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FLOTATION OF ACID CONSUMERS FROM ELLIOT LAKE ORES

by

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

EXTRACTION METALLURGY DIVISION

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FLOTATION OF ACID CONSUMERS FROM ELLIOT LAKE ORES

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W.R. Honeywell*, V.F. Harrison*, W.A. Gow** and H. W. Smith***

SUMMARY OF RESULTS

Laboratory flotation test work was done to investigate the possibility of removing acid consuming gangue minerals from Elliot Lake uranium ores by flotation prior to leaching in an effort to reduce acid leach costs.

Uranium which reported in the flotation concentrate was partially removed by magnetic means. This uranium product was combined with the flotation tailings for extraction by leaching.

Maximum uranium extraction on the flotation tailings plus magnetics was obtained with a sulphuric acid consumption of 21.3 lb/ton as compared to 35.8 lb/ton of the whole ore. The loss of uranium by flotation was 7.6% and the overall extraction was 88.1%. The cost of the flotation reagents used would be between 7 and 10 cents per ton of ore.

It was found that the alumina and silica contents of the leach solutions were appreciably decreased by acid consumer flotation.

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INTRODUCTION

In the Elliot Lake ores some of the matrix gangue minerals are acid soluble and so account for part of the leach acid consumption. Elimination of these minerals by flotation offers a means to reduce operating costs. The object of the present flotation work was to investigate the possibility of floating off the acid consumers, including chlorite, carbonate, serpentine, micas, pyrrhotite, and then to check the acid consumption of the uranium-bearing flotation tailings and their amenability to acid leaching for uranium extraction. In current practice the acid consumption for mine ore is approximately 40 lb H_2SO_4 per ton of ore*. In order for this work to be beneficial, the saving in overall acid requirement must be more than equal to the cost of the flotation process plus the value of the uranium lost by this procedure.

In addition to the saving in acid, an important consideration would be the partial elimination of soluble silica and alumina which could have adverse effects on thickening, filtration and ion exchange.

This work was designed to complement previous studies carried out by this Division to concentrate uranium by flotation[1]. With respect to this investigation, since the ores in the Elliot Lake area are similar to one another, the results obtained on one ore would be applicable to other ores in this area.

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*Acid to maintain excess acidity not included.

DETAILS OF INVESTIGATION

The present investigation was carried out on a rod mill feed sample from an Elliot Lake area mine (our Ref. No. 6/59-11). A head sample cut from this material was analysed for uranium and other significant elements. The results are given in Table 1.

TABLE 1

Chemical Analysis* of Head Sample

	%
U_3O_8	0.13
U_3O_8 (secondary)	0.027
ThO_2	0.04
CO_2 (evolution)	0.14
CO_2 (combustion)	0.44
S (sulphate)	0.043
S (total)	2.92
As	< 0.01
P_2O_5	0.04
Fe	4.34
F	0.01
V_2O_5	0.024
Ti	0.30
Mo	0.006
Mn	0.008

*Control Analysis Section laboratory number RF-1299.

Flotation Test Work

The general test procedure was to float off the acid consumers using a laboratory flotation cell and various reagents and reagent combinations. In some tests the flotation concentrate was cleaned by high intensity magnetic separation to recover uranium in the magnetic concentrate. The acid requirement of the beneficiated material was determined by an acid leach.

1. Feed Preparation

The flotation tests were carried out on 1150 g charges ground at 67% solids in distilled water for 20 minutes in an 8 inch porcelain Abbe jar mill with 20 lb of steel balls. This produced a grind of about 55% minus 200 mesh. The ground charge was filtered and the filtrate was used as make-up water for the flotation charge.

2. Flotation

The filter cake was repulped without desliming in a 500 g Fagergren cell using sufficient filtrate to bring the pulp up to the desired level. After the addition of the reagents, the pulp was conditioned for three minutes and a rougher flotation concentrate was removed. In some tests, the rougher concentrate was cleaned, but from results obtained it was found that a rougher float followed by a scavenger float was more beneficial and this procedure was followed in most of the tests. The scavenger concentrate was combined with the rougher concentrate to make up the acid consuming flotation concentrate.

During the progress of the work a number of reagents were investigated. The main promoter reagents used were stearic acid, oleic acid, sodium oleate, R-801*, Duomac T* and di-(2-butyl octyl) amine*. If, from the results obtained, a promoter showed some promise, several additional tests were carried out using this promoter in which other variables such as pH, uranium depressant, etc. were investigated. Flotation pH was controlled by using H_2SO_4, Na_2CO_3 or NaOH. The flotation tests are listed in Tables 2 and 8.

Concentrates from flotation tests C-3, C-6, C-11 and C-12 were sent for a semi-quantitative spectrographic analysis for Fe, Mg and other significant elements, and the results are given in Table 3. Some of the flotation concentrates were examined mineralogically.

