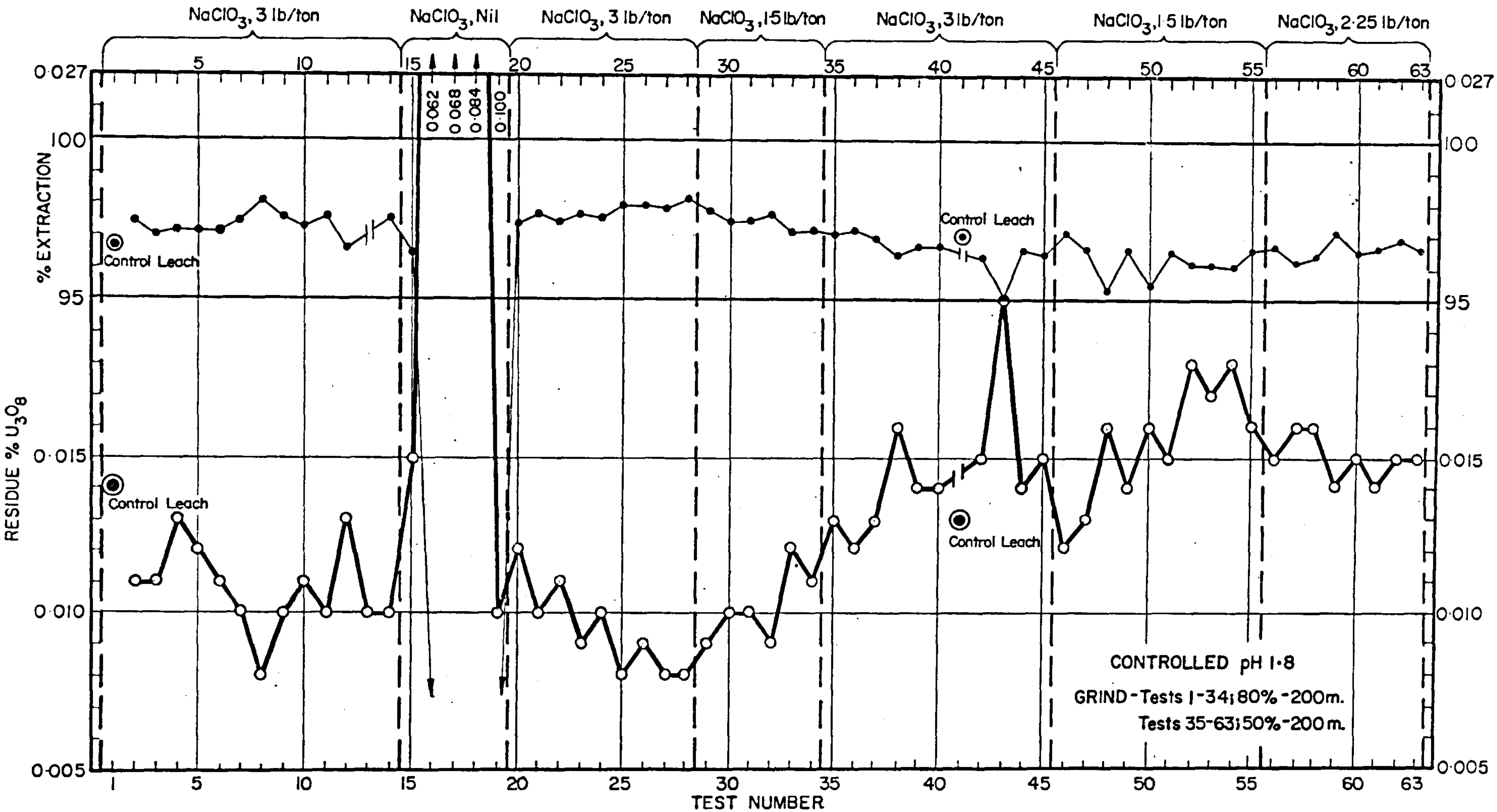


FIGURE 3

RECYCLE LEACH RESIDUES
AND PERCENT EXTRACTION

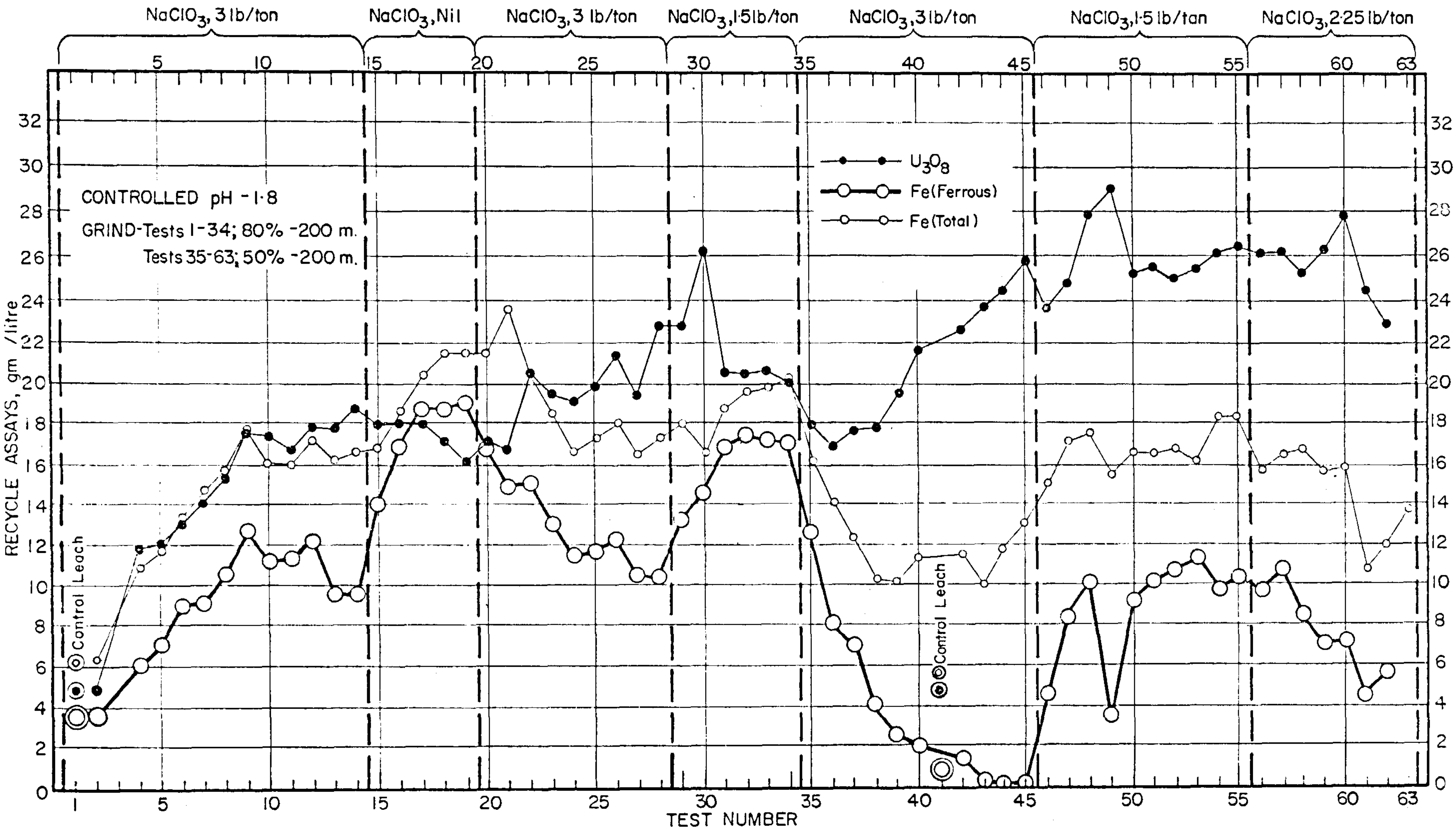


FIGURE 4

RECYCLING LEACH - ASSAYS OF FIRST FILTRATE (RECYCLE)

controlled pH of 1.8. A residue assaying 0.010 percent U_3O_8 was readily attained, resulting from 97.6 percent extraction of U_3O_8 from the ore. The residue assay increased to 0.015 percent U_3O_8 and the percentage extraction of U_3O_8 decreased to 96.4 percent when the grind was decreased to 40-50 percent minus 200 mesh. However, grinding costs are much less at 40-50 percent minus 200 mesh, and, furthermore, the acid consumption decreased considerably with the coarser grind (Figure 5), due to decreased dissolution of other components such as iron. The decreases are shown in Table 2.

TABLE 2

Decreases in Acid Consumption and Iron Content of Filtrates when Ore Grind is Reduced from 80% to 50% Minus 200 Mesh

	$NaClO_3$ added (lb/ton ore)	Decrease in Acid Consumption (lb/ton ore)	Decrease in Acid Consumption (%)	Decrease of Total Iron in Filtrates (%)
Recycle System	1 1/2 3	7.2 9.0	17.8 23.3	16 31
Standard Leach	3	6.9	15.6	25

It is also advantageous, in leaching, to obtain a decrease in the ferrous iron-ferric iron ratio in the solution (Figure 6). There was a considerable decrease in this ratio when the ore grind was decreased from 80 percent minus 200 mesh to 50 percent minus 200 mesh.

