

# Flotation of Nb, Ta and Sn Ores

Metallurgical Research and Development

## Breakthrough in Beneficiation of Niobium, Tantalum/Niobium and Tin Ores Using Flotation Techniques

### INTRODUCTION

The recoveries of niobium, tantalum and tin are usually quite low in operating plants treating niobium, tantalum/niobium and tin ores, and the concentrates often contain an appreciable amount of unwanted impurities. Losses of  $\text{Nb}_2\text{O}_5$ ,  $\text{Ta}_2\text{O}_5$  and  $\text{SnO}_2$  to the tailings can be attributed to a number of factors, some of which include:

- The nature and complex mineralogy of the ore
- The presence of fines (common with tin ores)
- The nature and occurrence of the niobium, tantalum and tin minerals.

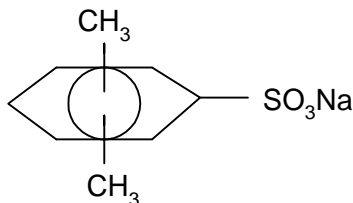
In the past 6 years, extensive research work has been carried out on a number of new deposits of niobium (Africa, Canada), tantalum/niobium (Australia, China and South America) and tin ores (South America), as well as existing operations, to develop new treatment processes for the beneficiation of these ores and to improve plant metallurgical results. These were ores or gravity tailings that were generally not readily amenable to physical concentration.

During this research programme, several new collectors with unique chemistry were developed, which yielded significant improvement in the floatability of niobium, tantalum and tin minerals.

### CHEMISTRY OF THE NEW COLLECTORS

#### Niobium and Tantalum/Niobium Collectors

The new niobium and tantalum/niobium collectors are a reaction product of alkyl sulphate, xylene sulphate with the following, general formula



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WHEN YOU NEED TO BE SURE

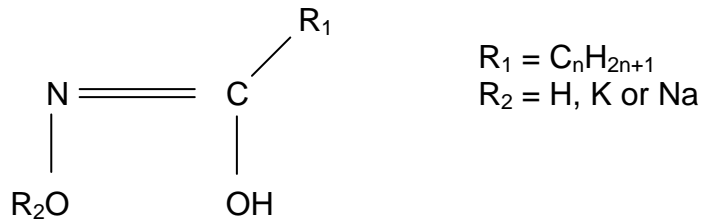
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and an amine with the formula



These collectors belong to the 'MP' series and are very effective for the treatment of tantalum and tantalum/niobium ores.

Collectors from the 'MR' series are products of the reaction between alkyl hydroxamate, with the general formula,



cocosalkyl phosphate and the amine from the MP series. The collectors from the MR series are also very effective for the treatment of niobium ores.

## TIN COLLECTOR

This collector is a reaction product of alkyl sulphates, alkyl hydroxamates and sulpho succinamates. These collectors have no frothing properties, they are insensitive to the presence of slimes and are designed for the recovery of fine tin and tin middlings. They are known as collectors from the 'TX' series.

## EXAMPLES OF THE PERFORMANCE OF THE NEW COLLECTORS

### The Effectiveness of the New Collectors for Niobium Flotation

#### - High iron niobium ore from Africa

This ore was composed of hematite and iron hydroxide slimes, with a small amount of dolomitic gangue and silica. Comparative flotation tests were conducted using a traditional amine collector and the new collectors, MR102 and MR107, in which the designations 102 and 107 refer to different ratios of alkyl hydroxamate to amine.

The results of these comparative tests are summarized in Table 1. Significant improvements in the niobium concentrate grade and recovery have been demonstrated using the new collectors, with the best metallurgical results being obtained using MR107.

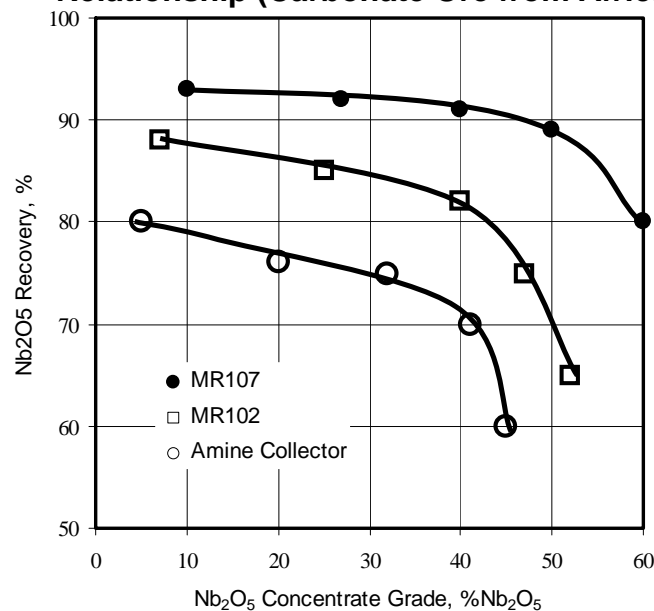
**Table 1. Effect of Collectors from the MR Series on Niobium Flotation from High Iron Ore**