3. Magnetic Separation

While the present series of tests was being carried out, it was discovered that the uranium or associated minerals in the Elliot Lake ores were slightly magnetic in a high intensity magnetic field. Accordingly high intensity magnetic separator tests were run with the object of recovering the uranium from the acid consuming flotation concentrates.

The concentrates from flotation tests C-9 and C-10 were treated in a Jones Wet Magnetic Separator at various intensities with power settings from 0 to 25 amps (Table 4). In subsequent tests the flotation concentrates were treated at 25 amps. In each case the

*Suppliers are listed in the Appendix

magnetic uranium products were combined with the flotation tailings for the acid consumption tests. The products used for the acid consumption tests are indicated by an asterisk in Tables 2 and 8.

After an efficient method for floating acid consumers had been developed, the next step was to produce a quantity of feed material ie uranium flotation tailings plus magnetics, for acid leaching tests to determine the extraction of uranium. The flotation technique used to produce this feed material was similar to the procedure used in test C-24, detailed below. These conditions were chosen since it was considered that they gave the best overall results on the basis of acid requirement for the flotation tailings and uranium losses in the flotation concentrate. Five replicate tests, numbered 104, 105, 106, 107 and 108 were done to produce the leach feed.

Reagents Added	lb/ton
H_2SO_4	1.0
Na_2SiO_3	1.0
NaCN	0.25
Cyanamid Reagent 801	0.04
Cresylic acid	0.04
Conditioned - 3 min (pH 5.7, temp 25°C)	
Rougher float - 4 min	
Cyanamid Reagent 801	0.04
Conditioned - 3 min	
1st Scavenger float - 3 min	

The floats were combined and treated magnetically, the magnetic portion then being combined with the flotation tails for the uranium extraction test work.

The results of the above flotation and magnetic separation procedure are given in Table 5.

Leaching Test Work

The efficiencies of the flotation procedures were studied by comparing the data obtained in sulphuric acid consumption tests on some of the individual tailings and on the original ore. In these tests the leach feed was subjected to a hot sulphuric acid treatment for several hours, and the acid consumption measured. The acid consumption data obtained are given with the flotation data in Tables 2 and 8.

To ascertain the effects of the flotation procedures in both uranium extraction and acid consumption, sulphuric acid uranium leach tests were made on the combined sample of flotation tailings and magnetic fractions, and on the original ore. The test data are given in Tables 6 and 7.

Details of the methods to determine the acid consumption and uranium extraction are given in the Appendix.

RESULTS

The test data and results of the flotation and leaching test work previously described are given in the following tables and figures.

Table 2 - Flotation Test Data and Results of Several Most Promising Tests, Including Acid Consumption Results.

Table 3 - Results of Semi-Quantitative Spectrographic Analyses on Flotation Concentrates.

Table 4 - Results with Jones Wet Magnetic Separator on Flotation Concentrates for Tests C-9 and C-10.

Table 5 - Results of Flotation and Magnetic Separation to Produce Feed for Uranium Extraction Tests.

Table 6 - Leach Charges and Test Results in Leaching of Composite Flotation Tailings.

Table 7 - Leach Product Analyses.

Table 8 - Flotation Test Data and Results and Acid Consumption Test Results.

Figure 1 - Acid Consumption Versus U_3O_8 Distribution in Flotation Tailings.

In Table 2 the results of flotation tests which are considered to be the most promising are tabulated. These are chosen from the point of view of low acid consumption and low uranium loss. Some tests given in the complete table of results, Table 8, have lower acid consumption but the loss in uranium is higher.

The results of the semi-quantitative spectrographic analyses on flotation concentrates from tests C-3, C-6, C-11 and C-12 are given in Table 3. In columns 11 to 15 of Table 3, the contents (weight x analysis) are given for the more significant elements. The actual quantity (contents) is significant since different amounts of concentrate are involved.

TABLE 2

Flotation Test Data and Results of Several Most Promising Tests, Including Acid Consumption Results

