CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 60-96

CONTROLLED pH LEACHING OF ELLIOT LAKE ORES

by

B. H. LUCAS AND W. A. GOW

EXTRACTION METALLURGY DIVISION

COPY NO. 10

OCTOBER 25, 1960

Investigation Report No. IR 60-96

CONTROLLED pH LEACHING OF ELLIOT LAKE ORES

by

W.A. Gow* and B.H. Lucas**

SUMMARY OF RESULTS

A laboratory investigation was conducted on samples of ore from the Elliot Lake, Ontario, uranium area to determine their amenability to the controlled pH leach technique. The testwork was done at leach acid levels of pH 1.0 and 1.5, and the effect of elevated leach temperature, up to 95°C, and fine grinding of the feed, to over 95% minus 200 mesh, on uranium extraction was investigated. The major portion of the work was done on two samples of fresh ore from the properties of the Algom Quirke Mine of Algom Uranium Mines Ltd., and Stanleigh Uranium Mining Corporation Ltd.

The best results obtained on these two samples are compared below with the results now being obtained in the plants using the stronger acid leach common to the area.

Comparison of Best Laboratory Results with Current Plant Operation

	Stanleigh		Algom Quirke	
	Plant	Test 18 at pH 1.0	Plant	Test 14 at pH 1.5
Grind, %-200 mesh	57	71.9	58	98.5
Leaching Temp, °C	63	85	68	85
Acid Consumption, lb/ton	85	50	80	23.5
$NaClO_3$ added, lb/ton	3.3	4.0	0	4.0
U_3O_8 Extraction, %	96.5	90.1	96.2	92.0

On the Algom Quirke sample, controlled pH leaching at a coarser grind (See Test 9, Table 2) resulted in a drop of 5.0% in uranium extraction as compared to the results shown above. The effect of grind on the Stanleigh ore was not investigated.

* Head, Ore Treatment Section, ** Scientific Officer, Extraction Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa.

INTRODUCTION

In the controlled pH sulphuric acid leaching of uranium ores, as practiced in the Bancroft, Ontario and Beaverlodge, Saskatchewan areas, the amount of sulphuric acid added is controlled to maintain the pH of the acid leach pulp in the range of 1.5 to 2.0 throughout the leaching step. The amount of acid required is, therefore, only enough to react with the acid consumers in the ore, plus the acid necessary to maintain a free acid concentration in the leach liquor of about 5 g H_2SO_4/l. The leach pulp temperature is ambient and is usually between 25°-35°C.

When the Elliot Lake, Ontario, uranium ores were first tested at the Mines Branch in 1953, the controlled pH leach technique, as described above, was applied and was found to be ineffective in that uranium extraction was low[1]. Consequently, the relatively strong acid leach technique now used in all the Elliot Lake operations was developed and no further work was done on controlled pH leaching. In the so-called strong acid leach process, the amount of acid added is such that the final leach liquor contains from 30-70 g H_2SO_4/l. Also, in the course of plant operation it was found that leaching temperatures of 60-65°C were advantageous in improving uranium extraction. This technique results in uranium extractions of about 95% in the operating plants of the area.

Since the controlled pH leach technique generally requires less acid and so would result in a lower leaching cost than the strong acid leach process being used, this investigation was begun early in 1959 to investigate more fully the response of the ores of the Elliot Lake area to controlled pH leaching, particularly at elevated temperature and with finer grinding. The variables investigated were pH, temperature and grind. The other leaching conditions such as sodium chlorate additions and pulp density were chosen to correspond to the conditions being used in the operating plants at the time the investigation was initiated.

TEST PROCEDURE

As a preliminary step in this investigation, eight ores from the Elliot Lake area were tested to determine their leaching characteristics at a leach pulp pH of 1.5, a temperature of 25°C, a pulp density of 60% solids and a $NaClO_3$ addition of 2 to 4 lb/ton ore. The grinds in these tests ranged from 58% to 71.8% minus 200 mesh. The ore samples used were stock samples which had been obtained for other testwork and had been stored for periods of up to two years prior to this testwork. The procedure used in this work was to wet grind an 1150 g sample of ore at minus 10 mesh in an Abbe porcelain laboratory jar mill, charged with 20 lb of 1/2 - 3/4 in. steel balls, for periods of 20-25 min. After grinding, the ground material was filtered, and a 150 g feed sample was taken from the filter cake. The balance of the filter cake was repulped with water and acid to the specified leaching density and pH and then the required amount of sodium chlorate was added. The leaching was carried out in an open glass beaker in a controlled temperature water bath, with agitation provided by a glass impeller driven by an adjustable speed stirring motor. The pH was maintained by a pH recorder-controller operating an electrically-actuated acid supply valve.