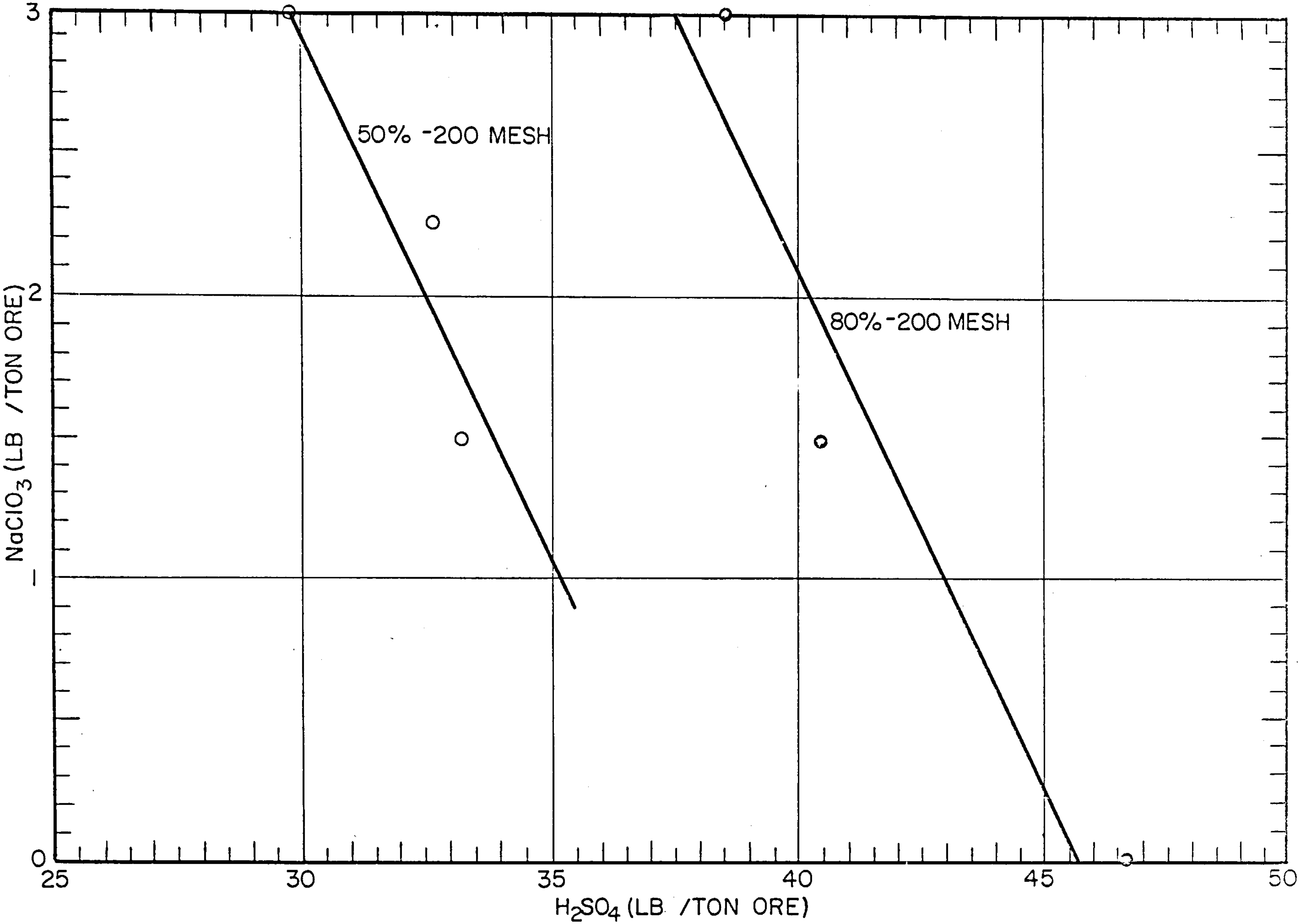


FIGURE 5

RECYCLING LEACH

ACID CONSUMPTION VS SODIUM CHLORATE ADDED

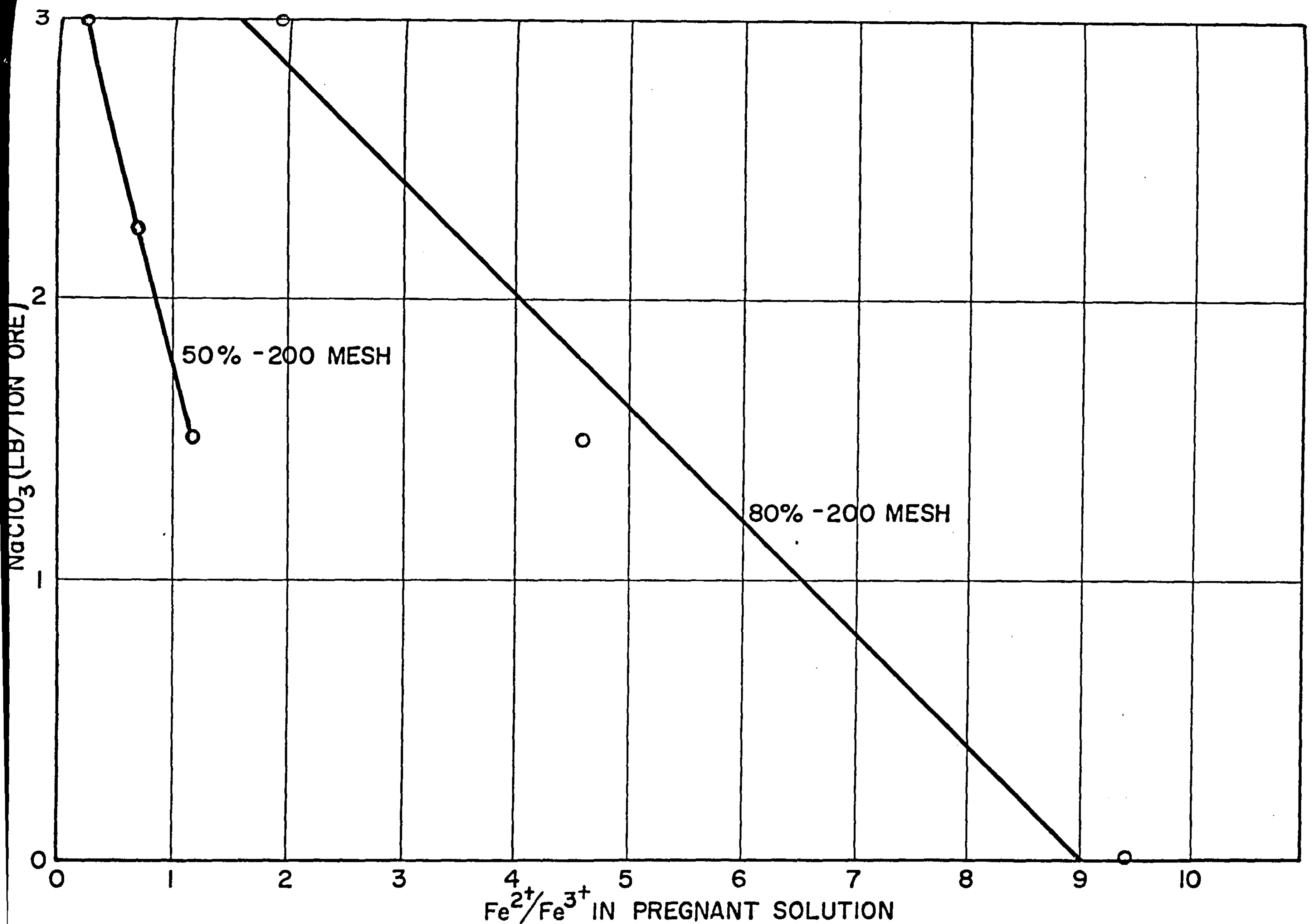


FIGURE 6

RECYCLING LEACH

FERROUS-FERRIC IRON RATIO IN SOLUTION VS SODIUM CHLORATE ADDED

The most satisfactory quantity of sodium chlorate appears to be 3 pounds per ton of ore (Table 1:Tests 57-63; 36-45). In order to maintain the uranium extraction at 96.5 percent when leaching ore ground to 40 to 50 percent minus 200 mesh, a reduction in sodium chlorate of 0.75 pound per ton of ore necessitates an increase in acid consumption of 2.9 pounds of sulphuric acid per ton ore. Considering the ore ground to 75 to 80 percent minus 200 mesh, a saving of 1.5 pounds of sodium chlorate costs 1.7 pounds of acid.

A study of the complete solution analyses (Tables 3 and 4) shows that the pregnant solution obtained at the end of 60 recycling leaches compares very favourably with standard leach pregnant solution. No special problems should be encountered when recovering the uranium from this solution.

TABLE 3

Averaged Test Data: Solution Assays (g/l)

