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journal or publication title	Science reports of the Research Institutes, Tohoku University. Ser. A, Physics, chemistry and metallurgy
volume	15
page range	32-50
year	1963
URL	http://hdl.handle.net/10097/27114

Studies on the Flotation of Molybdenite. I
Flotation of Molybdenite Ore Containing Clayey Gangue*

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(Received Dec. 17, 1962)

Synopsis

Some points to be considered in the flotation of molybdenite containing clayey gangue were investigated, and based on the results obtained, the method of flotation operation was examined at the Daito mine, Shimane Prefecture.

In the rougher flotation of molybdenite ore, high concentrate grade and recovery can be obtained by selecting the proper ratio of silica to soda and suitable concentration of sodium silicate to be added. Sodium silicate having the ratio of silica to soda 2: 1 shows the most effective depressing action on gangue minerals. The minimum content of SiO_2 in the froth product is obtained when the conditioning time after adding sodium silicate is 10–20 minutes. It is preferable to use sodium hydroxide instead of lime to regulate the pH value of the pulp containing much primary slime. On the contraty, lime is effective for the flotation of molybdenite ore containing no primary slime.

Though it is usual to use oily collectors as collecting agents for molybdenite, quantities to be added to obtain good flotation results are unexpectedly large. In some cases molybdenite can be recovered at high rates of recovery by using xanthate with oily collector, but we should be cautious of using much xanthate. However, a good flotation result cannot be expected with xanthate only.

At the Daito mine, the flotation results have been improved by modifications of flotation methods: slime is treated by a separate flotation circuit and the froths are returned to the main circuit. Sodium hydroxide is used to regulate the pH value of the pulp. Thus, no difficulty has been experienced in producing a molybdenite concentrate assaying 86.3–87.4% MoS_2 with a recovery of 95.5–97.9% from a flotation feed assaying 1.06–1.13% MoS_2.

I. Introduction

As widely known, molybdenite is one of the most readily floatable of all sulphide minerals, but enrichment of its ore by flotation is not always simple. At the Climax mine, the molybdenite concentrate containing more than 90% of MoS_2 has been extracted with a recovery of 98.5%[(1),(2)], and at the Knaben mine, concentrate assaying 96–97% MoS_2 is recovered with a recovery of 90%.[(3)]

Exclusive of such examples, it is often difficult to expect a good flotation result

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* The 140th report of the Research Institute of Mineral Dressing and Metallurgy. The original report was published in Japanese in Bull. Res. Inst. Min. Dress. Met., Tohoku University, **17** (1961), 69.

(1) E.J. Duggan, Am. Inst. Mining Met. Engrs., Tech. Publ. No. 1,456 (1942), 1.

(2) Mining Eng., **7** (1955), 742.

(3) After private communication from Associate Professor M. Digre.

owing to the limited mill facilities and properties of ore produced at mines of small-scale deposits, commonly found in this country.

The basin of the upper stream of the Ayo river, flowing through the Shimane Prefecture, is the famous district producing molybdenum ores in this country. The Daito mine, Taiyo Mining and Industrial Co., situated 4 km up the Ayo river, is one of the largest producers of molybdenite concentrate in this district. At this mine, molybdenite concentrate of 88% MoS_2 had been recovered with a recovery of 96% from ores containing about 1.3% MoS_2, but recently the treatment of crude ores containing clayey gangue from the Hinotani pit resulted in the decrease of the grade of concentrate down to 82% MoS_2 and the recovery of less than 80% MoS_2, the market specifications for the grade of concentrate being 85% MoS_2.

In order to get such condition out of the way and to contribute to the improvement of the flotation process of molybdenite, some points to be considered in the flotation of molybdenite containing clayey gangue were investigated. Based on the results obtained, the mill operation at the Daito mine was re-examined and the satisfactory results were obtained.

This paper deals with some results of fundamental flotation experiments and gives a brief review of the improvement of mill operation at the Daito mine.

II. Preparation of ore samples

Two kinds of molybdenite ores containing clayey gangue minerals were obtained from the Hinotani pit of the Daito mine and used in these investigations. The ores were first crushed through a Blake crusher and then through a roll jaw crusher. The crushed product was screened at 4-mesh and the oversize was re-crushed to the same mesh size. The undersize was ground dry in a laboratory ball mill to 80% of minus-100-mesh and was used for the flotation tests. Chemical analyses and size distributions of smaple A are presented in Tables 1 and 2 respectively. In the present study, sample A was usually used, unless otherwise specified where sample B was used, the analyses of sample B being 1.45% MoS_2, 6.22% Fe, and 76.30% SiO_2.