Collector	Product	Weight %	Assays % Nb <sub>2</sub> O <sub>5</sub>	% Distribution Nb <sub>2</sub> O <sub>5</sub>
600 g/t Amine	Nb <sub>2</sub> O <sub>5</sub> CI Conc	3.50	42.5	59.1
	Nb <sub>2</sub> O <sub>5</sub> Ro Conc	26.42	7.20	75.5
	Nb <sub>2</sub> O <sub>5</sub> Ro Tail	63.78	0.75	19.0
	Slimes	9.80	1.42	5.5
	Head (Calc)	100.00	2.52	100.0
480 g/t MR102	Nb <sub>2</sub> O <sub>5</sub> CI Conc	3.46	56.6	78.7
	Nb <sub>2</sub> O <sub>5</sub> Ro Conc	12.61	17.6	88.4
	Nb <sub>2</sub> O <sub>5</sub> Ro Tail	77.73	0.20	6.2
	Slimes	9.66	1.40	5.4
	Head (Calc)	100.00	2.51	100.0
480 g/t MR107	Nb <sub>2</sub> O <sub>5</sub> CI Conc	3.71	54.6	80.3
	Nb <sub>2</sub> O <sub>5</sub> Ro Conc	13.66	16.9	91.6
	Nb <sub>2</sub> O <sub>5</sub> Ro Tail	76.04	0.09	2.8
	Slimes	10.30	1.38	5.6
	Head (Calc)	100.00	2.52	100.0

**- Carbonate ore from Africa**

This ore was composed of dolomite, calcite and apatite, with pyrochlore as the main niobium mineral. Collectors MR102 and MR107 and a standard amine reagent were evaluated on this ore after a carbonate prefloat. Figure 1 shows the grade-recovery relationship obtained with the different collectors. There was substantial improvement in both niobium grade and recovery using the new niobium collectors, with MR107 again producing the best results.

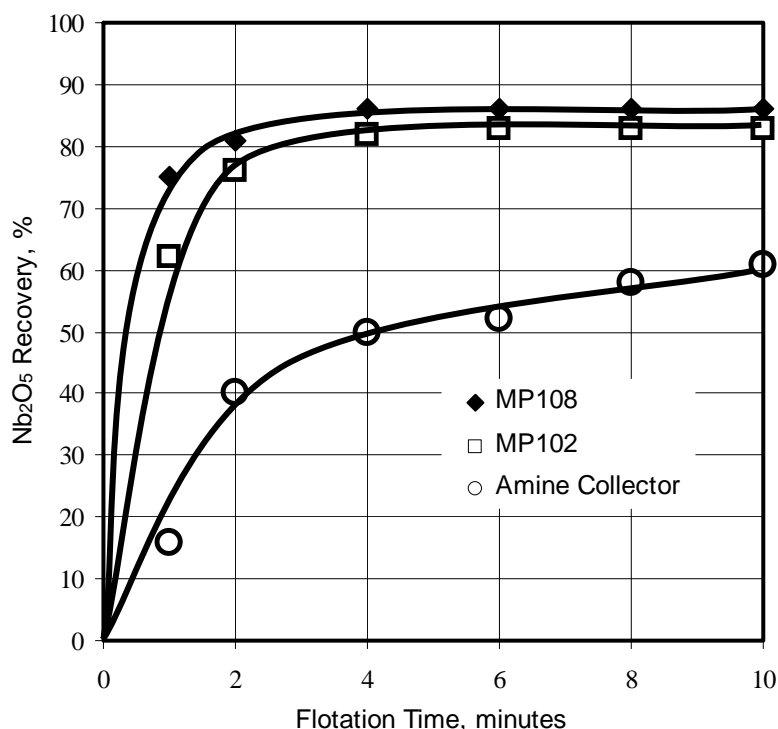
**Figure 1. Effect of Collectors MR102 and MR107 on Niobium Grade-Recovery Relationship (Carbonate Ore from Africa)**



## Niobium ore from Canada

This ore was composed of dolomite, calcite, apatite, hematite and iron hydroxide slimes, and was considered to be refractory to conventional treatment. The niobium was present as a variety of niobium minerals including columbite, pyrochlore and plumbopyrochlore, most of which were in the crystalline form. Figure 2 shows the rate of niobium flotation using a standard amine collector and collectors from the MP series.

