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FLOTATION OF ACID CONSUMERS FROM BANCROFT URANIUM ORES

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W. R. HONEYWELL, V. F. HARRISON, W. A. GOW & H. W. SMITH

EXTRACTION METALLURGY DIVISION

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FLOTATION OF ACID CONSUMERS FROM BANCROFT URANIUM ORES

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W.R. Honeywell^{*}, V.F. Harrison^{*}, W.A. Gow^{**}
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SUMMARY OF RESULTS

Laboratory flotation test work was done to investigate the possibility of removing acid-consuming gangue minerals from the ores of the Bancroft, Ontario, area by flotation prior to leaching. In the test work uranium reporting in the flotation concentrate with the acid consumers was partially recovered by magnetic separation.

On ore from Faraday Uranium Mines Ltd., flotation of the acid consumers prior to leaching using sodium oleate as a collector resulted in an acid saving of about 26% on ore normally requiring 44 lb H_2SO_4 /ton. Overall recovery of uranium, after leaching, and including a 1.3% loss of uranium to the acid consumer concentrate, was 92.1%. The cost of flotation reagents would be about 14 cents per ton ore.

Another collector, Pamak 15, a fatty acid from tall oil, gave similar results with the cost of reagents less than 4 cents per ton ore.

On ore from Bancroft Uranium Mines Ltd., a saving of about 26.5% of the acid was indicated in preliminary tests. The loss of uranium in this case was higher, however, at about 10%.

* Senior Scientific Officers, ** Head, Ore Treatment Section and
*** Senior Development Officer, Hydrometallurgy Sub-Division,
Extraction Metallurgy Division, Mines Branch, Department of
Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

The Bancroft area uranium ores contain several types of gangue minerals which are attacked by dilute sulphuric acid, and are therefore consumers of acid in leaching. If the acid-consuming gangue minerals can be removed by flotation it should be possible to effect substantial savings in leaching costs. Such flotation would have to be selective to leave as much of the uranium as possible in the flotation tailings for subsequent leaching. To be economically feasible the saving in acid must be more than equal to the cost of the flotation procedure plus any resultant loss of uranium.

This investigation was undertaken to ascertain the possibilities of beneficiating these ores by such a flotation treatment to remove acid-consuming gangue minerals selectively. Also, since it had been found earlier that some uranium and associated minerals were slightly magnetic in a highly magnetic field, some test work was included to recover the uranium from the flotation concentrates by magnetic methods for return to leaching with the flotation tailings.

As a measure of the flotation efficiencies, acid leach tests were made on the beneficiated products both to measure the reduction of leach acid requirements and to check the uranium extractions. For the acid consumption a simple acid treatment test was developed and for the complete metallurgical assessment a leach procedure approximating normal conditions was carried out.

DETAILS OF INVESTIGATION

This investigation was carried out on a sample of rod mill feed (our Ref. No. 3/60-16) from Faraday Uranium Mines Limited and a sample (our Ref. No. 4/55-14) from Bicroft Uranium Mines Ltd., (former Centre Lake property).

The mineralogical report⁽¹⁾ on a composite sample from Faraday ore bodies states that several different types of rock are present, namely a pyroxene granite pegmatite, a pink coloured granite and a fine to medium-grained amphibolite. The main uranium mineral was uranothorite; some uraninite and a small amount of allanite are also present.

Mineralogical work⁽²⁾ on an earlier Bicroft (Centre Lake) sample showed that the rock consists of a variety of siliceous rock types and contains mainly ferromagnesian minerals, feldspar and quartz, as well as pyrrhotite, zircon, apatite and fluorite and a small amount of calcite. The main radioactive minerals, uraninite and uranothorite, occur in grains which average approximately 48 mesh in size.

Most of the present work was done on the Faraday sample, and analysis of the head sample gave the following results:

	<u>%</u>
U ₃ O ₈	0.11
CO ₂ (evolution)	0.56
CO ₂ (combustion)	0.83

The analysis on the Biccroft sample gave 0.20% U_3O_8 and 0.59% CO_2 (evolution)

Flotation Test Work

The flotation tests were done on 1150 g charges ground for 20 minutes in an Abbe porcelain ball mill with 20 pounds of steel balls. This produced a grind of about 52% -200 mesh for both samples. Distilled water was used for the grinding. The charge was then filtered and the filtrate was retained for the subsequent flotation.