	Test Number	Feed Grind (%-200m)	Feed Head (% U_3O_8)	$NaClO_3$ (lb/ton)	Recycle (First Filtrate) U_3O_8	Recycle (First Filtrate) Fe (Total)	Recycle (First Filtrate) Fe^{2+}	Pregnant Solution (Wash Filtrate) U_3O_8	Pregnant Solution (Wash Filtrate) Fe (Total)	Pregnant Solution (Wash Filtrate) Fe^{2+}	Pregnant Solution (Wash Filtrate) pH	Volumes (l) Recycle	Volumes (l) Pregnant
Control Batches	1, 2	75	0.42	3	4.82	6.10	3.72	1.93	1.92	1.23	1.75	0.468	0.728
Recycle System	9-14	75-80	0.40	3	17.6	16.7	11.0	4.86	4.75	3.10	1.90	0.542	0.735
	21-24	"	0.41	3	18.9	19.7	13.6	5.07	5.00	3.64	1.90	0.574	0.718
	25-28				20.8	17.2	11.2	4.18	3.64	2.39		0.611	0.751
	30-34	"	0.40	1.5	21.6	19.1	16.7	5.12	5.09	4.18	1.95	0.587	0.767
	16-19	"	0.40	Nil	17.3	20.5	18.4	4.73	5.52	4.99	1.90	0.561	0.718
	19	"	"	"	16.1	21.4	19.1	3.60	4.76	4.18	1.90	0.610	0.645
Control Batches	41, 64, 65	54	0.46	3	5.91	4.46	0.90	1.07	0.93	0.23	1.85	0.598	0.738
Control Batches	66-70	45	0.44	3	5.66	4.17	0.99	1.08	0.80	0.19	1.75	0.615	0.767
	71-79	45	0.40	2.25	5.97	4.57	2.05	1.23	1.03	0.47	1.85	0.561	0.748
	80-82	43	0.39	1.5	5.68	4.64	3.64	1.17	1.08	0.90	1.85	0.590	0.742
Recycle System	36-38	48	0.42	3	17.4	12.1	6.3	4.23	3.00	1.70	1.90	0.680	0.742
	39-40, 42				21.2	10.9	1.9	4.20	2.27	0.40		0.657	0.763
	43-45				24.7	11.6	0.1	4.21	2.08	<0.10		0.613	0.728
	57-63	47	0.45	2.25	25.5	14.4	7.2	5.28	2.89	1.22	1.95	0.594	0.737
	49-55	45	0.45	1.5	26.2	16.8	10.3	5.26	3.64	1.97	1.85	0.602	0.727

