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REPORT
of the
ORE DRESSING AND METALLURGICAL LABORATORIES

Report No. 272

The Selective Flotation of a Copper-Zinc Ore from the Sherritt-Gordon Mines Limited, Manitoba

by A. K. Anderson

Shipments: Three lots of ore, designated as shipments Nos. 1,2 & 3 were received as follows: Shipment No.1, gross weight 200 lbs. August 25th. 1927. Shipment No. 2, consisting of three lots, total weight 109 lbs. arrived from the Temiskaming Laboratories, Cobalt on October 25th. 1927. Shipment No. 3 also from the Temiskaming Laboratories, arrived November 18th. 1927. This had a gross weight of 780 lbs. and consisted of 22 separate lots.

Characteristics of ore: All three shipments contained a high percentage of sulphides of copper, zinc, and iron. The ore when received, had been crushed to a fairly fine state of division, thus enabling oxidization to set in. Shipment No. 1 on which the major number of tests were performed appeared to have been crushed for some time. Shipment No. 2, which included three lots weighing 36, 36, and 37 lbs. respectively, were distinctive in appearance. No. 1 was quite brown containing a high percentage of zinc and iron sulphides, while Nos. 2 and 3 were of the characteristic colour of chalcopyrite. Shipment No. 3, consisting of 22 individual lots which were similar in appearance and sulphide content to Shipment No. 1, and were combined and thoroughly mixed together.

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Purpose of Tests: The object of undertaking the following tests was to separate the copper and zinc by selective flotation. A copper concentrate containing above 22% copper, and one of zinc above 48% zinc

were desired, with a minimum amount passing out with the tailing.

Sampling and Analysis: Each shipment as received was crushed and screened to pass 14 mesh, thoroughly mixed, passed through a Jones riffle sampler and a head sample cut out. The analysis of the lots is as follows:

	Cu %	Zn %	Pb %	Fe %	Au oz.	Ag oz.
Ship.No.1	3.12	4.63	nil		0.02	0.72
" No.2 (combined)	7.64	13.15		25.8	0.05	3.17
" No.2 Lot No.1	0.53	21.39			tr.	0.88
" No.2 Lot No.2	10.45	8.14			0.08	3.74
" No.2 Lot No.3	11.61	8.77			0.06	3.92
" No.3	5.55	7.02			0.05	2.30

As mentioned above most of the test work was on shipment No. 1 For each test 1000 grams of the -14 mesh material was ground to pass 100 mesh in a porcelain jar containing iron balls and a weight of water equal to that of the ore. As indicated in the tests, various reagents were also added while grinding. The pulp was then transferred to a small Ruth laboratory flotation machine in which all tests were made.

Shipment No. 1 - tests 1-7 were conducted to investigate the effect of various reagents on the recovery of copper, and the results secured when using potassium xanthate for the recovery of zinc. Tests 8-17 were to determine the effect of phospho-cresylic acid on the recovery of copper and zinc, using various conditioning reagents.

Shipment No. 2 - tests 1-3 were run to determine if this shipment is amenable to the same conditions as shipment no. 1

Shipment No. 3 - tests 1-3 had for their object the investigation of the behaviour of this ore under conditions similar to those of preceding tests. The tests in detail follow:

Shipment No. 1

Test No. 1: This test was run to determine the result of depressing the zinc and iron sulphides in a circuit alkaline with soda ash by the use of cyanide and floating the copper with phosphocresylic acid. Lime was then added and the zinc reactivated by copper sulphate and floated with potassium xanthate and pine oil.

Reagents to ball mill		to flotation machine	
Sodium cyanide	0.15 lb/ton	Lime	2.0 lb/ton
Phosphocresylic ac	0.12	Copper sulphate	5.0
Soda ash	5.0	Xanthate	0.3
		Pine oil	0.06

Product	Weight	Analysis				% of values			
	%	Cu %	Zn %	Au oz.	Ag oz.	Cu	Zn	Au	Ag
Cu conc.	12.42	19.06	7.20	0.12	2.92	78.64	20.14	78.95	56.55
Cu midd.	16.49	0.98	4.31	0.02	0.58	5.36	15.93	15.79	14.75
Zn conc.	11.90	2.56	21.16	0.01	0.53	10.10	56.26	5.26	9.63
Zn midd.	8.43	0.86	2.28	tr	0.29	2.39	4.32		5.74
Tailing	50.93	0.21	0.29	tr	0.20	3.52	3.36		15.53
Heads		3.12	4.63	0.02	0.72				

This test indicates that a selective separation of the copper and zinc is possible.