Table 1. Chemical analyses of molybdenite ore (A)

Composition	Grade (%)
MoS_2	1.37
SiO_2	65.03
Fe	6.46
Cu	0.024
Al_2O_3	12.15
CaO	0.67
MgO	0.54
P	0.026
S	3.746

The occurrence of molybdenite in these ores is considerably simple, the grain size being mostly coarse and that of less than 10 microns being seldom observed.

Table 2. Size distributions of molybdenite ore (A)

Size (mesh)	Weight (%)
+ 65	1.8
65 – 100	16.6
100 – 150	14.7
150 – 200	8.7
200 – 270	18.6
270 – 325	6.4
– 325	33.2

Pyrite and an extremely small amount of chalcopyrite are found besides molybdenite.

III. Flotation tests

1) Batch flotation test

All flotation tests were carried out with reference to the operating conditions at the Daito mine. The flotation results in the present study were obtained under the conditions of 20% solid of pulp density, and the additions of 2 kg/t of lime, 50 g/t of sodium silicate ($Na_2O/SiO_2=1/2$), and 400 g/t of mixed oil of Nikko flotation oil No. 125 and Nikko pine oil No. 5 in the proportion of 1: 1. Flotation tests were all done in a M.S. type flotation testing machine modified at the Kyoto University. The pulp was agitated for 5 minutes, and then conditioned for 15 minutes after adding lime, and for 5 minutes after adding sodium silicate. The pH value of the pulp was measured after flotation. 100 g/t of mixed oil was added to each froth product. The results obtained were as follows: the average grades of the first to the fourth froth products were 45.78% MoS_2, 4.06% Fe, and 26.48% SiO_2 and the recovery of MoS_2 was 50.23%, the grade of tailing being 0.82% MoS_2 (See curve I of Fig. 1).

2) Influence of the composition of sodium silicates

One of the most widely used gangue depressants in nonmetallic flotation is sodium silicate, which varies in silica to soda ratio from 1 to 3.75. Recently, Sollenberger et al.(4) reported that a systematic study was made of the effect of different silica-soda ratios of sodium silicate on the concentration by flotation of ores of scheelite, specular hematite and uranium minerals, and that good results could be obtained by selecting sodium silicate of proper silica-soda ratio and its concentration with the pH of the pulp.

Undoubtedly, the admixture of gangue minerals is responsible for being unable to obtain higher concentrate grades. In the present study, therefore, the dispersing effect of sodium silicate of different silica-soda ratios was investigated. Three kinds of sodium silicates of silica to soda ratios of 1: 1, 2: 1, and 3: 1 were offered from the Ube Soda Research Laboratories. The results of flotation with these reagents are

(4) C. L. Sollenberger and R.B. Greenwalt, Mining Eng., **10** (1958), 691.

shown in Fig. 1. Sodium silicate of silica to soda ratio of 2: 1 showed the most effective depressing action on gangue minerals, while that of silica to soda ratio of 1: 1 or 3: 1 showed a little inferior action. Therefore, in the tests described hereafter, sodium silicate of silica to soda ratio of 2: 1, called "sodium silicate", was used throughout.

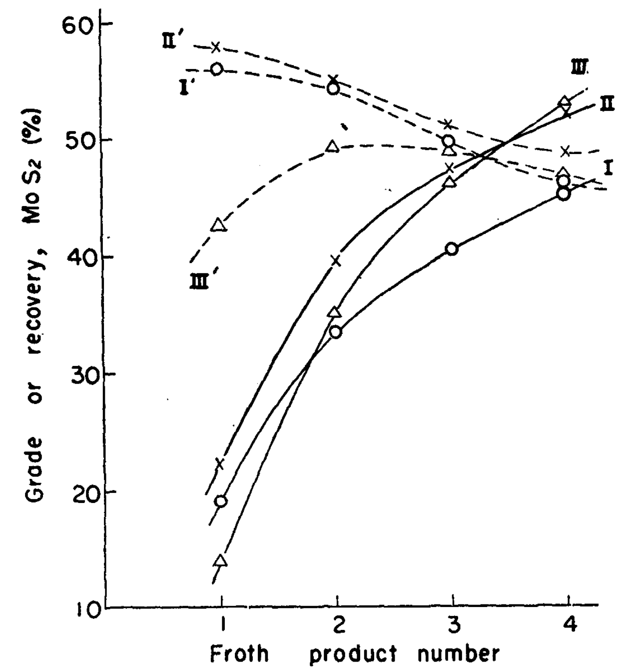

Fig. 1. Influence of the compositions of sodium silicates.
Compositions of sodium silicates (Na_2O/SiO_2):
Curves I, I′ 1/1; curves II, II′ 1/2;
curves III, III′ 1/3.
Curves I,II, and III represent the cumulative values of MoS_2 recovery of froth products, and curves I′, II′, and III′ the mean value of MoS_2 grade.