**Figure 2. Effect of the New MP Collectors on the Rate of Niobium Flotation**



The improvement in the rate of flotation using the new collectors was quite dramatic. Because of the high rate of niobium flotation during roughing, niobium losses during cleaning were significantly reduced. The results from batch cleaning tests obtained with amine and MP108 are shown in Table 2.

Not only was there improvement in niobium recovery, but concentrate grade also increased and impurity levels were reduced substantially.

**Table 2. Effect of Collector MP108 on Niobium Upgrading**

Collector	Product	Weight %	Assays %		% Distribution	
			Nb <sub>2</sub> O <sub>5</sub>		Nb <sub>2</sub> O <sub>5</sub>	
465 g/t Amine	Nb <sub>2</sub> O <sub>5</sub> 5th Cl Conc	0.66	48.3		50.2	
	Nb <sub>2</sub> O <sub>5</sub> Ro Conc	10.24	4.30		68.8	
	Combined Tails*	83.35	0.21		26.7	
	Slimes	6.41	0.45		4.5	
	Head (Calc)	100.00	0.64		100.0	
500 g/t MP108	Nb <sub>2</sub> O <sub>5</sub> 5th Cl Conc	0.80	58.5		72.2	
	Nb <sub>2</sub> O <sub>5</sub> Ro Conc	6.61	8.51		86.4	
	Combined Tails*	87.19	0.07		9.4	
	Slimes	6.20	0.44		4.2	
	Head (Calc)	100.00	0.65		100.0	

\*includes niobium tails, calcite cleaner concentrate and magnetics

### The Effectiveness of the New Collectors for Tantalum/Niobium Flotation

The new collectors were examined on an ore from Greenland and the gravity tailings from an operating plant in Australia. Collectors MP102 and MP108 were tested on the ore from Greenland, and the comparative results are presented in Table 3, where they are compared with a more traditional collector, PL5191.

**Table 3. Effect of MP102 and MP108 on Tantalum/Niobium Flotation on an Ore from Greenland**

Collector	Product	Weight %	Assays %		% Distribution	
			Ta <sub>2</sub> O <sub>5</sub>	Nb <sub>2</sub> O <sub>5</sub>	Ta <sub>2</sub> O <sub>5</sub>	Nb <sub>2</sub> O <sub>5</sub>
330 g/t PL519	Ta/Nb Bulk Cl Conc	4.25	0.57	11.5	58.1	66.0
	Ta/Nb Bulk Ro Conc	20.48	0.15	2.8	75.4	77.5
	Ta/Nb Ro Tail	76.12	0.012	0.20	22.1	20.2
	Slimes	3.40	0.030	0.50	2.5	2.3
	Head (Calc)	100.00	0.042	0.74	100.0	100.0
420 g/t MP102	Ta/Nb Bulk Cl Conc	2.17	1.28	26.6	73.1	80.0
	Ta/Nb Bulk Ro Conc	9.82	0.33	6.6	85.3	90.0
	Ta/Nb Ro Tail	86.52	0.006	0.06	11.8	7.2
	Slimes	3.66	0.030	0.55	2.9	2.8
	Head (Calc)	100.00	0.038	0.72	100.0	100.0
460 g/t MP108	Ta/Nb Bulk Cl Conc	2.11	1.42	28.4	75.1	82.3
	Ta/Nb Bulk Ro Conc	9.25	0.37	7.20	86.2	91.2
	Ta/Nb Ro Tail	87.55	0.005	0.05	11.2	6.5
	Slimes	3.20	0.031	0.53	2.6	2.3
	Head (Calc)	100.00	0.040	0.73	100.0	100.0

<sup>1</sup> S. Bulatovic, E. de Silvio, 'Process Development for Impurity Removal from a Tin Gravity Concentrate', Minerals Engineering, Vol 13, No. 8-9, pp871-879, 2000.

Substantial improvements in both concentrate grade and recovery were achieved using collectors from the MP series.