Test No. 2: This test has for its object the observing of the effect of lime added to the pulp prior to the floating of copper. Other conditions are the same as in test no. 1

Reagents to ball mill		to flotation machine	
Sodium cyanide	0.15 lb/ton	Copper sulphate	5.0 lb/ton
Soda ash	5.0	Xanthate	0.3
Lime	2.0	Pine oil	0.06
Phosphocresylic ac	0.12		

Product	Weight	Analysis				% of values			
	%	Cu %	Zn %	Au oz.	Ag oz.	Cu	Zn	Au	Ag
Cu conc.	11.41	18.50	5.55	0.12	1.93	68.21	15.23	82.35	41.51
Cu midd.	16.86	4.00	4.72	0.02	0.91	21.78	19.16	17.65	28.30
Zn conc.	8.55	0.77	26.98	tr	0.42	2.13	55.52		7.55
Zn midd.	8.24	0.82	3.68	tr.	0.30	2.19	7.31		5.77
Tailing	54.94	0.32	0.21	tr.	0.19	5.69	2.78		16.87
Head		3.12	4.63	0.02	0.72				

This test shows that lime used in the circuit before copper has been removed has a depressing action on that mineral. The copper concentrate produced is low grade with a large amount of middling product also to be handled. The zinc concentrate is slightly higher than in the preceding test, containing less copper.

Test No. 3: It will be noted that the gold and the greater part of the silver is associated with the copper sulphides. As the ore contains considerable iron sulphides, it is apparent that to raise the grade of the copper and zinc concentrates it is necessary to eliminate as much of the barren iron sulphide as possible. This test was run under conditions suitable for such results, depressing the zinc and iron sulphides by lime and cyanide and using thiocarbanilide and phosphocresylic acid to float the copper.

Reagents to ball mill		to flotation machine	
Lime	8.0 lb/ton	Phosphocresylic ac	0.10 lb/ton
Sodium cyanide	0.15	Copper sulphate	5.0
Thiocarbanilide	0.10	Xanthate	0.2
		Pine oil	0.06

Product	Weight	Assay				% of values			
	%	Cu %	Zn %	Au.oz	Ag oz	Cu	Zn	Au	Ag
Cu conc.	8.62	24.20	4.05	0.16	3.72	67.20	7.99	73.68	8.51
Cu midd.	4.95	4.84	5.81	0.05	1.45	7.72	6.57	10.53	19.15
Zn conc.	11.99	4.50	27.59	0.02	0.90	17.36	75.73	10.54	28.72
Zn midd.	7.50	1.48	4.05	0.01	0.58	3.54	6.98	5.25	11.71
Tailing	66.94	0.20	0.18	nil	0.18	4.18	2.75		31.91

In this test a satisfactory grade of copper concentrate was secured although the recovery was not high, 17% being contained in the zinc concentrate. This is due to the depressing action of lime on the copper sulphides. The recovery of zinc in a low grade concentrate is higher than in previous tests.

Test No. 4: This test was run to note the effect of zinc sulphate added in conjunction with cyanide to form zinc cyanide. An increased amount of lime was used to again note the effect of higher alkalinity. Sodium dichromate also was added to see if that reagent would benefit the grade of zinc concentrate

Reagents to ball mill			to flotation machine		
Sodium cyanide	0.20	lb/ton	Phosphocresylic acid	0.10	lb/ton
Lime	12.0		Copper sulphate	3.0	
Thiocarbanilide	0.1		Xanthate	0.2	
Zinc sulphate	0.15		Pine oil	0.06	
			Sodium dichromate	0.10	

Product	Weight %	Assay Cu %	Zn %	Au oz	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	7.94	24.08	3.84	0.18	3.52	62.44	7.00	70.0	55.04
Cu midd.	4.97	3.33	5.71	0.04	0.86	5.42	6.46	10.0	8.17
Zn conc.	19.38	3.82	16.68	0.02	0.52	24.16	73.66	20.0	19.20
Zn midd.	20.05	0.91	2.49		0.18	5.95	11.36		6.85
Tailing	47.66	0.13	0.14		0.14	2.03	1.52		12.74

