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METHOD OF CONCENTRATING ORES

Reginald T. N. Drake, Lynn Lake, Manitoba, Canada, assignor to Sherritt Gordon Mines Limited, Toronto, Ontario, Canada, a company of Ontario

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This invention relates to an improved method for the concentration of ores. The invention is particularly directed to improving the efficiency of the froth flotation of ores, and particularly the concentration by froth flotation of ores which contain, in addition to desired minerals or metal values, minerals such as talc, clay, magnesia, calcium, silica and the like which, under the conditions prevailing in the preparation for and in treatment by froth flotation, convert to slimes from which it is difficult, if not impossible, to obtain a satisfactory separation of desired minerals.

The problem of the presence of slimes in the operation of conventional froth flotation processes is known and a number of addition agents have been used in an endeavour to overcome it. For example, reagents such as dextrin and starch have been employed to arrest the tendency of the slimes to interfere with the action of the mineral collector. It is believed that the dextrin and/or starch neutralize the slime particles in such a way that they disperse throughout the pulp and allow the collector to move between the slime particles rather than being bound in and trapped by them.

The presence of a small amount of slimes in ore subjected to concentration by froth flotation does not present a serious problem, particularly in the preparation of ore concentrates for extraction and recovery of desired minerals by conventional pyrometallurgical methods. However, the presence of appreciable amounts of slimes in the ore interferes with the efficient recovery of desired minerals by froth flotation, and the presence of appreciable amounts of such slimes in the ore concentrates presents a serious problem in the extraction and recovery of desired minerals, and particularly if metal values are to be extracted and recovered by hydrometallurgical processes. The difficulty is that as the amount of slimes in the ores increases, the amount of dextrin and/or starch must be increased until the point is reached at which the addition of further amounts of starch or dextrin serves no useful purpose and interferes with the efficient separation and recovery of desired minerals.

It has been found that the problem of the presence of appreciable amounts of slimes, hereinafter referred to as "insoluble matter" or "insol," in ore subjected to froth flotation can be overcome by the use of a combination of auxiliary agents, one of which functions as a dispersant for the slimes and the other functions in the ore pulp, as a depressant for the slimes.

The present invention is, of course, based on results obtained in exhaustive investigations conducted with the object of overcoming the problem attendant with the presence of appreciable amounts of slimes in the ores and is entirely independent of hypothetical considerations. It is known that clay and talc slimes are relatively easy to flocculate but that slimes which contain insoluble carbonates, silicates and sulphides are difficult to flocculate. Also, flocs of sulphide slimes, when formed, are less stable than clay flocs and are easily destroyed. A

reasonable explanation of the phenomenon which takes place in the operation of this invention is that the addition of a depressant for the slimes alone tends to flocculate them, entraining in the floc values of minerals, particularly metal values, which it is desired to separate and recover from the gangue material in the pulp. Thus, while the addition of the depressant for the slimes tends to depress the slimes, it also results in the loss of desired metal values, thus lowering the overall efficiency of the recovery of desired minerals. However, if a dispersant for the slimes is added to the pulp mixture prior to the addition of the depressant, the slime particles are dispersed in the pulp to the extent that when the depressant is added they become inert to the action of the collector employed for the collection of the desired minerals and remain suspended in the pulp mixture while the desired minerals rise to and overflow from the upper part of the flotation cell. Thus, a relatively clean separation of desired minerals can be obtained from ores which contain a relatively high slime or insol content with resulting recovery of a satisfactory concentrate in which the insol content is substantially reduced without adversely affecting the overall recovery of desired minerals.

It is found that mannogalactan possesses unusual and unexpected properties as a depressant for slimes, particularly when they are associated with an ore which contains metal values. Mannogalactan occurs in the seeds of many legumes, an example of which is the endosperm of the pod bearing legume known as "guar." Mannogalactan which occurs in guar seeds consists of approximately 67% mannose units and 33% galactose units.

However, the addition of mannogalactan alone is not sufficient for the purpose of the present invention. It must be preceded by the addition of a dispersant to prevent flocculation of slimes with attendant entrainment of desired minerals. Thus, according to the present invention, a suitable dispersant is added to the pulp prior to the addition of the depressant for the slimes.