The filter cake was repulped, without desliming, in a 500 Fagergren cell at 25% solids. After the addition of reagents, the pulp was conditioned for a period of three minutes and a rougher flotation concentrate was removed. After further addition of reagents and conditioning, scavenger flotation concentrates were removed. The scavenger concentrates were combined with the rougher concentrate to make up the acid-consuming mineral concentrate. In some cases the combined concentrates were cleaned.

During the course of the work, a number of reagents were tested, including the promoters R-801 and Duomac T. These two reagents gave the best results on Elliot Lake ores but proved to be unsatisfactory on the Bancroft ores. Other promoter reagents tested were sodium oleate, Pamak 4 and 15, rosin amine, R-3037 and R-825. Sources of the flotation reagents are given in the Appendix. Flotation pH

was controlled by using sulphuric acid or sodium carbonate.

The results of each test and the reagents and the quantity used are given in Tables 1 and 2.

The flotation concentrate from test F-6 was treated without further grinding in a Jones Wet Magnetic Separator with the object of recovering the uranium from this concentrate. The separation was made at a power setting of 25 amps. The results are included in Table 1. The magnetic portion was combined with the flotation tailing for the acid consumption test.

After a satisfactory flotation method had been developed to give a good elimination of acid-consuming gangue with minimum uranium loss, the method was used to produce feed for acid leach tests. This flotation method, similar to that used for test F-9 Table 1, was as generally described on Page 3, and actual reagent additions were as follows:

<u>Reagents Added</u>	<u>lb/ ton</u>	
Sodium silicate	1.0	
Sodium carbonate	0.2	
Sodium oleate	0.4	
Conditioned		- 3 min (pH 9.7, temp 26°C)
Rougher Float		- 4 min
Sodium oleate	0.2	
Conditioned		- 3 min
1st Scavenger Float		- 3 min
Sodium oleate	0.2	
Conditioned		- 3 min
2nd Scavenger Float		- 3 min

The floats were combined and cleaned. The cleaner tailing was added to the rougher tailing and the cleaner float was treated on the Jones Wet Magnetic Separator. The magnetic portion was then combined with the flotation tailing for the uranium extraction test work. The non-magnetic portion of the cleaner float was the reject product.

The results of the above flotation and magnetic separation procedure are given in Table 3.

Leaching Test Work

To assess the efficiency of the removal of the acid consuming minerals, the flotation tailings and also the original ore samples from Faraday and Bicroft test series were leached in dilute H_2SO_4 at a controlled pH with no oxidizing agent. The acid consumption data on these products are given in Tables 1 and 2.

Subsequently, uranium extraction plus acid consumption data for Faraday combined flotation tailings and also Faraday original ore were determined by leaching the samples with dilute H_2SO_4 at a controlled pH with the addition of an oxidizing agent. The extraction results and acid consumption data are shown in Table 4, and leach solution and leach residue data are compiled in Table 5.

Leaching test procedures are detailed in the Appendix.

RESULTS

The results of the flotation and leaching test work previously described are given in the following Tables 1 to 5 inclusive.