After completion of the preliminary work, the effects of pH, temperature and grind on uranium extraction were investigated more fully on fresh samples of ore from the Algom Quirke mine of Algom Uranium Mines Ltd., and Stanleigh Uranium Mining Corporation Ltd. These ores were chosen to represent the north and central ore zones of the uranium area, and because the preliminary work had indicated that under the controlled pH leach conditions they were the most refractory ores of the area. It was considered that the results obtained on other apparently less refractory ores of the area would at least be as good as those obtained on the samples tested under similar leaching conditions.

The leach tests were carried out at pH levels of 1.0 and 1.5 over a temperature range of 25°-95°C. In all these tests, 4 lb $NaClO_3$/ton ore was used as an oxidant. In Tests 12, 13 and 14, on the Algom Quirke sample, the effect of increasing the fineness of grind from about 65% minus 200 mesh to over 95% minus 200 mesh, at pH 1.5, was investigated.

The general procedure in carrying out the more detailed testwork on the Algom Quirke and Stanleigh samples was similar to that used in the preliminary work and described above. The main differences were that a glass reaction kettle heated by a Glas-col heating mantle was used as a leaching vessel and the pH was manually controlled.

RESULTS

The results of the preliminary tests are given in Table 1. The results of these tests, carried out at pH 1.5, indicate that on some of the ores tested it is possible to obtain extractions of over 90% of the uranium in a weak acid solution. However, since the samples had been obtained some time before the testwork was started, oxidation may have made them slightly less refractory.

The results of the more detailed test programme which was carried out on fresh samples from the Algom Quirke and Stanleigh properties are given in Tables 2 and 3, and in graphical form in Figures 1 and 2. An extraction of over 88% of the uranium was obtained on the Algom Quirke sample at a pH of 1.5 and a temperature of 95° C, (Table 2, Test 10). The acid consumption was of the order of 25 lb 100% H_2SO_4/ton and the sodium chlorate added was 4.0 lb/ton. On the Stanleigh sample, 90% of the uranium was extracted at a pH of 1.0 and a temperature of 85° C, (Table 3, Test 18). Here, the acid consumption was 50 lb 100% H_2SO_4/ton and the sodium chlorate added was 4.0 lb/ton.

The effect of finer grinding of Algom Quirke ore is shown in Table 2, Tests 12, 13 and 14. The fine grind did result in increased extraction from 88.1% (Table 2, Test 10) to 92% (Table 2, Test 14) and this was effected at a lower temperature (85° C) than that required (95° C) at the coarser grind.

CONCLUSIONS

In the acid leaching of ores from the Elliot Lake area by the controlled pH technique, increasing the temperature increases the uranium extraction without appreciably increasing the acid consumption. The controlled pH process consumes much less acid as compared to the current practice and acid savings could vary, depending on the ore, by amounts ranging from 35 to 55 lb H_2SO_4/ton ore. On the other hand, relatively high temperatures appears to be essential and extraction is 5 to 7% lower than that obtained with current practice. Finer grinding in the controlled pH leach is also desirable. Table 4 shows a comparison of the best conditions and results of the tests reported here, and of plant practice.

TABLE 1

Results of Preliminary Leach Tests

Leaching Temp - 25°C
Pulp density - 60% solids

	Grind (%-200 mesh)	pH	$NaClO_3$ added (lb/ton)	Acid Consumption (lb/ton)	Leaching Time (hr)	U_3O_8 Extraction (%)	Head Analysis (% U_3O_8)
Algom Uranium Mines Ltd. (Quirke Mine)	63.5	1.5	3	18.8	96	74.0	0.09
Consolidated Denison Mines Ltd.	58.0	1.5	2	25.6	48	90.0	0.21
Consolidated Denison Mines Ltd.	58.0	1.5	3	34.0	96	93.0	0.21
Consolidated Denison Mines Ltd.	58.0	1.5	4	33.0	72	95.0	0.22
Can Met Explorations Ltd.	60.5	1.5	3	30.0	96	87.0	0.10
Algom Uranium Mines Ltd (Nordic Mine)	62.7	1.5	3	31.6	96	90.1	0.12
Milliken Lake Uranium Mines Ltd.	68.8	1.5	3	50.4	96	75.2	0.10
Northspan Uranium Mines Ltd. (Lacnor Mine)	71.8	1.5	3	25.6	96	75.2	0.08
Stanleigh Uranium Mining Corp Ltd.	66.5	1.5	3	23.8	96	63.8	0.10
Pronto Uranium Mines Ltd.	62.6	1.5	3	36.8	96	82.7	0.14