It is found that the dispersing agent must be a relatively highly ionized salt, particularly in the treatment of ores which contain a high slimes content. Alkali metal phosphates such as, sodium phosphate, sodium tripolyphosphate, sodium pyrophosphate and sodium hexametaphosphate and alkali metal silicates such as sodium silicate are illustrative of highly ionized salts suitable for use as dispersants in the present invention. It is found further that the dispersing agent, in order to obtain maximum effectiveness, must be added to the ore pulp or slurry prior to the addition of the collector.

In conventional flotation practice, the ore usually is subjected to a preliminary conditioning step during which the usual collector, such as a sodium or potassium xanthate, and frothing agent such as a high alcohol, are added. The conditioned ore pulp is then passed to the flotation cells. It has been found by this invention that it is very convenient to add the dispersant for the slimes to the conditioning step, during which it is dispersed throughout the pulp mixture. The mannogalactan depressant then can be added to the stream of pulp as it is passed from the conditioner to the flotation cells. Alternatively, of course, the various agents can be added at any other suitable point to the feed to the cells.

In the following examples which illustrate the operation of the invention, the ore subjected to the concentration process of this invention, contained pentlandite, chalcopyrite and pyrrhotite. The gangue minerals were principally talc, pyroxine and hornblende. The flotation circuit comprised a rougher circuit which produced a bulk nickel-copper concentrate, a nickel middling circuit from which final tailings were discharged and a cleaner circuit. The bulk nickel-copper concentrate was separated in a separa-

tion circuit into a high grade nickel concentrate and a high grade copper concentrate. Concentrate from the nickel middling cleaner circuit was added to the high grade nickel concentrate and tailings from that circuit were returned to the middling circuit.

The rougher and middling circuits were alkaline, from about pH 8 to 10, and the middling cleaner circuit was acid, about pH 6.5 with added sulphur dioxide. The ore subjected to treatment contained about 1.90% nickel, about 0.79% copper and about 65.6% insol.

The ore pulp, mixture of ore and water, about 40% by weight solids, was first conditioned for five minutes with the dispersant, about 0.4 pounds sodium hexametaphosphate per ton of ore, and the collector, potassium amyl xanthate. Aerofroth 70 was employed as a frothing agent. Mannogalactan was then added in the form of guar, about 0.3 pound per ton of ore, and the pulp was conditioned for about ½ minute and passed to the first rougher cells. If a conditioner cell is not employed, the various agents can be added to the overflow from the classifier or to such other source of feed to the flotation circuit which may be employed.

Additional guar and dispersant were added to either or both the middling and middling cleaner circuits of the order of about 0.2 pounds of each reagent per ton of ore. In this, it has been found that the effectiveness of the depressant is at least partially destroyed when it is present in a pulp mixture passed through a pump. Thus, it is best to add at least this reagent to the mixture between a pump which is employed for moving it to its point of use.

The effective range of the mannogalactan appears to be of the order of from about 0.1 to about 0.5 pounds per ton of ore. Greater amounts of these reagents appear to have a depressing effect on the sulphides with resultant lower metals recovery. Optimum results appear to be obtained by the use of from 0.25 to 0.35 pounds of mannogalactan and 0.35 and 0.45 pounds of dispersant per ton of ore. It is not intended that the invention should be limited to any specific amount of either or both these auxiliary reagents as these amounts must be varied with the slimes or "insol" content of the specific ore being treated.

In the use of the reagents employed in the operation of the present invention, the potassium amyl xanthate is a known conventional collector, the mannogalactan functions as a depressor for slimes, or insol, and also, has a selective flocculating effect on sulphides, and the dispersant functions as a slimes dispersant and froth modifier, producing a more selective froth than is obtained by conventional practice. In addition to its functions as a slimes or insol depressant, the use of the mannogalactan has effectively reduced the amount of collector and frother oil by about one-third of that which otherwise would be required.