Note: The results of the test immediately following a change in a variable are excluded.

TABLE 4

Solution Analyses (g/l)

	Control Batch Leach Test No. 41	Final Recycle Leach Test No. 63	
	First Filtrate (Pregnant)	First Filtrate Recycle	Second Filtrate (Pregnant)
U_3O_8	5.43	24.50	4.94
Fe Total	4.60	13.60	2.70
Fe^{2+}	0.80	6.41	1.02
As + P_2O_5	0.089	0.13	0.044
Cl+Br+I	0.71	2.18	0.45
Free Acid	2.7	Nil	1.5
Heavy Metals	0.64	1.04	0.28
Mo	0.0028	0.004	0.001
$Na_2S_4O_6$	0.02	0.022	0.013
SiO_2	1.36	5.46	1.06
SO_4	24.84	70.53	17.34
ThO_2	0.005	0.001	<0.0001
Ti	<0.02	0.01	<0.01
V_2O_5	<0.02	<0.02	<0.02
F	0.04	0.06	0.03
Rare Earth Oxides	0.065	* 0.25	* 0.05
$NaClO_3$	Nil	Nil	Nil

* Some yttrium in solution

ACKNOWLEDGMENT

This project was conceived by the late Dr. E.A. Brown, and was carried out by the authors under his direction.

REFERENCES

1. The Milling of Canadian Ores, Northern Mines Press Ltd., Toronto, 1958. Published by authority of the general committee of the Sixth Commonwealth Mining and Metallurgical Congress.

2. E.A. Brown et al - Some Variations of Uranium Ore Treatment Procedures. Submitted as a contribution from the Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada, to the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, September, 1958.

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(An appendix containing)
(Tables 5 and 6 follows,)
(on pages 18 to 20.)

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APPENDIX

Tables 5 and 6 give in detail the leach data that were obtained for each of the 82 tests upon which this study is based.

TABLE 5

Leach Data - Recycle System and Control Batches

Conditions: Solution to Ore Ratio=3/4
Controlled pH=1.8; Room Temp.