Flotation Test Data and Results and Acid Consumption Results on Faraday Ore

Test No.	Products	Wt (%)	U ₃ O ₈ (%)	U ₃ O ₈ Distrn (%)	Leach Acid Consump. (lb/ton leach feed)	Flotation Reagent Addition lb/ ton of Ore						pH	Remarks
						Na ₂ SiO ₃	Na ₂ CO ₃	Other Reagents					
	Original Ore				52.0								Comparative acid consumption test
F-1	Float Tailing Products	5.29 94.71 100.00	0.15 0.089 0.092	8.6* 91.4 100.0	50.6	0.5	H ₂ SO ₄ 2.0	R-801 0.2	NaCN 0.25	Cres. Acid 0.04		7.7	Reagents, best for Elliot Lake proved to be unsatisfactory
F-4	Float Tailing Products	3.01 96.99 100.00	0.22 0.12 0.123	5.4* 94.6 100.0	49.0	NaOH 0.5		Duomac T 0.15		Dowfroth 250 0.04		10.7	
F-5	Float Tailing Products	9.77 90.23 100.00	0.12 0.11 0.11	10.5* 89.5 100.0	36.8		H ₂ SO ₄ 4.0	Duomac T 0.1	Fuel Oil 0.04	Cres. Acid 0.04	Pine Oil 0.04	6.6	
F-6	Non-mags Magnetics Tailing Products	4.08 3.76 92.16 100.00	0.13 0.086 0.079 0.082	6.5* 3.9 89.6* 100.0	37.1	0.5	0.5	Na Oleate 0.6				9.5	R. Float and Scav. Floats combined and separated magnetically
F-7	Float Tailing Products	8.75 91.25 100.00	0.10 0.12 0.12	7.4* 92.6 100.0	37.7	1.0	0.5	Na Oleate 0.6				11.0	
F-8	Float Tailing Products	1.76 98.24 100.00	0.11 0.15 0.15	1.3* 98.7 100.0	41.6	0.5		Pamak 4 0.18		Cres. Acid 0.04		9.4	
F-9	Cl. Float Tailing Products	5.12 94.88 100.00	0.067 0.095 0.094	3.6* 96.4 100.0	38.4	1.0	0.4	Na Oleate 0.8				10.1	R. Float and 2 Scav. Floats combined and cleaned
F-10	Float Tailing Products	4.01 95.99 100.00	0.11 0.13 0.13	3.4* 96.6 100.0	36.2	0.5	0.25	Pamak 15 0.24				9.4	Pamak is a fatty acid from tall oil, distributed by Can. Industries Ltd.
F-11	Cl. Float Tailing Products	2.12 97.88 100.00	0.044 0.11 0.11	0.8 99.2* 100.0	48.0	0.5	0.2	Pamak 15 0.36	Cres. Acid 0.04			9.3	R. Float and 2 Scav. Floats combined and cleaned
F-12	Cl. Float Tailing Products	5.59 94.41 100.00	0.055 0.10 0.10	3.2* 96.8* 100.0	38.0	1.0	0.2	Na Oleate 0.8		Di (2-Butyl Octyl) Amine 0.08		9.2	Floats combined and cleaned
F-13	Float Tailing Products	2.90 97.10 100.00	0.18 0.11 0.11	4.6* 95.4 100.0	45.0	0.5		Rosin Amine 0.3		Cres. Acid 0.04		9.5	
F-14	Float Tailing Products	3.94 96.06 100.00	0.058 0.13 0.127	1.8* 98.2 100.0	48.4	1.0	0.2	Na Oleate 0.8	Calgon 0.1			9.8	
F-15	Float Tailing Products	6.02 93.98 100.00	0.18 0.12 0.14	8.7* 91.3 100.0	48.2	0.5	0.2	R-3037 0.4	Cres. Acid 0.04			9.5	
F-16	Float Tailing Products	3.59 96.41 100.00	0.17 0.16 0.16	3.8* 96.2 100.0	44.6	0.5	R-801 0.10	R-825 0.10	Cres. Acid 0.04			9.0	
F-17	Float Tailing Products	5.90 94.10 100.00	0.084 0.14 0.137	3.7* 96.3 100.0	37.4	1.0	0.4	Na Oleate 1.6				10.0	Twice amount of Na Oleate used as for F-9. Results similar.

* Indicates products used for acid consumption tests.