The improved results obtained in the operation of the present invention are illustrated in the following tables.

TABLE 1

The effect of using increasing amounts of guar without dispersant

[Rougher circuit pH 8.6]

Guar, Lbs./ton of ore	Assays			Recoveries			Tailings	
	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
Blank, Rougher Concentrate	8.24	4.00	40.7	84.1	93.3	8.60	.27	.05
0.1# Rougher Concentrate	8.00	3.55	38.2	89.1	93.2	8.71	.19	.05
0.2# Rougher Concentrate	8.24	3.60	34.8	89.5	91.7	7.70	.18	.06
0.3# Rougher Concentrate	9.40	4.45	30.0	89.0	92.1	5.78	.18	.06
0.4# Rougher Concentrate	9.72	4.55	26.4	88.2	90.5	4.83	.19	.07
0.5# Rougher Concentrate	10.20	4.80	24.3	88.1	90.5	4.20	.19	.07

The use of guar alone improved the grade of concentrate by about 2%. It increased the overall recovery of metal values by about 4% and it effected a substantial reduction in the slimes or insol in the resulting concentrate.

TABLE 2

Effect of increasing amounts of guar using 0.4 lbs. sodium hexametaphosphate per ton of ore

[Rougher circuit pH 9.6]

Sodium Hexametaphosphate, Lbs./ton	Guar, Lbs./ton	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
0.4#	0.20# Rougher Concentrate	10.37	4.08	28.5	86.0	90.3	8.03	.35	.09
0.4#	0.25# Rougher Concentrate	10.69	4.26	24.7	86.0	91.3	6.67	.34	.08
0.4#	0.30# Rougher Concentrate	11.12	4.45	22.7	85.8	90.1	5.8	.34	.09
0.4#	0.35# Rougher Concentrate	11.55	4.55	19.8	86.2	88.2	4.98	.34	.11
0.4#	0.40# Rougher Concentrate	11.92	4.75	18.3	85.0	89.1	4.48	.36	.10

The addition of the dispersing agent, sodium hexametaphosphate, increased the grade of the concentrate and reduced the amount of insol with only a slight decrease in the overall recovery of metal values.

TABLE 3

Effect of increasing amounts of dispersant using 0.3 lbs. guar

[Rougher circuit pH 8.6]

Sodium Hexametaphosphate, Lbs/ton	Guar, Lbs./ton	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
None	0.3# Rougher Concentrate	11.24	4.78	22.1	85.7	88.9	5.3	.34	.11
0.1#	do	11.96	5.05	21.6	84.7	92.3	5.0	.35	.07
0.2#	do	11.60	5.0	20.0	84.6	92.4	4.7	.36	.07
0.3#	do	12.48	5.35	17.1	85.1	91.7	3.85	.36	.08
0.4#	do	12.72	5.50	15.3	84.7	93.3	3.35	.35	.06
0.5#	do	13.12	5.75	14.3	84.9	94.6	2.95	.35	.05

The addition of the dispersing agent, sodium hexametaphosphate, increased the grade of the concentrate and reduced the insol content with only a slight reduction in the overall recovery.

TABLE 4

[Showing comparison of the effect of corn dextrin and sodium hexametaphosphate and guar—(A) Using 0.4 lbs. corn dextrin as Insol depressor in rougher circuit pH 8.6. (B) Using 0.4 lbs. sodium hexametaphosphate and 0.3 lbs. guar]

Sodium Hexametaphosphate, Lbs./ton	Guar, Lbs./ton	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
(A) 0.4 lbs./ton Dextrin	Rougher Concentrate	10.89	5.13	32.5	85.1	93.3	5.43	.26	.05
(B) Sodium Hexametaphosphate, 0.4 lbs./ton.	Guar, 0.3 lbs./ton Rougher Concentrate.	11.30	5.05	22.9	88.0	93.2	3.82	.21	.05

TABLE 5

Using guar in SO_2 (sulphur dioxide) middlings cleaning circuit with pH 6.5

[0.3 pound per ton guar having been used in the rougher circuit]