Test No.	Products	Wt (%)	U_3O_8 (%)	U_3O_8 distn. (%)	Leach Acid Consumption (lb/ton Leach Feed)	Flotation Reagent Addition (lb/ton of ore): NaCN	Na_2SiO_3	Collector	pH Regulator	Cresylic Acid	pH	Remarks
	Original Ore				37.2							Comparative acid consumption test.
C-24	Non-mags	4.90	0.16	6.3		0.25	0.5	R 801	H_2SO_4	0.04	5.1	Rougher float followed by a
	Magnetics	0.62	0.71	3.6*				0.10	1.0			scavenger float.
	Tailings	94.48	0.117	90.1*	15.9			0.04				Floats combined and treated
	Products	100.00	0.123	100.0								magnetically.
C-25	Floats	4.02	0.30	8.8		0.25	1.0	R 801	H_2SO_4	0.04	5.7	Rougher float followed by a
	Tailings	95.98	0.13	91.2*	13.0			0.10	1.0			scavenger float.
	Products	100.00	0.137	100.0				0.04				
C-31	Non-mags	4.77	0.058	2.0		1.0		Duomac T	NaOH		9.9	Rougher float followed by a
	Magnetics	0.43	0.27	0.9*				0.1	1.0			scavenger float.
	Tailings	94.80	0.14	97.1*	20.5			0.1				Floats combined and treated
	Products	100.00	0.137	100.0								magnetically.
C-32	Floats	6.92	0.093	4.7				Duomac T	NaOH		9.9	Rougher float followed by a
	Tailings	93.08	0.14	95.3*	18.8			0.1	1.0			scavenger float.
	Products	100.00	0.137	100.0				0.1				NaCN not used in test.
C-34	Floats	3.68	0.33	8.8		0.25	0.5	R 801	H_2SO_4	0.04	5.7	Rougher float followed by a
	Tailings	96.32	0.13	91.2*	14.4			0.1	1.0			scavenger float.
	Products	100.00	0.137	100.0				0.04				Float temp = 51°C
C-36	Floats	1.98	0.39	6.1		0.25	2.0	R 801	H_2SO_4	0.04	5.6	Larger quantity of Na_2SiO_3 used.
	Tailings	98.02	0.12	93.9*	16.2			0.1	1.0	0.04		Very light float. Rougher float followed
	Products	100.00	0.125	100.0				0.04				by a scavenger float.

* Indicates products leached

TABLE 3

Results of Semi-Quantitative Spectrographic Analyses on Flotation Concentrates

Flotation Concentrate Test No.	Analyses %: Al	Fe	Mg	Pb	Ca	Cu	Ti	Zn	P	Contents (Weight x Analysis): Al	Fe	Mg	Ca	P
C-3	3.5	5	0.2	0.7	0.08	0.1	0.2	Tr	ND	0.052	0.075	0.003	0.001	-
C-6	4.5	8	0.2	0.6	0.06	0.1	0.3	Tr	ND	0.206	0.366	0.009	0.003	-
C-11	4	7	0.2	0.7	0.8	0.1	0.25	0.9	ND	0.050	0.087	0.0025	0.010	-
C-12	3.5	4	0.2	0.3	Tr	0.05	0.2	Tr	0.5	0.389	0.444	0.022	0.001	0.055

The mineralogical study indicated that on one of the flotation concentrates examined, 90% of the concentrate consists of quartz and sericite, while sulphides account for 8-10% of the material floated. Chlorite was not detected.

The results of treating the combined flotation concentrate from tests C-9 and C-10 on the Jones Wet Magnetic (high intensity) Separator are given in Table 4.

TABLE 4

Results with Jones Wet Magnetic Separator on Flotation Concentrates for Tests C-9 and C-10

Products	Wt (%)	U_3O_8 (%)	U_3O_8 Distn (%)
Magnetics at 0 Amps	2.0	0.22	2.0
Magnetics at 3 Amps	2.2	0.94	9.5
Magnetics at 7 Amps	2.4	0.95	10.4
Magnetics at 17 Amps	2.0	0.90	8.2
Magnetics at 25 Amps	2.8	0.72	9.2
Non-Magnetics	88.6	0.15	60.7
Flotation concentrates	100.0	0.22	100.0

The distribution of uranium in the flotation concentrates of tests C-9 and C-10 was 14.6%. Since 39.3% of this amount, or 5.7% of the original uranium, was recovered magnetically, the overall recovery of uranium for the leach feed would be 91.1% (85.4% + 5.7%).

TABLE 5

Results** of Flotation and Magnetic Separation to Produce Feed for Uranium Extraction Tests

Products	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Distn (%)
Float, non-magnetics	4.08	0.24	7.6
Float, magnetics	0.29	1.44	3.3*
Tailings	95.63	0.12	89.1*
	100.00	0.13	100.0

*These products were combined for the extraction and acid consumption leach tests.

**The above results are those obtained by combining the products from five similar flotation tests.

TABLE 6

Leach Charges and Test Results in Leaching of Composite Flotation Tailings

Test No.	Leach Charge			Test Results			
	Ore Treated	H_2SO_4 (lb/ton)	$NaClO_3$ (lb/ton)	H_2SO_4 Consumed (lb/ton)		U_3O_8 Extraction (%)	
				for leach feed	overall	for leach feed	overall
114	Orignal Ore	89	3	35.8	35.8	95.0	95.0
104	Composite Tailings	99	3	22.2	21.3	95.4	88.1
105		78	3	21.2	20.2	94.6	87.4
106		68	3	20.8	19.9	92.4	85.4
107		57	3	19.6	18.8	90.0	83.2
108		46	3	18.4	17.6	85.4	79.0