The results from this test are similar to test no. 3, a satisfactory grade of copper concentrate being obtained. The increased alkalinity due to lime throws an increasing amount of copper into the zinc concentrate. A lower grade zinc concentrate and a lower recovery also results. No noticeable advantage was derived from the use of sodium dichromate

Test No. 5: The object of this test was to note the difference on results caused by the use of soda ash instead of lime

Reagents to ball mill			to flotation machine		
Soda ash	12.0	lb/ton	Phosphocresylic ac	0.08	lb/ton
Sodium cyanide	0.4		Copper sulphate	3.0	
Zinc sulphate	0.3		Xanthate	0.2	
Thiocarbanilide	0.2		Pine oil	0.06	

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	14.18	19.26	7.64			91.46	24.27		
Cu midd.	16.87	0.35	4.98			1.97	18.82		
Zn conc.	4.63	1.00	42.04			1.54	43.62		
Zn midd.	3.45	0.81	5.71			0.94	4.42		
Tailing	60.87	0.20	0.65			4.09	8.87		

This test shows that soda ash causes a higher recovery of copper as copper concentrate. However, it is lower grade containing more zinc than that secured when using lime as alkaline reagent. A large weight of middling product was produced. The resulting zinc concentrate is much higher grade than previously obtained. However, due to the zinc reporting with the copper concentrate the recovery is low.

Test No. 6: This test was run with higher alkalinity, using soda ash, to note any variations caused

Reagents to ball mill		to flotation machine	
Soda ash	16.0 lb/ton	Phosphocresylic acid	0.03 lb/ton
Zinc sulphate	0.3	Copper sulphate	3.0
Sodium cyanide	0.4	Potassium xanthate	0.2
Thiocarbanilide	0.2	Pine oil	0.06

Product	Weight %	Assay				% of values			
		Cu %	Zn %	Au oz.	Ag oz.	Cu	Zn	Au	Ag
Cu conc.	13.34	20.32	6.49	0.14	2.91	89.62	19.82	82.61	74.33
Cu midd.	14.69	0.84	4.41	0.03	0.31	4.07	14.85	17.39	8.62
Zn conc.	4.73	0.97	50.09	nil	0.32	1.52	54.29		2.87
Zn midd.	2.79	1.03	7.61	nil	0.37	0.95	4.86		1.91
Tailing	64.45	0.18	0.42	nil	0.10	3.84	6.18		12.27

These results show that a higher recovery of zinc can be obtained then previously found. This concentrate is of a suitable grade. A larger percentage of the zinc passes out with the tailing, probably due to the increase in alkalinity. The copper recovery of lower than in the preceding test, more mineral passing into the middling.

Test No. 7: In the previous tests phosphocresylic acid in conjunction with thiocarbanilide was used in the flotation of copper. The object of this test was to observe if this reagent was necessary.

Product	Weight %	Assay				% of values			
		Cu %	Zn %	Au oz.	Ag oz.	Cu	Zn	Au	Ag
Cu conc.	10.74	23.64	4.67			85.28	11.51		
Cu midd.	7.38	1.70	5.81			4.19	9.84		
Zn conc.	6.50	1.73	42.95			3.76	64.02		
Zn midd.	10.76	0.86	4.67			3.10	11.51		
Tailing	64.62	0.17	0.21			3.67	3.12		

Reagent to ball mill		to flotation machine	
Soda ash	16.0 lb/ton	Copper sulphate	3.0 lb/ton
Zinc sulphate	0.4	Potassium xanthate	0.2
Sodium cyanide	0.5	Pine oil	0.06
Thiocarbanilide	0.3		

This test shows that while making a satisfactory grade of copper concentrate more of the copper is left to be floated with the zinc. Phosphocresylic acid apparently is of benefit. A higher recovery of zinc was obtained, but in a lower grade concentrate.

Test No. 8: The object of this test was to determine the effect of adding lime to the flotation pulp after copper had been removed, depressing iron pyrite which in previous tests lowers the grade of zinc concentrate. On recleaning, this produces a large amount of middling. It was observed in preceding investigations that potassium xanthate caused large amounts of iron sulphides to float with the zinc. The use of that reagent was abandoned and phosphocresylic acid used.