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TABLE 2

Flotation Test Data and Results on Bicroft Ore

Test No.	Products	Wt (%)	U ₃ O ₈ (%)	U ₃ O ₈ Distn (%)	Leach Acid Consump (lb/ton leach feed)	Flotation Reagent Addition lb/ton of Ore					Temp °C.	pH	Remarks
						Na ₂ SiO ₃	Na ₂ CO ₃	Na Oleate					
Original Ore					83.4								Comparative acid consumption test
B-1	Cl. Float	9.81	0.12	10.6 _⊘	59.5	0.5	0.4	0.8			25	9.7	Floats combined and cleaned
	Tailing	90.19	0.11	89.4 _⊘									
	Products	100.00	0.11	100.0									
B-2	Cl. Float	5.24	0.088	3.1 _⊘	73.6	0.5	0.2	0.4			25	9.5	Floats combined and cleaned
	Tailing	94.76	0.15	96.9 _⊘									
	Products	100.00	0.15	100.0									
B-3	Cl. Float	3.08	0.021	0.4 _⊘	88.2	0.5	0.2	Double Distilled Oleic Acid			25	9.1	Purple float of fluor spar
	Tailing	96.92	0.17	99.6 _⊘									
	Products	100.00	0.165	100.0									
B-4	Cl. Float	13.54	0.12	9.0 _⊘	63.0	0.5	0.4	0.8			25	9.2	Similar to test B-1, except temp. Results similar
	Tailing	86.46	0.19	91.0 _⊘									
	Products	100.00	0.18	100.0									
B-5	Cl. Float	5.38	0.075	2.4 _⊘	73.5	0.5	0.2	0.4			12	8.3	Similar to test B-2, except temp. Results similar
	Tailing	94.62	0.17	97.6 _⊘									
	Products	100.00	0.165	100.0									
B-6	Cl. Float	9.93	0.12	5.2 _⊘	72.0	0.5	0.2	0.6			25	8.3	
	Tailing	90.07	0.24	94.8 _⊘									
	Products	100.00	0.23	100.0									

⊘ Indicates products used for acid consumption tests.

TABLE 3

Results of Flotation and Magnetic Separation to Produce Feed
for Leach Tests (Faraday Ore)

Products	Wt (%)	U ₃ O ₈ Assay (%)	U ₃ O ₈ Distn (%)
Float, non-magnetics	1.93	0.068	1.3
Float, magnetics	1.96	0.068	1.3*
Tailing	<u>96.11</u>	<u>0.10</u>	<u>97.4*</u>
	100.00	0.099	100.0

* These products were combined for the uranium extraction and acid consumption tests (Table 4).

TABLE 4

Uranium Extraction and Acid Consumption Data for Faraday Combined
Flotation Tailings

Test No.	Controlled pH	Leach Charge		Acid Consump. H ₂ SO ₄ (lb/ton ⁴ feed)	U ₃ O ₈ Extraction (%)	
		Feed	NaClO ₃ (lb/ton)		Feed	Overall
139	1.50	original ore	2	44.2	94.4	94.4
132	1.35	composite tailings	2	38.2	93.3	92.1
130	1.50		2	32.8	93.3	92.1
131	1.80		2	21.2	91.0	89.8

TABLE 5

Data from Extraction Tests on Faraday Ore and Combined Flotation Tailings

Test No.	Leach Feed % U_3O_8	Leach Liquor					Wash Filtrate					Total Soluble Contents		Leach Residue	
		pH	Vol (ml)	U_3O_8 (g/l)	Al (g/l)	SiO_2 (g/l)	pH	Vol (ml)	U_3O_8 (g/l)	Al (g/l)	SiO_2 (g/l)	Al (g)	SiO_2 (g)	Wt (g)	U_3O_8 (%)
139*	0.12	1.40	560	1.15	0.88	0.83	1.40	757	0.39	0.28	0.23	0.70	0.64	993	0.008
132**	0.089	1.20	515	1.29	1.23	1.35	1.35	780	0.39	0.40	0.29	0.95	0.92	988	0.006
130**	0.089	1.52	455	1.26	1.09	0.96	1.65	792	0.39	0.34	0.30	0.76	0.67	994	0.006
131**	0.089	1.70	543	1.21	0.63	0.65	1.60	767	0.34	0.20	0.21	0.50	0.51	982	0.008

* on original ore

** on combined flotation tailings

DISCUSSION

Referring to the Faraday ore, test F-9 using sodium oleate at a pH of 10 in the flotation step is an example of one of the better results obtained. In this test a rougher and two scavenger flotation concentrates were taken off; all the concentrates were combined and then cleaned. The loss of uranium in flotation was, in this case, 3.6%. Without the cleaning step, as in test F-7, the loss of uranium was 7.4%. With magnetic separation being used the uranium loss in flotation was reduced to 1.3%. The reagent cost for the flotation would be about 14 cents/ton ore (based on using oleic acid and caustic soda for the sodium oleate). The leach acid consumption was reduced by 26%, to 32.8 lb H_2SO_4 /ton.