TABLE 7

Leach Product Analyses

Test	Leach Feed (% U_3O_8)	Initial Acid Conc (g H_2SO_4/l)	Leach Liquor						Wash Filtrate						Leach Residue	
			pH	Vol (ml)	U_3O_8 (g/l)	H_2SO_4 (g/l)	Al (g/l)	SiO_2 (g/l)	pH	Vol (ml)	U_3O_8 (g/l)	H_2SO_4 (g/l)	Al (g/l)	SiO_2 (g/l)	Wt (g)	U_3O_8 (%)
114	0.12	80	0.35	377	2.38	52.0	2.93	1.94	0.61	725	0.61	14.7	0.73	0.47	1124	0.006
104	0.13	80	0.30	367	2.30	66.0	1.11	1.07	0.82	745	0.37	13.9	0.19	0.18	884	0.006
105	0.13	70	0.30	365	2.18	55.0	1.13	1.24	0.88	730	0.48	11.7	0.19	0.19	982	0.007
106	0.13	60	0.40	374	2.46	44.0	1.11	1.14	1.00	725	0.46	9.6	0.18	0.20	987	0.010
107	0.13	50	0.49	350	2.37	36.0	0.98	1.19	1.10	735	0.46	8.2	0.17	0.20	986	0.013
108	0.13	40	0.65	368	2.13	24.6	0.82	1.12	1.18	738	0.41	6.4	0.16	0.19	986	0.019

TABLE 8

Flotation Test Data and Results and Acid Consumption Test Results

Test No.	Products	Wt (%)	U_3O_8 (%)	U_3O_8 Distn (%)	Leach Acid Consumption (lb/ton leach feed)	Flotation Reagent Addition (lb/ton of ore): NaCN	Na_2SiO_3	Collector	pH Regulator	Frother	pH	Remarks
Original Ore					37.2							Comparative acid consumption test.
C-1	R. Float	0.60	0.32	1.6	24.4	0.5		Alpha Sulpha Stearic			7.3	
	1st Scav. Float	0.63	0.25	1.3				0.02				
	Tailings	98.77	0.12	97.1*				0.02				
	Products	100.00	0.12	100.0								
C-2	Cl. Float	0.88	0.29	2.1	28.2	0.5		Alpha Sulpha Stearic			7.3	
	Cl. Tailings	4.42	0.21	7.4*		0.025		0.5				
	Tailings	94.70	0.12	90.5*				0.5				
	Products	100.00	0.13	100.0								
C-3	R. Float	1.49	0.50	5.2	20.6	0.5		R-801		Pine Oil	7.3	
	Tailings	98.51	0.14	94.8*				0.1		0.04		
	Products	100.00	0.14	100.0								
C-4	R. Float	3.04	0.37	7.6	19.0	0.5		R-801	H_2SO_4	Cres. Acid	5.0	pH lowered with H_2SO_4.
	Tailings	96.96	0.14	92.4*				0.1	1.0	0.04		
	Products	100.00	0.147	100.0								
C-5	R. Float	2.70	0.30	6.5	19.6	0.5	0.5	R-801	H_2SO_4		5.9	
	Tailings	97.30	0.12	93.5*				0.1	1.0			
	Products	100.00	0.125	100.0								
C-6	Cl. Float	0.72	0.41	2.3	18.6			R-801	H_2SO_4	Cres. Acid	5.0	
	Cl. Tailings	3.85	0.24	7.3				0.1	1.0	0.04		
	Tailings	95.43	0.12	90.4*								
	Products	100.00	0.127	100.0								
C-7	Cl. Float	1.13	0.41	3.5	22.2	0.1		D.D. Oleic Acid	Na_2CO_3		9.8	pH increased with Na_2CO_3.
	Cl. Tailings	14.26	0.33	35.4*				0.5	2.0			
	Tailings	84.61	0.096	61.1*								
	Products	100.00	0.37	100.0								
C-8	Cl. Float	1.19	0.37	3.4	22.0	0.05		R-825		Pine Oil	7.0	
	Cl. Tailings	10.65	0.16	13.4*				0.1		0.04		
	Tailings	88.16	0.12	83.2*								
	Products	100.00	0.127	100.0								

*Indicates products leached

TABLE 8 (continued)