TABLE 2

Leaching Results on Algom Quirke Sample

Test No.	1	2	3	4	5	6	7	8	9	10	12	13	14
Conditions													
Leaching pH	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Leaching Temp(°C)	30	45	65	85	95	30	45	65	85	95	45	65	85
$NaClO_3$ added, lb/ton	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Grind, %-200 mesh	67.4	64.2	68.2	60.5	70.3	65.6	67.3	65.3	63.8	64.6	97.4	98.2	98.5
Final pulp density, % solids	68.1	67.3	78.7	72.2	75.1	70.3	66.6	72.6	72.2	68.2	64.0	67.7	68.7
Contact time, hr	48	48	48	48	48	48	48	48	48	48	48	48	48
100% H_2SO_4 added, lb/ton	34.0	32.4	31.0	32.0	32.0	22.0	22.0	19.0	23	22.2	25.0	24.0	23.5
Residue analyses, % U_3O_8 at													
0 hr (leach feed)	0.11	0.11	0.12	0.11	0.12	0.12	0.12	0.12	0.11	0.11	0.12	0.15	0.13
6 hr	0.038	0.030	-	0.023	0.024	0.055	-	0.033	0.024	0.024	0.043	0.043	0.026
24 hr	0.027	0.022	0.020	0.022	0.020	0.038	-	0.034	0.020	0.019	0.032	0.039	0.015
30 hr	0.029	0.021	0.020	0.018	0.018	0.035	0.030	0.033	0.020	0.016	0.032	0.035	0.013
48 hr (final residue)	0.023	0.024	0.019	0.014	0.015	0.032	0.028	0.024	0.016	0.012	0.027	0.033	0.011
Final residue													
Wt, g	902	900	920	904	920	902	930	916	884	915	924	937	938
U_3O_8 content, g	0.208	0.216	0.175	0.127	0.138	0.289	0.260	0.220	0.141	0.110	0.249	0.309	0.103
Leach liquor													
Vol, ml	298	319	149	255	195	281	220	206	212	210	343	324	268
pH	1.05	1.15	1.15	1.08	1.10	1.45	1.46	1.42	1.40	1.42	1.55	1.62	1.53
U_3O_8 analysis, g/l	1.48	1.95	3.00	2.34	2.82	1.96	2.34	2.16	2.56	1.61	1.57	2.01	2.75
U_3O_8 content, g	0.441	0.622	0.447	0.597	0.550	0.551	0.515	0.445	0.543	0.338	0.539	0.652	0.737
Wash liquor													
U_3O_8 analysis, g/l	0.36	0.32	0.66	0.49	0.53	0.35	0.47	0.56	0.53	0.61	0.35	0.43	0.60
U_3O_8 content, g	0.256	0.232	0.472	0.363	0.377	0.256	0.340	0.380	0.400	0.477	0.273	0.315	0.458
Head analysis, % U_3O_8													
Analysed	0.11	0.11	0.12	0.11	0.12	0.12	0.12	0.12	0.11	0.11	0.12	0.15	0.13
Calculated	0.10	0.12	0.12	0.11	0.11	0.12	0.12	0.11	0.12	0.10	0.11	0.14	0.14
Extraction, %													
(based on calc head)	77.0	79.8	84.0	88.3	86.5	73.8	76.7	79.0	87.0	88.1	77.2	75.8	92.0