Reagents to ball mill		to flotation machine	
Soda ash	16.0 lb/ton	Lime	6.0 lb/ton
Sodium cyanide	0.5	Copper sulphate	3.0
Zinc sulphate	0.4	Phosphocresylic ac	0.06
Thiocarbanilide	0.3		

Product	Weight %	Analysis Cu %	Zn %	% of values Cu	Zn
Cu conc.	11.42	23.74	5.19	88.62	13.61
Cu midd.	12.08	1.23	5.14	4.87	14.89
Zn conc.	6.17	1.00	46.01	2.03	65.16
Zn midd.	13.39	0.47	1.61	2.05	4.64
Tailing	56.94	0.13	0.18	2.43	2.34

This test shows that a high recovery of copper in a suitable grade of concentrate can be obtained. The use of phosphocresylic acid as a reagent for floating the zinc gives slightly better results than previously obtained. A large amount of zinc middling is produced, low in value. The copper concentrate in this test on analysis is found to contain 0.05% lead

Test No. 9: This test is similar to no. 8, with the exception that no lime was added to the pulp after removal of the copper concentrate.

Reagents	to ball mill		to flotation machine	
Soda ash	16.0 lb/ton		Copper sulphate	3.0 lb/ton
Sodium cyanide	0.5		Phosphocresylic ac	0.06
Zinc sulphate	0.4			
Thiocarbanilide	0.3			

Product	Weight %	Analysis Cu %	Zn %	% of values Cu	Zn
Cu conc.	10.81	25.01	4.46	86.95	10.65
Cu Midd.	6.98	1.53	5.86	3.44	9.03
Zn conc.	7.49	1.52	44.28	3.50	70.32
Zn midd.	17.94	0.52	1.61	2.99	6.34
Tailing	57.18	0.17	0.29	3.18	3.66

The copper recovery is the same as in the previous test, any variation in results being due to differences in manipulation. The absence of lime appears to be detrimental as a lower grade of concentrate was obtained and a larger weight of middling produced. A higher total recovery of zinc was obtained due to the fact that less zinc floated with the copper.

Test No. 10: As somewhat over 10% of the zinc reports with the copper middling an attempt was made in this test to see if this could be recovered. The middling product resulting from recleaning the rougher copper concentrate was treated with copper sulphate to reactivat the zinc mineral and floated with phosphocresylic acid

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc	9.36	24.82	3.89	0.11	3.35	78.06	8.23	52.65	58.18
Zn conc.	6.35	2.68	44.28	0.06	0.76	5.71	63.66	21.05	8.92
Conc from Cu midd.	2.47	3.71	5.39	0.03	0.89	3.09	3.00	5.26	4.09
Midd " "	3.49	4.26	6.28	0.06	0.82	5.00	4.95	10.53	5.39
Zn midd.	12.76	0.97	3.58	0.02	0.27	4.16	10.33	10.53	6.31
Tailing	65.57	0.18	0.67	nil	0.14	3.98	9.93		17.11

The zinc contained in the copper middling does not respond to selective flotation, possibly because it is too intimately associated with the copper mineral.

Test No. 11: This test was conducted with a change of reagents, TT mixture being used in place of thiocarbanilide. The rougher concentrate were not cleaned.

Reagents	to ball mill	to flotation machine	
Lime	4.0 lb/ton	TT mixture	0.06 lb/ton
Sodium cyanide	0.3	Copper sulphate	3.0
		Phosphocresylic ac	0.06

Product	Weight %	Analysis Cu %	Zn %	% of values Cu	Zn
Cu conc.	16.47	16.24	4.94	87.36	18.48
Zn conc.	1.47	2.95	5.90	1.41	1.97
Tailing	82.06	0.42	4.27	11.23	79.55

The conditions were not right for good results. The zinc refused to float, only a thin black froth resulting after the copper had been removed.