Flotation Test Data and Results and Acid Consumption Test Results

Test No.	Products	Wt (%)	U_3O_8 (%)	U_3O_8 Distn (%)	Leach Acid Consumption (lb/ton leach feed)	Flotation Reagent Addition (lb/ton of Ore) NaCN	Na_2SiO_3	Collector	pH Regulator	Frother	pH	Remarks
C-9	R. Float	5.39	0.23	9.74			0.5	R-801	H_2SO_4	Cres.Acid		
	1st Scav. Float	1.77	0.20	2.75				0.1	1.0	0.04	5.3	
	Tailings	92.84	0.12	87.51*	18.8			0.1				
	Products	100.00	0.127	100.00								
C-10	R. Float	6.10	0.28	13.0		0.25	0.5	R-801	H_2SO_4	Cres.Acid	5.3	
	1st Scav. Float	2.53	0.19	3.7				0.1	1.0	0.04		
	Tailings	91.37	0.12	83.3*	18.8			0.1				
	Products	100.00	0.13	100.0								
C-11	Carb. Float	1.24	0.20	2.1				Na Oleate	Na_2CO_3			Carbonate float
	Tailings	98.76	0.12	97.9*	23.6		1.0	1.5	2.0		9.5	conditions tried
	Products	100.00	0.12	100.0								
C-12	R. Float	8.31	0.26	15.1		0.25	0.5	R-801	H_2SO_4	Cres.Acid		
	1st Scav. Float	2.80	0.22	4.3				0.2	1.0	0.04	5.5	
	Tailings	88.89	0.13	80.6*	17.0			0.1				
	Products	100.00	0.14	100.0								
C-13	R. Float	5.64	0.35	14.8		0.25	0.5	R-801	Hexameta-phosphate	Pine Oil 0.04		
	Tailings	94.36	0.12	85.2*	18.8			0.2	0.3	Fuel Oil	7.3	
	Products	100.00	0.13	100.0				0.1		0.1		
C-14	Floats**	4.57	0.39	11.8		0.25		R-801	Hexameta-phosphate	Fuel Oil 0.1	7.2	
	Tailings	95.43	0.14	88.2*	22.0			0.4	0.3	Pine Oil		
	Products	100.00	0.15	100.0						0.04		
C-15	Floats	10.29	0.22	20.1		0.25	0.5	R-801	H_2SO_4	Cres.Acid	5.6	Another ore used. The
	Tailings	89.71	0.10	79.9*	20.6			0.4	1.0	0.04		original ore consumed 29.9
	Products	100.00	0.11	100.0								lb. acid/ton
C-16	Carb. Floats	0.98	0.19	1.6			1.0	Na Oleate	Na_2CO_3		9.7	Combination of
	Cl. Float	11.66	0.30	28.6				1.0	2.0			carb. and
	Cl. Tailings	39.32	0.12	38.5*		0.25	0.5	R-801	H_2SO_4		5.7	chlorite float
	Tailings	48.04	0.08	31.3*	19.4			0.2	2.0			
	Products	100.00	0.12	100.0								
C-17	Floats**	7.82	0.32	21.3		0.25	2.0	R-801	Na_2CO_3	Na Oleate	9.6	Test similar to
	Tailings	92.18	0.10	78.7*	18.0			0.1	2.0	0.5	4.8	C-16, except
									H_2SO_4			additional
	Products	100.00	0.12	100.0					3.0			Na_2SiO_3 used

* Indicates products leached
** Combined rougher and scavenger floats

TABLE 8 (continued)

Flotation Test Data and Results and Acid Consumption Test Results

Test No.	Products	Wt (%)	U_3O_8 (%)	U_3O_8 Distn (%)	Leach Acid Consumption (lb/ton leach feed)	Flotation Reagent Addition (lb/ton of Ore) NaCN	Na_2SiO_3	Collector	pH Regulator	Frother	pH	Remarks
C-18	Floats** Tailings Products	5.72 94.28 100.00	0.38 0.14 0.15	14.1* 85.9* 100.0	19.2	0.25	0.5	R-801 0.4	Hexameta-phosphate 0.3	Pine Oil 0.04 Fuel Oil 0.1	7.2	Reagents recommended for talc float
C-19	Floats Tailings Products	13.35 86.65 100.00	0.19 0.075 0.09	28.1 71.9* 100.0	17.3	0.25	0.5	R-801 0.1	Hexameta-phosphate 0.3 H_2SO_4 0.5	Pine Oil 0.04 Fuel Oil 0.5	5.0	Similar to C-19, except pH
C-20	Floats** Tailings Products	7.46 92.54 100.00	0.28 0.16 0.17	12.4 87.6* 100.0	22.0		0.5	R-801 0.1	Hexameta-phosphate 0.3	Cres.Acid 0.04	6.7	
C-21	Floats** Tailings Products	9.62 90.38 100.00	0.18 0.12 0.13	13.8 86.2* 100.0	21.2		0.5	R-801 0.1	Hexameta-phosphate 0.3 NaOH 0.5	Cres.Acid 0.04	9.7	pH adjusted with NaOH
C-22	Floats Tailings Products	7.37 92.63 100.00	0.077 0.125 0.12	4.7 95.3* 100.0	21.0	1.0		Duomac T 0.2	NaOH 1.0		10.7	
C-23	Non-mags. Magnetics Tailings Products	3.17 0.44 96.39 100.00	0.22 0.79 0.13 0.136	5.2 2.6* 92.2* 100.0	16.8	0.25	0.5	R-801 0.10 0.04	H_2SO_4 1.0	Cres.Acid 0.04	5.3	R. Float, Scavenger Float Floats combined and treated magnetically
C-24	Non-mags. Magnetics Tailings Products	4.90 0.62 94.48 100.00	0.16 0.71 0.117 0.123	6.3 3.6* 90.1* 100.0	15.9	0.25	0.5	R-801 0.10 0.04	H_2SO_4 1.0	Cres.Acid 0.04	5.1	R. Float, Scavenger Float Floats combined and treated magnetically
C-25	Floats** Tailings Products	4.02 95.98 100.00	0.30 0.13 0.137	8.8 91.2* 100.0	13.0	0.25	1.0	R-801 0.10 0.04	H_2SO_4 1.0	Cres.Acid 0.04	5.7	
C-26	Float Tailings Products	2.68 97.32 100.00	0.32 0.15 0.155	5.6 94.4* 100.0	13.0	0.25	0.5	R-801 0.1	H_2SO_4 1.0	Cres.Acid 0.04	4.0	-100 + 325M only floated

