TRI-76-82

R. 305

MOINA TUNGSTEN—TIN MINING CO

RECOVERY OF BISMUTH CONCENTRATE FROM STORED REJECT PYRITE PRODUCT

Sample

A drum containing 80 lbs of moist pyrite reject was received from the company on the 30th November, 1956.

The necessity for the retention of the sample in its moist condition made it difficult to cut out a representative head sample, and to ensure that some 55 flotation charges similarly cut out were substantially identical. Under the circumstances some discrepancies between assayed and derived heads inevitably show up in the tests.

Analysis of Head Sample

Bi	14.3 per cent, equivalent to Bi_2S_3		17.6 per cent
Sn	5.3 per cent, equivalent to SnO_2		6.7 per cent
Fe	33.3 per cent, equivalent to	FeS_2	63.7 per cent
		Fe_2O_3	4.6 per cent
Zn	1.0 per cent, equivalent to ZnS		1.5 per cent
Cu	0.4 per cent, equivalent to $CuFeS_2$		1.2 per cent
MoS_2	N.D. (present)		
Pb	Nil		
S	38.2 per cent		
Acid Insol.	2.9 per cent	Insol.	2.9 per cent
	95.4 per cent		98.2 per cent

The predominant sulphide is pyrite, followed by bismuthinite sphalerite and chalcopyrite.

Investigation

The company requested research to develop flotation procedure for the recovery of a saleable bismuth product from a quantity of this pyrite reject now in wet storage.

No responsibility is accepted for the results shown in this report except in so far as they apply to the sample tested.

Summary

The problem was approached from two angles:—

A. Attempts to float a saleable bismuth product, leaving the pyrite depressed in a waste sink product.

The following two tests show the bismuth concentrate obtained with a small amount of xanthate after depression of the pyrite with lime and cyanide.

		Per cent		Per cent Recovery	
Test 14	**Wght.**	**Bi**	**Sn**	**Bi**	**Sn**
Bismuth Conc.	20.2	47.35	6.1	68.7	23.6
Test 17					
Bismuth Conc.	20.9	43.5	8.1	72.7	53.2

Attempts to upgrade these rougher concentrates by cleaning were failures, the improvement in bismuth tenor being negligible. This method shows a marked separation of the tin and bismuth, only 25 to 50 per cent of the tin being floated with the bismuth.

B. Attempts to float a waste pyrite product, leaving the bismuth depressed in a saleable sink product.

This objective was achieved in a number of tests by modifying the surface of the bismuth mineral with various reagents to reduce its flotability while leaving the pyrite so little altered that it can be floated off without additional reagent other than frother, or with the help of a minor amount of a selective promoter.

		Per cent		Per cent Recovery		Bismuth Modifying
Test 8	**Wght.**	**Bi**	**Sn**	**Bi**	**Sn**	**Reagents**
Bismuth Product	33.0	34.9	10.6	84.7	83.2	Sod. silicate
Test 22						
Bismuth Product	33.1	38.0	13.2	86.7	86.4	$KMnO_4 + H_2SO_4$
Test 20						
Bismuth Product	38.6	35.0	13.0	94.5	93.2	$K_2Cr_2O_7 + H_2SO_4$
Test 33						
Bismuth Product	30.5	42.0	N.D.	91.8	....	$K_2Cr_2O_7 + H_2SO_4$
Test 35						
Bismuth Product	33.9	38.6	15.4	90.8	94.0	$K_2Cr_2O_7 + H_2SO_4$
Test 38						
Bismuth Product	38.7	34.2	13.0	92.6	93.0	$K_2Cr_2O_7 + H_2SO_4$
Test 50						
Bismuth Product	31.8	39.4	N.D.	89.5	....	$K_2Cr_2O_7 + H_2SO_4$

The differential between pyrite and bismuth created by the above modifying reagents was neither as complete nor as positive as could be desired. Some pyrite was depressed with the bismuth, and attempts to float off such pyrite with small amounts of promoter, particularly xanthate, resulted in much bismuth also floating. All the above bismuth products therefore contain some pyrite dilution.

In all method B tests the tin remained with the bismuth. Recoveries of both bismuth and tin are much higher than in method A, but the bismuth content of the product is lower.

The composition of the bismuth products made by the two methods is generally as follows:—

	A. Floated Bismuth Product	B. Residual Bismuth Product
Bi	46.5 per cent	37.7 per cent
Sn	7.3 per cent	14.3 per cent
Fe	9.6 per cent	14.0 per cent
Cu	0.5 per cent	0.4 per cent
Zn	0.6 per cent	0.5 per cent
As	Possible trace	Possible trace
S	19.9 per cent	18.3 per cent
Acid Insoluble	10.3 per cent	6.6 per cent

Of the two methods, A is perhaps the more positive and reliable in operation, at the cost of lower recoveries. It might be more satisfactory than B on low bismuth feed.