Test No. 12: This test was run to note any differences in results when using soda ash instead of lime, under conditions similar to those of test no. 11. Soda ash 16 lb/ton added to ball mill

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	7.20	26.06	3.34	0.08	5.58	63.83	5.37	26.09	57.14
Cu midd.	9.47	7.15	5.97	0.06	1.36	23.04	12.64	26.09	18.57
Zn conc.	4.93	1.42	30.19	0.06	0.63	2.38	55.34	13.05	4.28
Zn midd.	19.96	1.00	4.98	0.04	0.40	6.77	22.23	34.77	11.43
Tailing	58.44	0.20	0.34	nil	0.11	3.98	4.42		8.58

The effect of soda ash as against that of lime is quite apparent. A clean copper concentrate of good grade can be secured. Although the recovery is not as high as in previous tests, the copper reporting with the copper middling could doubtless be recovered under correct conditions. The grade of zinc concentrate is satisfactory although recovery is low. A large quantity of zinc middling is again produced.

In all tests performed the chief difficulty is in making a high grade concentrate with a good recovery of this metal. To secure a tailing low in zinc it is necessary to float a large bulk of mineral. This contains a high percentage of iron sulphide. On cleaning this product a large weight of middling is produced.

Test No. 13: This test was run to note the effect of using Aerofloat in place of TT mixture

Reagents	to ball mill	to flotation machine	
Lime	4.0 lb/ton	Aerofloat	0.12 lb/ton
Zinc sulphate	0.3	Copper sulphate	3.0
Sodium cyanide	0.3		

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	9.95	23.46	4.26	0.16	3.08	76.82	9.89	64.21	53.40
Cu midd.	4.96	3.46	4.57	0.04	0.86	5.63	5.28	10.53	7.33
Zn conc.	5.70	2.99	49.68	0.01	1.05	5.59	66.21	5.26	10.47
Zn midd.	7.00	1.99	6.44	tr	0.50	4.58	10.52		6.11
Tailing	72.39	0.31	0.48	nil	0.18	7.38	8.10		22.69

This test bears out the conclusion previously arrived at that lime has a depressing action on the copper sulphides, more reporting in the tailing than in test no. 12. The recovery as copper concentrate is higher due to a greater weight being secured than in the former test. A higher recovery of zinc also is effected with a lower grade less bulky middling product, although the zinc content of the tailing is somewhat higher.

Test No. 14: To check previous observations that lime is detrimental to copper recovery, this test was run under conditions similar to test No. 13, but with increased lime.

Reagents	to ball mill		to flotation machine	
Lime	8.0	lb/ton	Aerofloat	0.12 lb/ton
Sodium cyanide	0.3		Copper sulphate	3.0
Zinc sulphate	0.3			

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	8.76	20.62	3.94	0.16	2.92	58.33	7.81	70.00	53.44
Cu midd.	5.54	2.98	5.81	0.01	0.66	5.33	7.29	5.00	7.51
Zn conc.	7.71	9.37	35.73	0.03	1.07	23.32	62.38	10.00	17.12
Zn midd.	17.41	1.76	5.14	0.02	0.36	9.80	20.31	15.00	13.15
Tailing	60.58	0.16	0.16	nil	0.07	3.13	2.21		8.78

This shows that flotation of this ore in a circuit containing high lime is not the best practice. The copper is depressed and on being reactivated by copper sulphate floats with the zinc, Lowering the grade of that product. These conditions also product a large amount of zinc middling.

Test No. 15: In order to note any differences caused by a decreased amount of sodium cyanide, this test was run under conditions similar to test no. 13

Reagents	to ball mill		to flotation machine	
Lime	4.0	lb/ton	Aerofloat	0.14 lb/ton
Sodium cyanide	0.1		Copper sulphate	1.0
Zinc sulphate	0.1			

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	9.50	25.06	6.07	0.14	3.32	79.82	13.29	50.00	66.59
Cu midd.	9.58	4.20	5.86	0.05	0.77	13.48	12.92	19.23	15.64
Zn conc.	6.08	0.76	43.06	0.02	0.30	1.54	60.32	3.84	3.81
Zn midd.	32.25	0.28	1.43	0.01	0.06	3.02	10.63	11.54	4.02
Tailing	42.59	0.15	0.29	0.01	0.11	2.14	2.84	15.39	9.94

The necessity of adding sufficient cyanide to depress the zinc minerals is clearly indicated. More zinc is floated with the copper and also a larger amount of iron floats with the zinc which on cleaning, yields a large amount of zinc middling

Test No. 16: An attempt was made in this test to cut down the amount of iron floated with the zinc by the addition of lime after the copper had been floated