* Indicates products leached
** Combined rougher and scavenger floats

TABLE 8 (continued)

Flotation Test Data and Results and Acid Consumption Test Results

Test No.	Products	Wt (%)	U_3O_8 (%)	U_3O_8 Distn (%)	Leach Acid Consumption (lb/ton leach feed)	Flotation Reagent Addition (lb/ton of Ore)					pH	Remarks
						NaCN	Na_2SiO_3	Collector	pH Regulator	Frother		
C-27	Floats	3.02	0.38	9.0	16.3		0.2	Kerosene 0.25	Na_2CO_3 1.0	Pine Oil 0.12	9.1	Pine oil and kerosene used
	Tailings	96.98	0.12	91.0*								
	Products	100.00	0.13	100.0								
C-28	Floats**	23.68	0.18	30.0	12.3	0.5		Duomac T 0.2	NaOH 1.0	Pine Oil 0.08	10.0	
	Tailings	76.32	0.13	70.0*								
	Products	100.00	0.14	100.0								
C-29	Floats**	5.71	0.27	12.0	16.9		0.2	Fuel Oil 0.25	Na_2CO_3 1.0	Pine Oil 0.12	9.0	Pine oil and fuel oil used
	Tailings	94.29	0.12	88.0*								
	Products	100.00	0.13	100.0								
C-30	Float	12.96	0.17	17.4	19.3	0.5		Duomac T 0.1	NaOH 1.0	Pine Oil 0.04	9.9	
	Tailings	87.04	0.12	82.6*								
	Products	100.00	0.126	100.0								
C-31	Non-mags.	4.77	0.058	2.0	20.5	1.0		Duomac T 0.1 0.1	NaOH 1.0		9.9	R. Float and Scavenger Floats combined and treated magnetically
	Magnetics	0.43	0.27	0.9*								
	Tailings	94.80	0.14	97.1*								
	Products	100.00	0.137	100.0								
C-32	Floats**	6.92	0.093	4.7	18.8			Duomac T 0.2	NaOH 1.0		9.9	
	Tailings	93.08	0.14	95.3*								
	Products	100.00	0.137	100.0								
C-33	Floats**	4.01	0.31	9.72	13.4	0.25	0.5	R-801 0.1 0.04	H_2SO_4 1.0	Cres.Acid 0.04	5.5	Float temp 43°C
	Tailings	95.99	0.12	90.28*								
	Products	100.00	0.128	100.00								
C-34	Floats**	3.68	0.33	8.8	14.4	0.25	0.5	R-801 0.1 0.04	H_2SO_4 1.0	Cres.Acid 0.04	5.7	Float temp 51°C
	Tailings	96.32	0.13	91.2*								
	Products	100.00	0.137	100.0								
C-35	Non-mags.	4.77	0.14	5.4	19.7	0.25	1.0	R-801 0.1 0.04	H_2SO_4 1.0	Cres.Acid 0.04	5.7	Coarser grind used 32.1% -200M
	Magnetics	0.50	0.80	3.2*								
	Tailings	94.73	0.12	91.4*								
	Products	100.0	0.127	100.0								

* Indicates products leached

** Combined rougher and scavenger floats

TABLE 8 (concluded)