Sodium Hexametaphosphate, Lbs./ton of ore	Guar, Lbs./ton of ore	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
None	Blank, Cleaner Concentrate	5.73	1.80	32.0	93.9	96.6	75.2	2.27	.39
None	0.1# Cleaner Concentrate	6.38	2.80	25.0	94.0	97.8	54.7	1.49	.24
None	0.2# Cleaner Concentrate	7.12	2.82	18.1	91.7	96.1	33.6	1.37	.24
None	0.3# Cleaner Concentrate	7.60	2.82	12.1	89.4	95.1	19.8	1.41	.23
None	0.4# Cleaner Concentrate	7.89	3.37	11.3	84.1	94.6	19.8	2.20	.28
0.4#	0.2# Cleaner Concentrate	7.89	2.80	13.1	94.8	97.1	26.4	.98	.19

TABLE 6

Comparison of corn dextrin with guar in SO_2 (acid) cleaner circuit using corn dextrin in rougher circuit

Sodium Hexametaphosphate, Lbs./ton of ore	Guar, Lbs./ton of ore	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
Pounds per ton of Ore:									
0.5 lbs./ton Dextrin	Cleaner Concentrate	6.54	1.67	31.4	86.1	89.0	47.4	1.68	.32
0.5 lbs./ton Guar	do	6.46	1.68	20.8	96.0	96.9	36.3	.61	.12

Tables 7, 8, 9 and 10 illustrate the results obtained in using various salts as dispersants.

TABLE 7

Effects of increasing amounts of sodium phosphate— Na_2HPO_4 with 0.27# guar

Sodium Phosphate Na_2HPO_4, Lbs./ton	Guar, lbs./ton	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
0.18#	0.27# Rougher Concentrate	9.00	4.32	31.2	87.5	89.1	6.43	.22	.09
0.27#	do	10.12	4.67	28.8	86.7	87.8	5.46	.24	.10
0.36#	do	8.84	4.22	28.3	88.0	90.2	6.00	.21	.08
0.45#	do	9.64	4.65	24.2	87.3	90.5	4.75	.22	.09
Sodium Hexametaphosphate, lbs./ton: 0.36#	0.27# Standard Concentrate	9.28	4.37	30.3	88.8	89.2	6.25	.20	.09

TABLE 8

Effects of increasing amounts of tripolyphosphate— $Na_5P_3O_{10}$ with 0.26# guar

Sodium Tripoly-Phosphate $Na_5P_3O_{10}$, Lbs./ton	Guar, lbs./ton	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
0.17#	0.26# Rougher Concentrate	7.92	3.62	28.8	88.7	93.0	7.63	.22	.06
0.26#	do	7.76	3.55	28.3	88.6	91.8	7.58	.22	.07
0.34#	do	8.32	3.90	26.7	87.6	93.0	6.70	.24	.06
0.43#	do	8.72	4.08	23.7	87.9	90.3	5.4	.22	.08
Sodium Hexameta-Phosphate, lbs./ton: 0.34#	0.26# Standard Concentrate	8.56	3.97	27.6	87.8	88.3	6.48	.23	.10

TABLE 9

Effects of increasing amounts of pyrophosphate $Na_4P_2O_7$ with 0.3# guar

Pyrophosphate $Na_4P_2O_7$, Lbs./ton	Guar, lbs./ton	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
0.2#	0.3# Rougher Concentrate	9.96	4.40	25.0	85.2	92.5	5.36	.29	.06
0.3#	do	9.24	3.92	23.2	88.6	92.7	5.66	.23	.06
0.4#	do	8.56	3.72	22.6	88.0	91.6	5.90	.24	.07
0.5#	do	9.96	4.30	18.8	87.7	91.3	4.14	.24	.07
Sodium Hexameta-Phosphate, lbs./ton: 0.4#	0.3# Standard Concentrate	9.00	3.85	25.3	87.9	90.3	6.11	.24	.08