Test	Feed			$NaClO_3$	First Filtrate (Recycle)		Wash Filtrate (Preg. Solution)				Residue	U_3O_8 Extraction	H_2SO_4 (100%)
	Grind (%-200M)	Assay (% U_3O_8)	H_2O*	(lb/ton)	Amount*	U_3O_8(g/l)	Amount*		U_3O_8(g/l)		(% U_3O_8)	(%)	(lb/ton)
							1**	2	1	2			
3	75-80	0.36	0.237	3	0.450	-	0.700		2.09		0.011	96.9	43.6
4	"	0.45	0.245	"	0.460	11.79	0.745		4.05		0.013	97.1	-
5	"	0.41	0.278	"	0.480	11.70	0.830	0.250	3.87	0.015	0.012	97.1	40.2
6	"	0.38	0.194	"	0.500	13.01	0.750	0.250	4.26	0.015	0.011	97.1	39.7
7	"	0.39	0.245	"	0.515	13.95	0.750	0.250	3.69	0.020	0.010	97.4	43.0
8	"	0.42	0.206	"	0.570	15.20	0.725	0.270	3.17	0.042	0.008	98.1	40.3
9	"	0.41	0.220	"	0.522	17.50	0.730	0.260	4.76	0.077	0.010	97.6	38.6
10	"	0.39	0.160	"	0.545	17.33	0.740	0.250	4.39	0.160	0.011	97.2	39.2
11	"	0.43	0.210	"	0.600	16.60	0.750	0.260	4.06	0.085	0.010	97.7	38.6
12	"	0.38	0.172	"	0.525	17.81	0.755	0.260	5.49	0.180	0.013	96.6	38.6
13	"	-	0.226	"	0.540	17.62	0.720	0.260	5.14	0.041	0.010	-	39.9
14	"	0.40	0.215	"	0.520	18.67	0.715	0.255	5.32	0.200	0.010	97.5	38.7
15	"	0.42	0.220	Nil	0.570	17.91	0.710	0.260	4.70	0.320	0.015	96.4	40.3
16	"	0.41	0.240	"	0.555	17.97	0.730	0.255	5.04	0.290	0.062	84.9	47.0
17	"	0.44	0.240	"	0.560	17.87	0.735	0.230	4.49	0.190	0.068	84.5	46.9
18	"	0.35	0.204	"	0.520	17.13	0.760	0.240	5.78	0.270	0.084	76.0	46.2
19	"	0.40	0.195	"	0.610	16.09	0.645	0.340	3.60	0.050	0.100	75.0	46.3
20	"	0.44	0.186	3	0.600	16.96	0.750	0.270	4.59	0.013	0.012	97.3	47.9
21	"	0.45	0.206	"	0.600	18.63	0.740	0.270	4.35	0.058	0.010	97.8	39.8
22	"	0.41	0.215	"	0.540	20.36	0.710	0.250	5.70	0.120	0.011	97.3	40.6
23	"	0.40	0.110	"	0.575	19.51	0.700	0.260	5.17	0.250	0.009	97.7	42.4
24	"	0.40	0.134	"	0.580	19.05	0.720	0.240	5.04	0.250	0.010	97.5	37.0
25	"	0.39	0.150	"	0.585	19.82	0.730	0.275	4.22	0.230	0.008	97.9	38.4
26	"	0.42	0.160	"	0.570	21.19	0.730	0.230	4.32	0.100	0.009	97.9	37.6
27	"	0.36	0.187	"	0.660	19.34	0.790	0.450	3.73	0.002	0.008	97.8	37.2
28	"	0.42	0.190	"	0.630	22.71	0.755	0.240	4.43	0.009	0.008	98.1	35.2
29	"	0.41	0.170	1.5	0.570	22.71	0.760	0.255	5.14	0.150	0.009	97.8	32.4
30	"	0.39	0.172	"	0.585	26.28	0.785	0.200	5.24	0.041	0.010	97.4	39.8
31	"	0.39	0.105	"	0.580	20.48	0.730	0.260	5.30	0.300	0.010	97.4	39.7
32	"	0.40	0.110	"	0.595	20.52	0.700	0.230	5.04	0.010	0.009	97.7	40.8
33	"	0.42	0.083	"	0.610	20.59	0.735	0.230	5.28	0.050	0.012	97.1	41.1
34	"	0.39	0.160	"	0.565	20.02	0.885	0.260	4.72	0.090	0.011	97.2	40.6
35	63.2	0.44	0.053	3	0.595	17.89	0.680	0.250	6.11	0.400	0.013	97.0	37.4
36	49.3	0.42	0.160	"	0.670	16.93	0.710	0.300	4.27	0.100	0.012	97.1	31.8
37	40.5	0.42	0.092	"	0.665	17.57	0.775	0.275	4.19	0.066	0.013	96.9	30.6
38	53.3	0.43	0.090	"	0.705	17.78	0.740	0.290	4.24	0.085	0.016	96.3	28.5
39	50.0	0.43	0.085	"	0.700	19.48	0.755	0.230	4.09	0.004	0.014	96.7	29.2
40	52.1	0.42	0.068	"	0.645	21.50	0.785	0.270	3.86	0.330	0.014	96.7	29.8
42	51.5	0.41	0.111	"	0.625	22.61	0.750	0.230	4.66	0.003	0.015	96.3	29.9