Flotation Test Data and Results and Acid Consumption Test Results

Test No.	Products	Wt (%)	U_3O_8 (%)	U_3O_8 Distn (%)	Leach Acid Consumption (lb/ton leach feed)	Flotation Reagent Addition (lb/ton of Ore)					pH	Remarks
						NaCN	Na_2SiO_3	Collector	pH Regulator	Frother		
C-36	Float **	1.98	0.39	6.1		0.25	2.0	R-801	H_2SO_4	Cres. Acid	5.6	Double quantity of Na_2SiO_3 used. Very light float.
	Tailings	98.02	0.12	93.9*	16.2			0.1	1.0	0.04		
								0.04		0.04		
	Products	100.00	0.125	100.0								
C-37	Float	5.06	0.17	6.5				Amine		Cres. Acid	6.1	Di-(2-Butyl Octyl) Amine used.
	Tailings	94.94	0.13	93.5*	17.0			0.08		0.04		
	Products	100.00	0.132	100.0								
C-38	Sul. Float	3.52	0.050	1.5				R-801	NaOH	Cres. Acid	10.8	Both Duomac T and R-801 used.
	Chlorite Fl.	9.85	0.18	14.3			1.0	0.1	1.0	0.04	5.0	
	Tailings	86.63	0.12	84.2*	16.2			Duomac T	H_2SO_4			
									2.0			
	Products	100.00	0.124	100.0								
C-39	Float **	5.14	0.28	12.1		0.25	1.0	R-801	H_2SO_4	Cres. Acid	5.5	
	Tailings	94.86	0.11	87.9*	15.1			0.1	1.0	0.04		
								0.04				
	Products	100.00	0.12	100.0								

* Indicates products leached.
** Combined rougher and scavenger floats.

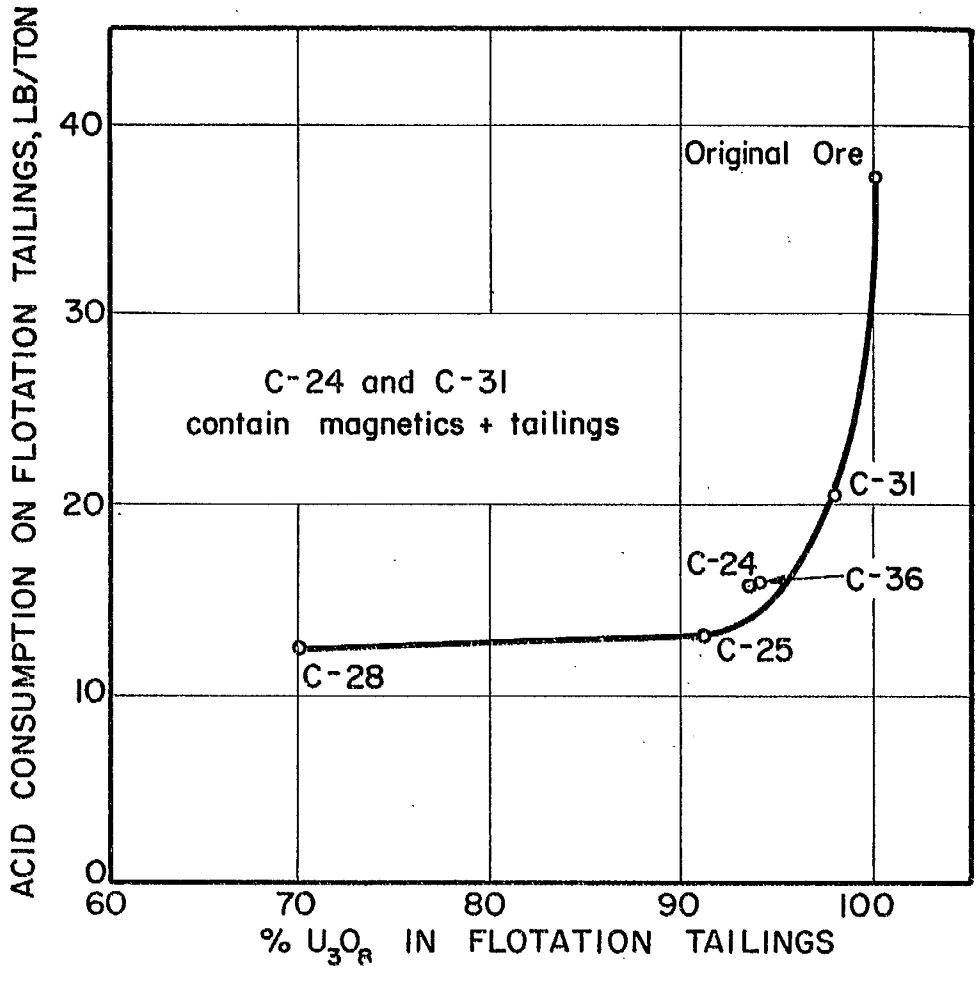

FIGURE I

ACID CONSUMPTION VERSUS

U_3O_8 DISTRIBUTION IN FLOTATION TAILINGS

DISCUSSION

In the flotation work, tests C-24 and C-25 have shown the best overall results on the basis of acid requirement for the flotation tailings and uranium losses in the flotation concentrates, and thus it appears that the fatty acid reagent Cyanamid R-801 was the most efficient of the reagents investigated. The diamine type, Duomac T, shows good possibilities, as indicated by test C-31. Flotation reagent costs should be moderate, of the order of 7-9 cents/ ton.