Method B may have been especially favoured by the relatively high bismuth content of the sample. A previous sample contained only five per cent of bismuth, and this depression technique may be of little value for such low-grade material. The sodium silicate procedure was simple and apparently positive in action, again at some expense in grade and recovery. Not enough tests were done with $KMnO_4$ to expose its possibilities, but it appears to hold considerable promise. The $K_2Cr_2O_7$ showed generally higher grades and recoveries but behaved erratically in some tests, possibly because, at the low pH used in all its tests, it established the flotation differential by surface cleansing instead of decisive chromate film depression of the bismuth. With both sodium silicate and potassium dichromate the floated pyrite was a brilliant brass colour.

Both methods yielded highly enriched bismuth products, but, probably hampered by existing reagent coatings on the constituent sulphide minerals, neither achieved a high-grade bismuth concentrate.

Test Results

Method A

This method was used for tests 10 to 19 inclusive and 26.

Test 14—Rougher-Cleaner Flotation with Lime and Cyanide.

Flotation Conditions	lbs. ton/minutes	
Reagents	**Rougher**	**Cleaner**
*Lime	1.0	0.5 In dilute
*Sodium Cyanide	0.75/5	0.25/5 pulp
Soda Ash	2.25	....
Potassium Amyl Xanthate	0.09(3 stages)	0.03(2 stages)
Cresylic Acid	0.30(3 stages)	....
Flotation time, minutes	/16	/5
pH value	9.8 /9.2	/8.5

* Scrub in thick pulp, then dilute to flotation volume.

		Per cent		Per cent Dist.	
	Wght.	**Bi**	**Sn**	**Bi**	**Sn**
Cleaner Conc.	18.0	50.8	4.46	65.7	15.2
Cleaner Tailing	2.2	19.2	20.0	3.0	8.4
Rougher Tailing	79.8	5.45	5.05	31.3	76.4
Composite	100.0	13.9	5.3	100.0	100.0
Rougher Conc.	20.2	47.35	6.1	68.7	23.6

Test 17

This was similar to Test 14 except that a little more lime and cyanide (1.5 and 1 lbs. respectively) were used in the rougher. The rougher concentrate was cleaned twice, greatly reducing the tin recovery figure while giving only a minor increase in bismuth tenor.

		Per cent		Per cent Dist.	
	Wght.	**Bi**	**Sn**	**Bi**	**Sn**
Recleaned Conc.	17.7	45.7	7.0	64.6	38.6
Rougher Conc.	20.9	43.5	8.1	72.7	53.2

In both tests the pulp was conditioned with the lime and cyanide in a thick state, before diluting to flotation volume, with the object of securing more intensive action to over-ride the existing xanthate filming. This vigorous scrub may not be necessary—the lime and cyanide may be just as effective when added after the pulp has been diluted to flotation consistency (24 per cent solids in the above tests).

Method B

Flotation of pyrite, depression of bismuthinite.

This method was used on the remaining 39 of the 50 tests in the research programme. The following tests are indicative of the results achieved with the principal modifying reagents tried.

Test 8—Rougher Pyrite Flotation with Sodium Silicate.

Flotation Conditions	
Reagents	**lbs. ton/minutes**
Sodium Silicate (Scrub in thick pulp, then dilute to flotation volume)	10/5
Flotation time	/2
pH value	/10.4

	Wght.	Per cent Bi	Sn	Per cent Dist. Bi	Sn
Rougher Conc. (Pyrite Reject)	67.0	3.1	1.05	15.3	16.8
Rougher Tailing (Bi Product)	33.0	34.95	10.6	84.7	83.2
Composite	100.0	13.6	4.2	100.0	100.0

Test 9—Identical with Test 8, but using only 4 lbs. Sodium Silicate.

Rougher Conc. (Pyrite Reject)	67.0	3.8	1.34

The optimum amount of sodium silicate would seem to lie between 4 and 10 lbs. Again it is possible that the sodium silicate may be equally effective when conditioned in thin instead of thick pulp. Flotation was very rapid in both tests, and the pyrite was a brilliant brass colour, suggesting that the flotation differential had been established as a result of intensive surface cleaning—a process which would be facilitated by a thick pulp scrub. The bismuth was merely rendered less flotable than the pyrite; it was not depressed, only wetted, for it would float immediately on addition of a little amyl xanthate.

Test 22—Rougher Pyrite Flotation with Potassium Permanganate.

Flotation Conditions
Reagents

*Potassium Permanganate	1.5/5
*Sulphuric Acid	1.5/5
Cresylic Acid	0.1
Flotation time	/11
pH value	/5.6

*Scrub in thick pulp, then dilute to volume.