43	46.3	0.40	0.020	"	0.615	23.68	0.730	0.220	4.19	0.008	0.020	95.0	24.6
44	45.8	0.41	0.060	"	0.605	24.43	0.720	0.250	4.39	0.003	0.014	96.6	33.8
45	47.6	0.42	0.110	"	0.620	25.92	0.735	0.260	4.05	0.013	0.015	96.4	28.9
46)	47.0	0.42	0.090	1.5	0.650	23.59	0.750	0.250	4.72	0.011	0.012	97.1	-
47)***	-	0.39	0.095	"	0.640	24.90	0.720	0.260	4.71	0.016	0.013	96.7	Nil
48)	47.8	0.33	0.087	"	0.580	28.11	0.700	0.250	4.62	0.007	0.016	95.2	22.2
49	47.4	0.41	0.117	"	0.560	29.44	0.705	0.265	4.75	0.094	0.014	96.6	31.9
50	43.9	0.45	0.117	"	0.620	25.31	0.760	0.230	5.73	0.088	0.016	95.4	32.9
51	44.5	0.43	0.126	"	0.625	25.48	0.720	0.250	5.21	0.018	0.015	96.5	32.6
52	43.1	0.48	0.090	"	0.610	25.07	0.745	0.245	5.51	0.100	0.018	96.2	33.6
53	48.4	0.45	0.145	"	0.605	25.53	0.715	0.250	5.33	0.120	0.017	96.2	32.4
54	42.3	0.46	0.088	"	0.600	26.26	0.710	0.220	4.94	0.019	0.018	96.1	36.4
55	47.6	0.47	0.158	"	0.595	26.59	0.735	0.205	5.32	0.031	0.016	96.6	32.6
56	49.3	0.46	0.110	2.25	0.600	26.40	0.740	0.235	5.43	0.004	0.015	96.7	30.4
57	44.2	0.42	0.100	"	0.570	26.39	0.730	0.240	6.07	0.110	0.016	96.2	33.2
58	45.4	0.44	0.113	"	0.580	25.41	0.740	0.230	5.26	0.004	0.016	96.4	33.4
59	47.4	0.49	0.080	"	0.590	26.54	0.700	0.230	4.37	0.033	0.014	97.1	31.9
60	48.0	0.44	0.125	"	0.560	28.11	0.735	0.215	5.22	0.055	0.015	96.6	34.3
61	42.3	0.43	0.105	"	0.535	24.44	0.790	0.240	6.36	0.029	0.014	96.7	29.8
62	52.7	0.49	0.101	"	0.645	22.88	0.735	0.270	4.71	0.034	0.015	96.9	33.0
63	48.0	0.44	0.113	"	0.620	24.50	0.730	0.230	4.94	0.005	0.015	96.6	32.4
****													
1	72.4	0.41	0.220	3	0.455	4.82	0.775		2.05		0.014	96.6	44.6
2	78.3	0.42	0.230	"	0.480	-	0.680		1.81		0.011	97.4	43.8
41	54.6	0.43	0.111	"	0.660	5.43	0.735	0.250	0.94	0.002	0.013	97.0	42.9
64	53.2	0.45	0.212	"	0.605	5.70	0.740	0.250	1.20	0.003	0.010	97.8	43.2
65	54.0	0.49	0.115	"	0.530	6.59	-	-	-	-	0.013	97.3	37.2
66	43.8	0.43	0.175	"	0.625	5.31	0.765		1.00		0.017	96.0	36.8
67	43.2	0.41	0.170	"	0.600	5.51	0.760		1.08		0.014	96.6	38.3
68	41.5	0.43	0.203	"	0.625	5.35	0.760		1.22		0.018	95.8	36.8
69	48.4	0.47	0.155	"	0.645	5.79	0.790		1.01		0.016	97.6	38.2
70	45.9	0.46	0.268	"	0.580	6.33	0.760		1.08		0.014	97.0	36.6
71	48.5	0.40	0.200	2.25	0.590	6.37	0.750		1.19		0.012	97.0	41.1
72	45.5	0.45	0.198	"	0.590	6.23	0.750		1.10		0.013	97.1	38.6
73	44.4	0.42	0.214	"	0.550	6.74	0.730		1.15		0.012	97.1	40.2
74	45.3	0.36	0.220	"	0.390	5.60	0.740		1.99		0.015	95.8	37.0
75	45.1	0.38	0.211	"	0.560	5.90	0.739		1.09		0.016	95.8	39.3
76	45.0	0.36	0.225	"	0.575	6.13	0.690		0.91		0.013	96.4	40.1
77	45.2	0.41	0.218	"	0.650	5.15	0.700		0.90		0.015	96.3	37.8
78	43.4	0.41	0.220	"	0.615	5.18	0.710		1.04		0.016	96.1	37.8
79	41.6	0.38	0.192	"	0.530	6.47	0.730		1.43		0.015	96.1	41.8
80	42.8	0.40	0.197	1.5	0.560	5.59	0.770		1.38		0.018	95.5	41.8
81	42.3	0.42	0.215	"	0.570	6.12	0.720		1.31		0.017	96.0	40.5
82	43.1	0.35	0.235	"	0.640	5.34	0.735		0.82		0.019	94.6	39.2