Conditions found to be beneficial with the reagent R-801 were the use of sulphuric acid to give a float pH of 5-6, and heating the pulp to 50°C

Some of the uranium or associated minerals were found to be slightly magnetic and the high intensity Jones Magnetic Separator recovered approximately one third of the uranium lost in the flotation concentrate. There are commercial size separators of this type available which could be suitable for an operating plant.

Flotation of the acid consuming minerals did not reduce the amount of free acid initially required for leaching, and therefore recycling part of the leach liquor would be essential if the reduction in acid consumption is to be realized.

An important result from flotation of the acid consuming minerals from Denison ore was the reduction, in the subsequent leaching step, of the amount of dissolved Al and SiO_2. Since SiO_2 can be detrimental to ion exchange operations, the lower concentration figure obtained from the tailings sample might assist in extending resin life. Presence of soluble Al is said to hinder filtration of the neutralized leach slurries, and keeping it to a minimum value would be helpful in plant practice. Filtration of the leach pulp was observed to be normal for a vacuum of 25 in. of Hg, but the solids washing rate was slower than that for leached solids from the original ore.

CONCLUSION

The significant features in the beneficiation of this ore by acid consumer flotation could be (1) a saving of up to 40% of the acid actually consumed, (2) a decrease in acid soluble impurities, (3) little change in the filtration properties of the leach slurries, (4) a reduction of 7% in overall uranium recovery in solution, (5) an additional reagent cost of 7-9 cents/ ton for flotation.

Promoters R-801 and Duomac T were the most suitable of the reagents tried.

ACKNOWLEDGMENT

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REFERENCE

1. W.R. Honeywell. Flotation of Uranium Ores from the Elliot Lake Area, Ontario, Mines Branch Technical Bulletin TB 2, Department of Mines and Technical Surveys, Ottawa, (1959).

APPENDIX

Leaching Test Methods

Acid Consumption Tests

The flotation tailings samples C-1 to C-39, weighing from 292 to 1000 grams, and a 1000 gram original ore sample were leached with sulphuric acid for 4 hours retention time at a constant temperature of 88°C and at a solution concentration of 60 to 65 g H_2SO_4/l. The 55 to 60% minus 200 mesh leach feeds were dried, weighed and mixed with a sufficient quantity of distilled water and the required amount of acid to give a pulp density of 60% solids. The equipment consisted of a pyrex beaker with cover and glass stirrer, and an electric heating mantle. The final slurries were filtered in a buchner funnel and flask, and the solids washed three times with distilled water to recover all the unused acid. The total acid present in solution at the end of leaching was estimated from the volumes and free H_2SO_4 analyses of the leach liquor and combined wash filtrates. The acid consumption was then calculated on the difference between the H_2SO_4 added and the unreacted H_2SO_4 in solution, and the weight of the leach feed treated.

Uranium Extraction Tests

Extraction tests were made on five batches of the composite tailings sample and on one batch original ore sample in a covered pyrex beaker, with glass stirrers, set in a water bath. Nine hundred grams of feed were leached in test 104, 1000 grams in tests 105, 106, 107 and 108 and 1140 grams in test 114. The following leaching conditions were employed: 55 to 60% minus 200 mesh feed, 50°C temperature, 48 hr retention time, 3 lb $NaClO_3$/ton of feed, 65% solids pulp density and from 40 to 80 g H_2SO_4/l initial acid concentrations. On the original ore, an initial acid concentration of 80 g H_2SO_4/l was used because this particular concentration yielded optimum uranium extraction for the combined tailings sample. The slurries were prepared for leaching by mixing the moist feed with distilled water and sulphuric acid, and adding the oxidizing reagent one half hour after beginning of agitation. The filtered leach pulp was washed twice with 250 ml of 1/4% H_2SO_4 and once with 250 ml of distilled water. The solutions were analyzed for U_3O_8, free H_2SO_4, Al and SiO_2, and the leach residue for U_3O_8. Uranium extraction was based on the U_3O_8 analyses of the feed and residue. Acid consumption was based on the difference between the amount of acid added and that remaining in the solution after leaching.

Close agreement was noted in acid consumptions obtained by the rapid method of leaching the ore at 88°C for 4 hr and the standard method of leaching at 50°C for 48 hr. The rapid method gave a figure of 37.2 lb H_2SO_4/ton compared to 35.8 lb H_2SO_4/ton for standard leaching. The acid consumption at the mine leach plant is approximately 40 lb H_2SO_4/ton. No difference could be observed in the filtering characteristics of the leach slurries or in the clarity of the solutions between those of the original ore and the flotation tailings.

<u>Flotation Reagent Sources</u>

R-801	Cyanamid of Canada, 160 Bloor St. East, Toronto 1, Ont.
Duomac T	Armour Chemical Division, 1355 West 31st, Chicago 9, Ill., U.S.A.
di-(2-butyl octyl)amine	Carbide and Carbon Chemicals Co., 30 East 42nd St., New York 17, N.Y., U.S.A.

WRH/ VFH/ WAG/ HWS/ im