	Wght.	Per cent Bi	Sn	Per cent Dist. Bi	Sn
Rougher Conc. (Pyrite Reject)	66.9	2.86	1.08	13.3	13.6
Rougher Tailing (Bi Product)	33.1	38.0	13.2	86.7	86.4
Composite	100.0	14.5	5.1	100.0	100.0

Test 25

Using 0.5 lb. permanganate and no sulphuric acid, so that pyrite flotation was at pH 8.7, gave 67.9 per cent weight of rougher concentrate. It was not assayed.

The permanganate was used on these and other tests as an oxidiser to destroy existing xanthate filming and leave the bismuth less flotable than the pyrite. It showed promise of doing this more dependably than dichromate. Nitric acid was tried for the same purpose. but with insufficient success to encourage a lengthy trial.

Test 20—Rougher Pyrite Flotation with Potassium Dichromate.

Flotation Conditions
Reagents

*Potassium Dichromate	1.5/5
*Sulphuric Acid	2.8/5
Potassium Dichromate	1.5/5
Cresylic Acid	0.35
	(2 stages)
Flotation time, minutes	/20
pH value	/5.9

* Scrub in thick pulp, then dilute to volume.

	Per cent			Per cent Dist.	
	Wght.	Bi	Sn	Bi	Sn
Rougher Conc. (Pyrite Reject)	61.4	1.28	0.6	5.5	6.8
Rougher Tailing (Bi Product)	38.6	35.0	13.0	94.5	93.2
Composite	100.0	14.3	5.4	100.0	100.0

The floated pyrite was of a brilliant brass colour. It floated slowly, in a lightly loaded froth. Periodical additions of cresylic acid, made when the rate of pyrite flotation tapered off, always brought up a pronounced fresh crop of pyrite. These frother additions played an important role in securing the removal of all pyrite flotable without additional promoter. The addition of a small amount of amyl xanthate to remove pyrite remaining in the rougher tailing resulted in the immediate flotation of some 50 per cent of the bismuth, suggesting that the flotation differential between the pyrite and bismuth was the result of surface cleaning rather than chromate filming of the bismuth. The pyrite reject from the dichromate-sulphuric acid tests was notably lower in the tin content than that from permanganate or sodium silicate.

Test 38

This closely resembled Test 20, but reduced the sulphuric acid to 2.5 lbs. and dichromate to 2.25 lbs. and used 0.1 lb. sodium aerofloat as scavenger in the closing stages of the pyrite float.

	Per cent			Per cent Dist.	
	Wght.	Bi	Sn	Bi	Sn
Rougher Conc. (Pyrite Reject)	61.3	1.72	0.62	7.4	7.0
Rougher Tailing (Bi Product)	38.7	34.2	13.0	92.6	93.0
Composite	100.0	14.3	5.4	100.0	100.0

The use of much larger amounts of sulphuric acid resulted in a higher grade bismuth product without material loss in recovery. Thus:—

Test 33

Used 7.5 lbs. sulphuric acid in the thick pulp scrub, and a further 4 lbs. plus 3.5 lbs dichromate after dilution. The result was—

	Per cent		Per cent Dist.
	Wght.	Bi	Bi
Rougher Conc.	69.5	1.93	8.2
Rougher Tailing	30.5	42.0	91.8
Composite	100.0	15.0	100.0

Test 35

Used 12.5 lbs. sulphuric acid and 1 lb. dichromate in the thick pulp, and 2 lbs. dichromate after dilution.

	Per cent			Per cent Dist.	
	Wght.	Bi	Sn	Bi	Sn
Rougher Conc.	66.1	2.0	0.5	9.2	6.0
Rougher Tailing	33.9	38.6	15.4	90.8	94.0
Composite	100.0	14.4	5.6	100.0	100.0

In all the foregoing tests some or all of the acid and dichromate was added to a thick pulp scrub. A series of four tests, Nos. 47 to 50, suggests that this scrubbing procedure can be eliminated and the pulp conditioned at flotation consistency with the acid and dichromate. Thus:—

Test 50

Flotation Conditions	lbs. ton/minutes	
Reagents	Rougher Conc. 1	Rougher Conc. 2
Potassium Dichromate	2.5/5	0.5
Sulphuric Acid	7.5/5	....
Sodium Aerofloat	...	0.025
Cresylic Acid	0.3 (2 stages)	0.07
Flotation time, minutes	/12	/5
pH value	3.2/—	—/4.3

	Per cent			Per cent Dist.	
	Wght.	Bi	Sn	Bi	Sn
Rougher Conc. 1	63.9	1.67	N.D.	7.6	....
Rougher Conc. 2	4.3	9.32	N.D.	2.9	....
Rougher Tailing	31.8	39.40	N.D.	89.5	....
Composite	100.0	14.0	....	100.0	....

Composite Rougher Conc. 1 + 2, i.e., Pyrite Reject 68.2 per cent weight, 2.15 per cent Bi.