Collector MP108 was compared with collector CBS4 in an examination of the Australian gravity tailings, which were high in muscovite and iron oxides. CBS4 had been evaluated previously in a pilot plant in Australia<sup>2</sup>. A portion of the tantalum in the feed to these tests was in the form of middlings from the operating plant. Results from the comparative tests are shown in Table 4.

**Table 4. Effect of Collector MP108 on Tantalum/Niobium Flotation from Gravity Tailings**

Collector	Product	Weight %	Assays %		% Distribution	
			Ta <sub>2</sub> O <sub>5</sub>	Nb <sub>2</sub> O <sub>5</sub>	Ta <sub>2</sub> O <sub>5</sub>	Nb <sub>2</sub> O <sub>5</sub>
330 g/t CBS4	Gravity Conc	0.46	4.4	14.4	55.2	60.1
	Ta/Nb 3 <sup>rd</sup> CI Conc	5.18	0.50	1.58	70.1	74.3
	Ta/Nb Ro Conc	22.58	0.12	0.38	77.3	76.8
	Ta/Nb Ro Tail	74.32	0.01	0.03	25.1	20.1
	Slimes	3.10	0.02	0.11	1.6	3.1
	Head (Calc)	100.00	0.037	0.11	100.0	100.0
300 g/t MP108	Gravity Conc	0.21	12.1	36.7	70.0	77.1
	Ta/Nb 3 <sup>rd</sup> CI Conc	2.47	1.2	3.32	82.6	85.0
	Ta/Nb Ro Conc	15.40	0.20	0.57	85.5	88.0
	Ta/Nb Ro Tail	81.80	0.005	<0.01	12.8	9.2
	Slimes	2.80	0.02	0.10	1.7	2.8
	Head (Calc)	100.00	0.036	0.10	100.0	100.0

From the results obtained, it was demonstrated that over 70% of the tantalum in the gravity tailings was recoverable in a relatively good concentrate.

### Evaluation of the New Tin Collector

The new tin collector was examined on a sample of gravity tailings from an operating plant in South America. The sample used in this testwork contained high amounts of slimes (<20µm). Tin from this tailing is being floated in a commercial plant using a Cytec succinamate collector, R845. One of the main problems experienced in the plant has been high loss of tin in the slime fraction and poor floatability of the middlings. To reduce tin losses in the slime fraction, desliming was performed at 4µm in the lab testwork, by simulating thickener desliming. Comparative tests were then carried out using the new TX4 and TX5 collectors on lightly deslimed gravity tailings. The results are shown in Table 5, where they are compared with the performance of R845.

When using the new collector, not only was the tin recovery improved, but an appreciable improvement in selectivity was realised. This was attributed in part to an

<sup>2</sup> S. Bulatovic, Report of Investigation, Pilot Plant Tests, May 2001

improvement in the rate of tin flotation, as illustrated in Figure 3, and a reduction in the excess frothing that is a feature of the performance of R845.

**Table 5. Effect of the New Tin Collectors on Tin Flotation from a Gravity Tailing**

Collector	Product	Weight %	Assays % SnO <sub>2</sub>	% Distribution SnO <sub>2</sub>
440 g/t R845	SnO <sub>2</sub> 3 <sup>rd</sup> Cl Conc	2.87	22.0	55.0
	SnO <sub>2</sub> Ro Conc	19.26	4.0	67.0
	SnO <sub>2</sub> Ro Tail	72.24	0.41	25.5
	Slimes	8.50	1.01	7.5
	Head (Calc)	100.00	1.16	100.0
420 g/t TX4	SnO <sub>2</sub> 3 <sup>rd</sup> Cl Conc	2.31	38.5	75.4
	SnO <sub>2</sub> Ro Conc	11.87	8.8	88.5
	SnO <sub>2</sub> Ro Tail	79.35	0.06	4.2
	Slimes	8.60	1.01	7.3
	Head (Calc)	100.00	1.18	100.0
550 g/t TX5	SnO <sub>2</sub> 3 <sup>rd</sup> Cl Conc	2.01	46.2	80.0
	SnO <sub>2</sub> Ro Conc	9.67	10.2	85.1
	SnO <sub>2</sub> Ro Tail	82.83	0.12	8.6
	Slimes	7.50	0.99	6.4
	Head (Calc)	100.00	1.16	100.0

**Figure 3. Rate of Tin Rougher Flotation Using Different Collectors**