Floating with the reagent Pamak 15 in test F-10, which is a fatty acid derived from tall oil, also resulted in tailings with a low acid consumption. However, in test F-11, when the flotation concentrates were reduced by cleaning, the acid consumption was higher, but the loss in uranium was very small. Probably when using this reagent it would not be necessary to use the cleaning step. The cost of Pamak 15 is 7.5 cents/lb plus freight, which makes the flotation reagent cost for test F-10 to be about 4 cents/ton of ore.

On the Bicroft ore, tests B-1 and B-4 showed a savings of 23.9 and 20.4 lb H_2SO_4 /ton of leach feed, respectively, however

the corresponding loss of uranium was 10.6 and 9.0%. This loss could probably be reduced considerably by magnetic separation. The above results are based on acid consumption tests only, as extraction tests were not conducted on this sample. The average acid saving based on these results would be 26.5%.

Flotation of Faraday ore gave a combined tailings product that resulted in little apparent reduction of the soluble Al and SiO₂, at optimum uranium extraction conditions. (Some uranium leach plant operators consider that these impurities have adverse effects in plant operations).

The difference in acid requirements of the original ore in acid consumption tests (Table 1) and extraction tests (Table 4) results from the effect of the oxidizing agent used in the latter tests. The ratio of the acid consumption of the optimum flotation tailing to that of the original ore are of the same order in each case.

CONCLUSION

A saving of about 26% of the sulphuric acid used in leaching Faraday ore was effected by the removal of acid consumers by flotation prior to leaching. A similar saving was indicated on Bicroft ore, based on a limited amount of work.

Promoters sodium oleate and Pamak 15 gave the best flotation results based on acid consumptions and losses of uranium. The cost of the flotation using the Pamak reagent would be less.

REFERENCES

1. M. R. Hughson. Mineralogical Report on a Bulk Sample from Faraday Mines Ltd., Bancroft, Ontario. Mines Branch Special Report SR 333/55, Department of Mines and Technical Surveys, Ottawa, Canada, (1955).
2. S. Kaiman. Mineralogy of Radioactive Ore Sample from Centre Lake Uranium Mines Ltd., Cardiff Twp., Ontario. Mines Branch Special Report SR 305/55. Department of Mines and Technical Surveys, Ottawa, Canada, (1955).

APPENDIX

Leaching Test Methods

In the acid consumption tests on Faraday and Bicroft flotation tailings and original ore samples, the feeds were dried, weighed and mixed with distilled water in a pyrex beaker. The 60% solids pulp was agitated by a glass stirrer for 24 hours at 25°C, and the pH was maintained at 1.50 with H₂SO₄ solution (1000 g H₂SO₄/l) during the retention period. The amount of acid consumed in each test (Tables 1 and 2) was calculated from the total grams of H₂SO₄ added for leaching and the weight of the ore treated. No sodium chlorate was used.

Uranium extraction and acid consumption figures were obtained for the Faraday composite tailings sample and the original ore by mixing the moist filter cake with distilled water and H₂SO₄. The 60% solids pulp was agitated by a glass stirrer in a pyrex beaker for 24 hours at 25°C, and when the desired pH was reached by the addition of acid, 2 lb NaClO₃/ton of leach feed were added to the test. Three tests were run on the composite sample at pH levels of 1.35, 1.50 and 1.80, and one test was made on the original ore at a pH of 1.50. The leach slurries were filtered on a buchner funnel and flask, and the solids in each test were washed twice with 250 ml 1/4% H₂SO₄ and once with 250 ml distilled water. The solutions were analysed for U₃O₈, Al and SiO₂, and the residues

were analysed for U_3O_8 . Uranium extraction was estimated from the U_3O_8 analyses of the leach feed and final residues, and acid consumption was obtained from the total amount of H_2SO_4 added for leaching and the weight of the ore treated.

Flotation Reagent Sources

R-801, R-3037, R-825	Cyanamid of Canada, 160 Bloor St. East, Toronto 1, Ont.
Duomac T	Armour Chemical Division, 1355 West 31st Street, Chicago 9, Illinois.
Pamak 4 and 15	Canadian Industries Ltd., Box 10, Montreal, Que.
Rosin amine	Hercules Powder Co., Wilmington, Delaware.

WRH/VFH/WAG/HWS/im