TABLE 3

Leaching Results on Stanleigh Sample

Test No.	15	16	17	18	19	21	22	23	24	25
Conditions										
Leaching pH	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5
Leaching Temp (°C)	30	45	65	85	95	30	45	65	85	95
$NaClO_3$ added, lb/ton	4	4	4	4	4	4	4	4	4	4
Grind, %-200 mesh	63.5	71.4	73.1	71.9	65.4	67.6	65.3	65.0	68.6	65.3
Final pulp density, % solids	68.5	72.2	68.9	67.8	66.6	67.5	68.7	72.2	71.9	69.8
Contact time, hr	48	48	48	48	48	48	48	48	48	48
100% H_2SO_4 added, lb/ton	40.4	41.8	40.0	50.0	46.5	30.5	32.0	32.0	31.0	32.0
Residue analyses, % U_3O_8 at										
0 hr (leach feed)	0.11	0.093	0.11	0.10	0.10	0.11	0.11	0.12	0.10	0.10
6 hr	0.037	0.023	-	0.020	0.023	0.044	-	0.032	0.029	0.022
24 hr	0.027	0.019	0.019	0.015	0.023	0.035	0.031	0.026	0.024	0.020
30 hr	0.027	0.017	0.018	0.014	0.021	0.035	0.031	0.026	0.024	0.023
48 hr (final residue)	0.023	0.015	0.012	0.010	0.021	0.031	0.029	0.025	0.022	0.023
Final residue										
Wt, g	922	919	915	914	908	908	890	920	919	910
U_3O_8 content, g	0.212	0.138	0.110	0.091	0.173	0.282	0.258	0.230	0.202	0.209
Leach liquor										
Vol, ml	280	180	280	293	351	248	259	249	166	292
pH	1.13	1.00	1.12	0.98	1.08	1.50	1.58	1.53	1.49	1.52
U_3O_8 analysis, g/l	1.59	1.87	1.98	1.66	1.46	1.49	1.90	1.72	1.95	1.73
U_3O_8 content, g	0.445	0.337	0.554	0.486	0.513	0.370	0.492	0.428	0.327	0.505
Wash liquor										
U_3O_8 analysis, g/l	0.35	0.47	0.40	0.44	0.23	0.42	0.38	0.37	0.47	0.27
U_3O_8 content, g	0.267	0.376	0.300	0.349	0.170	0.341	0.277	0.270	0.383	0.204
Head Analysis, % U_3O_8										
Analysed	0.11	0.093	0.11	0.10	0.10	0.11	0.11	0.10	0.10	0.10
Calculated	0.10	0.093	0.10	0.10	0.094	0.11	0.12	0.10	0.10	0.10
Extraction, %										
(based on calc head)	77.0	83.9	88.6	90.1	79.8	71.6	74.8	75.3	77.8	77.2