Reagents	to ball mill		to flotation machine	
Lime	4.0	lb/ton	Lime	4.0 lb/ton
Sodium cyanide	0.1		Copper sulphate	1.0
Zinc sulphate	0.1		Aerofloat	0.14

Product	Weight %	Assays Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	10.94	23.40	6.33	0.14	3.04	83.88	16.26	55.56	69.37
Cu midd.	11.62	2.72	5.24	0.05	0.56	10.35	14.30	22.22	13.54
Zn conc.	5.96	0.78	41.23	0.01	0.27	1.51	57.70	3.70	3.33
Zn midd.	21.49	0.28	1.35	tr	0.12	1.96	6.82		5.42
Tailing	49.99	0.14	0.42	0.01	0 .08	2.30	4.92	18.52	8.34

This shows that lime added after copper has been floated decreases the bulk of zinc middling produced. The zinc passing into the tailing is also increased.

Test No. 17: This test was run to note any benefit dreived from an increase in the amount of cyanide added.

Reagents to ball mill		to flotation machine	
Lime	4 lb/ton	Copper sulphate	1.0 lb/ton
Sodium cyanide	0.4	Aerofloat	0.08
Zinc sulphate	0.3		

Product	Weight %	Assay				% of values			
		Cu %	Zn %	Au oz.	Ag oz.	Cu	Zn	Au	Ag
Cu conc.	13.90	18.58	5.19	0.12	2.46	84.00	16.59	73.91	79.35
Cu midd.	5.45	3.17	4.62	0.04	0.48	5.63	5.79	8.70	6.03
Zn conc.	8.68	1.39	32.17	0.01	0.28	3.93	64.24	4.35	5.56
Zn midd.	26.89	0.45	1.56	0.01	0.08	3.93	9.64	13.04	4.88
Tailing	45.08	0.17	0.36	tr	0.04	2.51	3.74		4.17

No apparent benefit results from an increased addition of cyanide. From the results obtained in the last few tests may be drawn the conclusions that the zinc is in a condition that it is difficult to make a good grade of concentrate with a corresponding high recovery. This is doubtless due to excessive oxidization setting in, as the acidity has shown a consistent increase.

Shipment No. 2

Test No. 1: This test was run on lot no. 1 of this shipment.

This material contained a high percentage of zinc and low copper.

The object was to determine if this ore behaved similarly to shipment no. 1

Reagents to ball mill		to flotation machine	
Lime	4.0 lb/ton	Aerofloat	0.10 lb/ton
Sodium cyanide	0.2	Copper sulphate	1.0
Zinc sulphate	0.2		

Product	Weight %	Analysis		% of values	
		Cu %	Zn %	Cu	Zn
Head		0.53	21.39		
Cu conc.	0.83	23.32	10.70	34.11	0.40
Cu midd.	4.51	6.05	18.13	47.80	3.75
Zn conc.	33.06	0.21	55.84	12.13	84.65
Zn midd.	12.10	0.20	18.44	4.20	10.24
Tailing	49.50	0.02	0.42	1.76	0.96

These results indicate that this class of material answers to the same conditions as the previous shipment. The copper minerals float quite readily and the zinc also can be recovered in a high grade concentrate.

Test No. 2: This test was run on lot no. 2 of this shipment, the material containing much more copper and less zinc than lot no.1

The object was to determine if this class of ore acts similarly to the previous shipment.

Reagents to ball mill		to flotation machine	
Lime	4.0 lb/ton	Aerofloat	0.1 lb/ton
Sodium cyanide	0.2	Copper sulphate	1.0
Zinc sulphate	0.2		

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Head		10.45	8.14	0.08	3.74				
Cu conc.	27.76	30.86	2.92	0.10	6.02	82.28	9.72	36.37	57.78
Cu midd.	20.25	7.75	17.56	0.12	3.02	15.06	42.66	31.17	21.11
Zn conc.	8.06	0.71	42.06	0.03	1.03	0.55	40.67	2.59	2.77
Zn midd.	10.38	0.92	3.81	0.06	2.08	0.91	4.86	7.79	7.61
Tailing	33.55	0.37	0.52	0.05	0.93	1.19	2.09	22.08	10.73

These results indicate that this ore is of much the same nature as the preceding shipment. A selective flotation of the copper and zinc being possible.