TABLE 10

Effects of increasing amounts of sodium silicate with 0.3# guar

Sodium Silicate, Lbs./ton	Guar, lbs./ton	Assays			Recoveries			Tailings	
		Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu	Percent Insol.	Percent Ni	Percent Cu
0.5#	0.3# Rougher Concentrate	10.16	4.57	24.1	88.2	89.8	4.71	.21	.08
1.0#	do	11.46	5.15	20.1	87.4	90.7	3.41	.22	.07
1.5#	do	10.92	4.95	20.7	87.5	90.9	3.72	.22	.07
2.0#	do	12.20	5.55	17.2	86.0	89.4	2.69	.24	.08
2.5#	do	12.32	5.65	16.4	86.6	89.6	2.51	.23	.08
Sodium Hexameta-Phosphate, lbs./ton: 0.4#	do	11.12	5.15	22.5	87.9	90.9	3.93	.21	.07

The process of the present invention processes a number of important advantages. Primarily, the slimes or insol content of an ore which contains a high slimes content is substantially reduced to the extent that a satisfactory ore concentrate can be produced with which no particular difficulties are encountered during its subsequent treatment, whether by pyrometallurgical or hydrometallurgical methods for the extraction and recovery of desired metal values. The use of the auxiliary reagents does not add appreciably to the overall cost per ton of preparing the ore concentrate. Also, of course, the reagents can be added easily to the pulp mixture and their presence does not create new problems either in the froth flotation process or in subsequent treatment processes to which the ore concentrate is subjected.

It will be understood, of course, that modifications can be made in the operation of the process of the present invention without departing from the scope of the invention as defined by the appended claims.

What I claim as new and desire to protect by Letters Patent of the United States is:

1. In a method of separating valuable constituents from metal bearing sulphide ores which contain slime forming constituents, the improvement which comprises subjecting a metal bearing sulphide ore pulp to froth flotation in the presence of a mineral collector, a finite amount of mannogalactan as a depressant for slimes and a finite amount of a compound selected from the group consisting of alkali metal phosphates and alkali metal silicates as a dispersant for said slimes, said dispersant having been added to the ore pulp prior to the addition of the mannogalactan.

2. In a method of separating valuable constituents from metal bearing sulphide ores which contain slime forming constituents, the improvement which comprises subjecting a metal bearing sulphide ore pulp to froth flotation in the presence of a mineral collector, a finite amount of mannogalactan as a depressant for slimes, and a finite amount of a dispersant for slimes of the group consisting of alkali metal phosphates, alkali metal pyrophosphates, alkali metal polyphosphates, and sodium silicate, the dispersant having been added to the ore pulp prior to the addition of the mannogalactan.

3. In a method of separating valuable constituents from metal bearing sulphide ores which contain slime forming constituents, the improvement which comprises subjecting a metal bearing sulphide ore pulp to froth flotation in the presence of a mineral collector, from about 0.1 to 0.5 pound of mannogalactan as a depressant for slimes per ton of ore and from about 0.2 to 0.5 pound per ton of ore of a dispersant for slimes of the group consisting of alkali metal phosphates, alkali metal pyrophosphates, alkali metal polyphosphates, and sodium silicate, the dispersant having been added to the ore pulp prior to the addition of the mannogalactan.

4. In a method of separating valuable constituents from metal bearing sulphide ores, the improvement which comprises subjecting a metal bearing sulphide ore pulp to froth flotation in the presence of a mineral collector, from about 0.1 to about 0.5 pound of guar per ton of ore and from about 0.2 to about 0.5 pound per ton of ore of a compound selected from the group consisting of alkali metal phosphates and alkali metal silicates, the said compound having been added to the ore pulp prior to the addition of the guar.

5. The method according to claim 4 in which the said compound is a member selected from the group consisting of alkali metal pyrophosphates and alkali metal polyphosphates.

6. In a method of separating valuable constituents from metal bearing sulphide ores, the improvement which comprises subjecting a metal bearing sulphide ore pulp to froth flotation in the presence of a mineral collector, from about 0.1 to 0.5 pound of guar per ton of ore and from about 0.2 to 0.5 pounds of sodium silicate per ton of ore, the sodium silicate having been added to the ore pulp prior to the addition of guar.

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