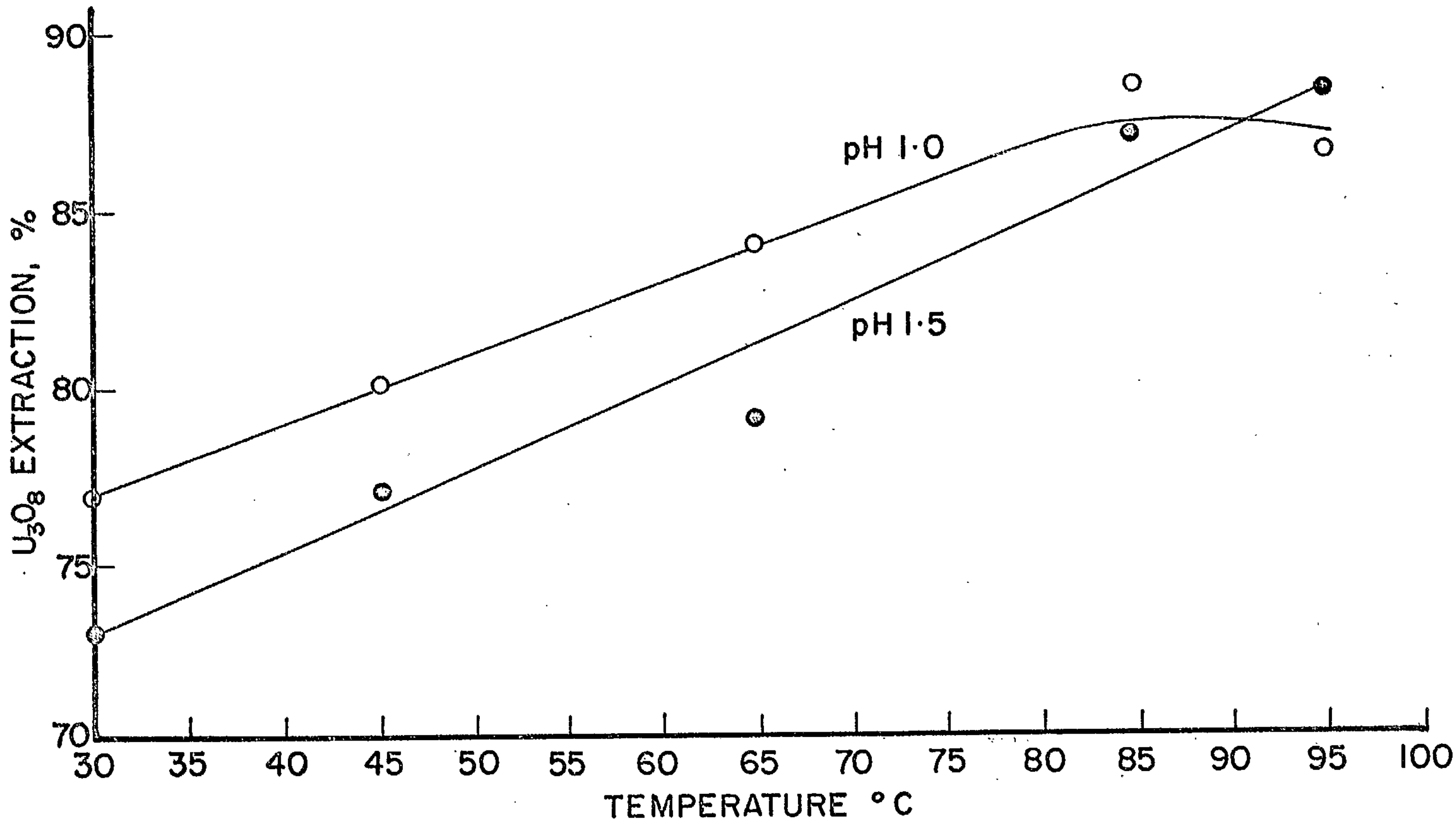

FIGURE 1

TEMPERATURE VS U_3O_8 EXTRACTION, ALGOM QUIRKE

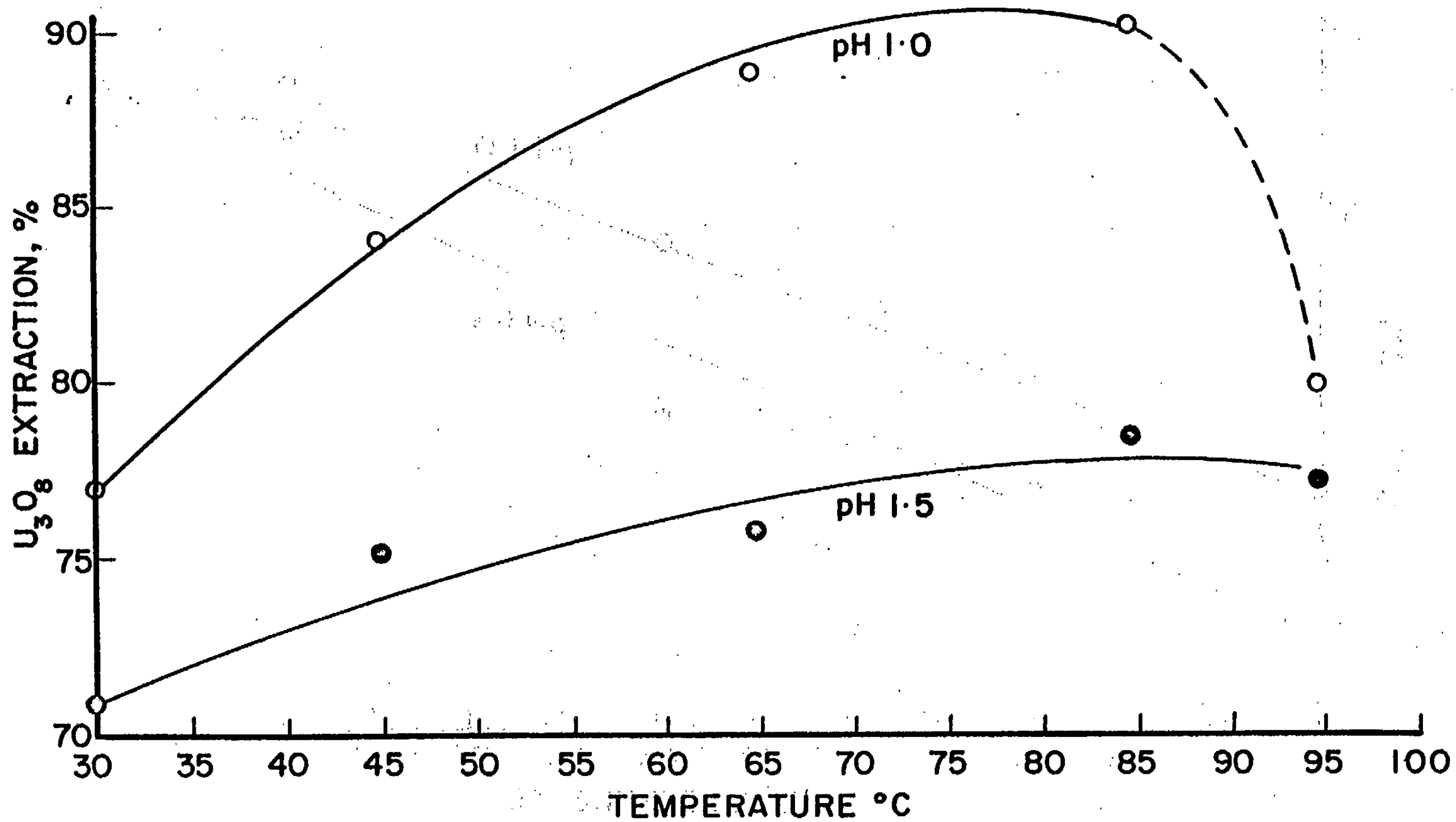

FIGURE 2

TEMPERATURE VS U_3O_8 EXTRACTION, STANLEIGH

DISCUSSION

Under present market conditions the controlled pH acid leach technique at pH 1.0 or 1.5 would not be attractive. The loss in uranium recovery and the costs involved in operating with increased temperature and finer grind would out-weigh the acid savings. However, if the value of uranium were to drop appreciably, it may prove advantageous to the operator to accept a loss in extraction in order to reduce operating costs. If this situation should develop, controlled pH leaching should be considered.

It is pointed out that, in this investigation, only two ores were tested to any extent. The results were such that work on the ores from other properties is warranted to check if they are more amenable to controlled pH leaching than the ores tested in this work. It is suggested that this work should be done at the plants so that more accurate comparisons with plant practice may be obtained. This point is emphasized by the Algom Quirke data shown in Table 4. The results obtained by controlled pH leaching on this sample compare more favourably, particularly with respect to sodium chlorate requirement, with the plant results of the first quarter, when the sample for the testwork was taken, than they do with