Test No. 3: This test was run on the three combined lots comprising the shipment to determine what results could be obtained under practice similar to that employed on shipment no. 1.

Reagents to ball mill		to flotation machine	
Lime	4.0 lb/ton	Copper sulphate	1.0 lb/ton
Sodium cyanide	0.2	Aerofloat	0.14
Zinc sulphate	0.2		

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Head		7.64	13.15	0.08	3.17				
Cu conc.	20.22	28.50	7.46	0.18	8.02	72.72	11.46	56.25	62.08
Cu midd.	22.77	8.61	22.43	0.04	2.44	24.73	38.80	14.06	21.46
Zn conc.	16.41	0.59	37.61	0.03	0.91	1.23	46.89	7.81	5.75
Zn midd.	8.08	0.50	2.35	0.05	1.50	0.50	1.44	6.25	4.57
Tailing	32.52	0.20	0.57	0.03	0.51	0.82	1.41	15.63	6.14

On lots 1 & 2 of this shipment, 4 lb. of lime per ton was found sufficient to give an alkaline reaction. However, the above test was found to be acid, showing that oxidation with the formation of sulphuric acid had set in. The results therefore are unsatisfactory a large amount of zinc being found in the copper middling, a lower grade of zinc concentrate and a lower recovery also results.

Test No. 4: In this test, the acidity in the ore required 14 lb/ton lime to give an alkaline reaction. Other conditions were similar to test no. 3

Reagents to ball mill		to flotation machine	
Lime	14 lb/ton	Copper sulphate	1.0 lb/ton
Sodium cyanide	0.2	Aerofloat	0.12
Zinc sulphate	0.2		

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	16.51	31.80	3.34	0.18	8.66	67.48	4.27	51.72	52.19
Cu midd.	11.69	18.12	12.74	0.10	5.84	27.23	11.45	20.69	24.82
Zn conc.	15.53	0.72	54.80	0.02	0.67	1.57	65.87	5.17	3.65
Zn midd.	4.40	3.04	16.21	0.07	2.32	1.72	5.52	5.17	3.65
Tailing	51.87	0.30	3.21	0.02	0.84	2.00	12.89	17.25	15.69

This test shows, as formerly noted, the depressing action of lime on the copper minerals, a lower recovery being made with more copper reporting with the other products instead of with the copper concentrate. The zinc recovery is improved, although the final tailing is much higher than in test no. 3

Shipment No. 3

Test No. 1: This shipment containing a mixture of 22 lots was tested under conditions similar to those of previous shipments

Reagents	to ball mill	to flotation machine	
Soda ash	24 lb/ton	Copper sulphate	2.0 lb/ton
Sodium cyanide	0.5	Aerofloat	0.14
Zinc sulphate	0.4		

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Head		5.55	7.02	0.05	2.30				
Cu conc.	15.67	29.28	2.74	0.18	8.32	83.52	6.39	68.29	69.15
Cu midd.	9.49	7.73	7.73	0.04	4.41	13.34	10.92	9.76	22.34
Zn conc.	7.66	0.43	52.73	0.01	0.54	0.60	60.19	2.44	2.13
Zn midd	13.22	0.44	8.48	0.02	0.60	1.06	16.72	7.31	4.25
Tailing	53.96	0.15	0.72	0.01	0.47	1.48	5.78	12.20	8.13

This test shows that the ore in this shipment can be treated by selective flotation, a satisfactory grade of copper concentrate and a reasonable recovery being secured. The use of soda ash, while producing clean copper concentrate, allows a large amount of iron to float with the zinc thus producing a bulky middling.

Test No. 2: This test is similar to the preceding one, using lime in place of soda ash

Reagents	to ball mill	to flotation machine	
Lime	14.0 lb/ton	Copper sulphate	2.0 lb/ton
Sodium cyanide	0.5	Aerofloat	0.14
Zinc sulphate	0.4		

Product	Weight %	Assay Cu %	Zn %	Au oz.	Ag oz.	% of values Cu	Zn	Au	Ag
Cu conc.	6.74	32.04	1.72	0.30	9.30	38.66	1.71	46.53	18.64
Cu midd.	7.26	20.65	3.92	0.12	9.15	26.83	4.21	20.93	19.52
Zn conc.	14.69	10.72	33.44	0.03	3.11	28.19	72.55	9.30	13.61
Zn midd.	8.88	2.34	6.39	0.06	2.52	2.87	6.50	9.30	5.03
Tailing	64.43	0.30	1.58	0.01	2.27	3.45	15.03	13.94	43.20

This test again shows the detrimental effect of lime on copper flotation, resulting in a poor recovery as copper concentrate and throwing the remainder into the other products. The grade of zinc concentrate is low also due to its copper content. The zinc tailing is again higher due to the rapid oxidization of the ore and also to the effect of lime.