Notes:
* Expressed as a fraction of the dry weight of the ore (1000g).
** Under "Wash Filtrate", the columns headed 1 and 2 refer to the first three washes combined and the fourth wash, respectively. For details, see page 4 in the section on Test Procedure.
*** Tests 46-47 are excluded from study because of pH auto-control failure. Excessive H_2SO_4 was added to leach 46. Tests 47 and 48 were required to gain steady conditions.
**** Tests below broken line are control batch leaches with no recycling.

TABLE 6

Leach Solution Iron Assays (g/l)

Test No.	Ore Grind (%-200M)	$NaClO_3$ (lb/ton)	Recycle Solution		Wash Solution (Pregnant)		
			Fe(total)	Fe^{2+}	Fe(total)	Fe^{2+}	pH
3	75-80	3	-	-	1.37	1.09	1.85
4	"	"	10.8	6.1	4.94	3.16	1.90
5	"	"	11.7	7.1	3.85	2.74	1.90
6	"	"	13.0	8.9	4.38	2.97	1.70
7	"	"	14.6	9.0	4.05	2.64	1.80
8	"	"	15.7	10.5	3.40	2.27	1.80
9	"	"	17.8	12.5	4.96	3.42	1.80
10	"	"	16.1	11.1	4.40	2.89	1.95
11	"	"	16.0	11.3	4.00	2.87	1.90
12	"	"	17.2	12.0	5.40	3.78	1.85
13	"	"	16.2	9.4	4.95	2.85	1.95
14	"	"	16.6	9.5	4.80	2.81	1.90
15	"	Nil	16.8	14.0	4.32	3.79	1.75
16	"	"	18.6	16.9	5.25	4.79	1.90
17	"	"	20.4	18.7	5.08	4.69	1.75
18	"	"	21.4	18.7	7.00	6.28	1.90
19	"	"	21.4	19.1	4.76	4.18	1.90
20	"	3	21.4	16.8	5.80	4.51	1.80
21	"	"	23.5	14.7	4.83	3.52	1.90
22	"	"	20.2	15.0	5.70	4.34	1.90
23	"	"	18.4	12.9	5.10	3.50	1.90
24	"	"	16.8	11.6	4.35	3.20	1.95
25	"	"	17.2	11.7	3.75	2.60	1.90
26	"	"	18.0	12.2	3.84	2.59	2.00
27	"	"	16.5	10.4	3.18	2.02	1.90
28	"	"	17.2	10.3	3.80	2.36	1.90
29	"	1.5	18.2	13.4	4.28	3.14	1.95
30	"	"	17.3	14.7	4.64	3.67	2.00
31	"	"	18.8	16.8	5.75	4.15	1.95
32	"	"	19.5	17.5	4.88	4.33	1.95
33	"	"	19.8	17.3	5.35	4.70	1.95
34	"	"	20.2	17.1	4.83	4.07	1.95
35	40-50	3	16.5	12.5	6.05	4.40	1.90
36	"	"	14.0	8.0	3.48	2.50	1.95
37	"	"	12.2	6.8	2.95	1.60	1.95
38	"	"	10.2	4.0	2.58	1.00	1.75
39	"	"	10.1	2.4	2.22	0.50	1.85
40	"	"	11.2	1.9	2.04	0.40	1.95
42	"	"	11.4	1.3	2.56	0.29	1.90
43	"	"	10.0	0.3	1.80	0.12	1.85
44	"	"	11.8	<0.1	2.40	<0.1	1.85
45	"		13.0	<0.1	2.04	<0.1	2.00
46	"	1.5	15.0	4.6	3.15	1.01	1.25
47	"	"	17.2	8.4	3.85	1.65	1.90
48	"	"	17.5	10.1	3.04	1.80	1.90
49	"	"	15.3	10.5	3.74	1.68	1.75
50	"	"	16.5	9.2	4.00	2.28	1.85
51	"	"	16.5	10.3	3.50	1.90	1.85
52	"	"	16.8	10.8	3.60	2.38	1.80
53	"	"	16.1	11.3	3.58	2.30	1.75
54	"	"	18.2	9.7	3.40	1.50	1.80
55	"	"	18.3	10.5	3.68	1.78	2.05
56	"	2.25	15.5	9.7	3.35	2.30	1.70
57	"	"	16.4	10.8	3.90	2.49	1.90
58	"	"	16.8	8.3	2.95	1.15	2.00
59	"	"	15.5	7.0	2.63	0.90	2.00
60	"	"	15.8	7.1	3.08	1.08	2.00
61	"	"	10.8	4.5	3.12	1.49	2.05
62	"	"	12.0	5.5	1.85	0.40	1.90
63	"	"	13.6	7.2	2.70	1.02	1.80
1	75-80	3	6.10	3.72	2.68	1.61	1.65
2	"	"	-	-	1.15	0.85	1.85
41	50-55	"	4.60	0.80	0.93	0.18	1.90
64	"	"	4.54	1.23	0.93	0.28	1.80
65	"	"	4.25	0.67	-	-	-
66	40-50	"	4.20	0.75	0.84	0.20	1.70
67	"	"	4.50	1.54	0.84	0.23	1.80
68	"	"	4.05	0.50	0.76	0.10	1.75
69	"	"	3.90	1.00	0.76	0.21	1.80
70	"	"	4.18	1.17	0.81	0.21	1.75
71	"	2.25	4.80	2.50	0.90	0.40	1.70
72	"	"	4.25	2.01	1.05	0.41	2.00
73	"	"	5.00	1.83	0.82	0.32	1.95
74	"	"	4.25	2.05	1.58	0.80	1.85
75	"	"	4.26	2.10	0.80	0.49	1.95
76	"	"	5.20	2.52	0.92	0.48	1.75
77	"	"	4.30	1.66	0.96	0.40	1.75
78	"	"	4.05	1.95	1.09	0.42	1.85
79	"	"	4.98	1.87	1.16	0.47	1.95
80	"	1.5	4.88	3.82	1.27	1.03	1.90
81	"	"	4.45	3.40	1.13	0.94	1.95
82	"	"	4.60	3.70	0.83	0.73	1.75

See footnotes on Table 5.

VMMc/WAG/dm