the plant results for the fourth quarter. Since the improvement in plant results in the fourth quarter could be due, at least in part, to the ore being less refractory, a proper evaluation of the controlled pH method would require further tests on current ore.

TABLE 4

Comparison of Best Laboratory Results with Plant Practice

Conditions and Results	Stanleigh		Algom Quirke		
	Plant practice 1959	Controlled pH lab test 18	Plant practice 1959, 1st quarter*	Plant practice 1959, 4th quarter	Controlled pH lab test 14
Grind, %-200 mesh	57	71.9	55	58	98.5
Pulp density, % solids	76	67.8	73	73	68.7
Contact time, hr	65	48	-	48	48
Leaching temp, °C	63	85	50	68	85
Free acid at start, g/l	65	pH 1.0	-	85	pH 1.5
Free acid at end, g/l	49	pH 1.0	85	70	pH 1.5
Acid consumption, lb/ton	85	50	90	80	23.5
$NaClO_3$ added, lb/ton	3.3	4.0	4.0	0	4.0
U_3O_8 extraction, %	96.5	90.1	-	96.2	92.0

* complete data not available but uranium extraction would be in the order of 95%

The tendency for the uranium extraction to drop off at the highest temperatures investigated is perhaps related to an observed decrease in the ferric/ferrous ratio in the leach solution with increasing temperature.

REFERENCE

R.P. Ehrlich, Laboratory Investigations on a Diamond Drill Core Sample Submitted by Pronto Uranium Mines Ltd. Radioactivity Division Special Report SR-210/53, Department of Mines and Technical Surveys, Ottawa, Canada, 1953.

BHL/WAG/dm