Summary of Tests: In tests nos. 1-7, it is noted that potassium xanthate when used for the flotation of zinc gives poor results. A large weight of middling results due to iron pyrite being lifted. This reagent therefore was omitted as being too powerful to produce a satisfactory zinc concentrate. In all tests where soda ash was used instead of lime it will be noted that the former reagent produces a copper concentrate higher in zinc than that secured when lime is used. The total copper floated however is consolidated in the copper concentrate. On the other hand when lime is used in the circuit for copper flotation the copper concentrate is lower in zinc and the total copper recovered in this product is lower. The copper not reporting with the copper concentrate is recovered when the zinc is floated, lowering the grade of that product. The use of lime benefits

the grade of the zinc concentrate recovered due to the depressing action of this reagent on iron sulphides.

In tests 1-8 a comparison of results with different reagents used for lifting the copper shows that best results are obtained when using thiocarbanilide. This must be added to the grinding circuit as it is insoluble in water. In tests 11-12 the use of TT does not offer any inducement for its adoption, giving a lower recovery. "Aerofloat" or phosphocresylic acid, appears to be suitable for the flotation of both copper and zinc. Results secured in tests 1-7 show this reagent to be superior to potassium xanthate, especially in the flotation of zinc. In tests 13-15, the necessity of the proper amount of cyanide used is apparent, an insufficient quantity causing a low grade bulky concentrate due to iron sulphides floating with the zinc.

In all tests, apart from desiring a suitable grade of concentrate together with a good recovery, the attempt was made to keep as much as possible of the iron sulphides in the tailing. Owing to the fact that the ore was finely crushed and had been in that condition for some time prior to the date received, oxidization had set in. This made it difficult to make a good recovery of the zinc in a clean concentrate. The mineral was hard to float, iron pyrite coming up with it. This condition either caused a concentrate low in zinc, or a very bulky middling product.

The majority of the tests show that the greater part of the gold and silver is associated with the copper sulphides. This is fortunate as these metals will be recovered in the copper refinery

Tests 3-4 on shipment no. 2, show the necessity of maintaining an alkaline circuit. The fourth test also shows the detrimental effect of too much lime being used, resulting in poor recoveries of copper, and a higher loss of zinc in the tailing.

In calculating the recovery in all tests no attempt was made to eliminate the middling product. From former experimental work it has been found that at least 50% of the values can be recovered, thus raising the total recovery indicated in all tests.

It has been noticed in experimental work done on other ores of a similar nature that results secured on freshly crushed ore could not

be duplicated after the material had been allowed to stand in contact with air for any length of time. Oxidization setting in makes the flotation action much slower, with a lower recovery. As these shipments had been crushed prior to their arrival it is to be expected that better results can be obtained on freshly mined ore.

The practice indicated by these tests will be grinding with cyanide and zinc sulphate in a circuit alkaline with soda ash to a mesh fine enough to free the various minerals, the copper then floated either by the addition of thiocarbanilide to the grinding mill or Aerofloat to the classifier overflow or to the head of the copper flotation machine, where a rougher concentrate is taken off and cleaned in following cells.

Lime should then be added to the tailing from the copper cells together with the requisite amount of copper sulphate, and passed to a mixing tank where a time contact is secured prior to reaching the zinc flotation machines. The addition of Aerofloat to the mixing tank or at the head of the cells produces a rougher zinc concentrate which passed to cleaner cells, yields the finished concentrate. The middling product from the copper flotation cells may be returned to the grinding circuit, to the head of the copper flotation machine, or treated in a separate unit, which method yielding the best results yet to be determined. The zinc middling also will require further treatment to recover the contained values.

No great difficulties are anticipated in the recovery of copper and zinc in suitable products from freshly mined ore. Selective flotation will doubtless yield results well within the required limits.