3) Influence of the amount of sodium silicate

Influence of the amount of sodium silicate to be added was studied in both cases where mixed oil alone was used and where potassium ethylxanthate together with mixed oil was used. Fig. 2 illustrates the results of flotation obtained with mixed oil only. Additional remarks under Fig. 2 shows the conditions of flotation tests. The addition of 50 g/t of sodium silicate resulted in the highest grades of MoS_2 of the froth products, while it failed to bring about a good recovery of MoS_2. In the case of 200 g/t addition of sodium silicate, the grade of MoS_2 in the froth product was lower than that of 50 g/t addition, but the total recovery from the first to the seventh froth products amounted twice that of zero addition. This value is equivalent to 1.2 times that of obtained 50 g/t addition. The recovery of MoS_2 increased regularly with the increase in the amount of sodium silicate between 0 to 200 g/t addition of sodium silicate while decreased over 200 g/t addition. From these features it may be concluded that sodium silicate has a remark-

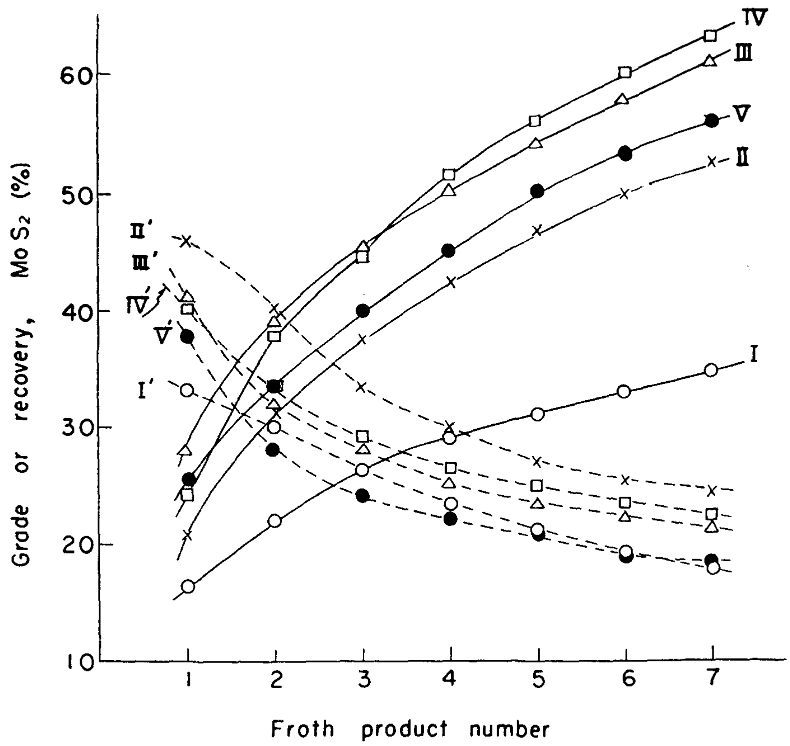

Fig. 2. Influence of the quantities of sodium silicate, using mixed oil.
Sodium silicate added (g/t): curves I, I′ 0; curves II, II′ 50; curves III, III′ 100; curves IV, IV, 200, curves V, V′ 400.
Pulp density 20%; preliminary agitation 10 min; conditioning after the addition of sodium silicate 20 min; Nikko mixed oil for each froth product 100 g/t; flotation period 10 min for each froth product; pH of the pulp 4.9-6.2; temperature of the pulp 11.5-27.0°C.

able dispersing effect while its use beyond a suitable quantity causes a bad flotation effect.

There are found limited examples of the use of xanthate as collector for molybdenite. It may, however, be considered that the use of xanthate is one of the methods of improving the recovery of molybdenite. Therefore, flotation tests were carried out by using 100 g/t potassium ethylxanthate with mixed oil, 2 kg/t lime being added, the pH of the pulp adjusted to 9.7–9.6, and the quantities of sodium silicate varied between 100–400 g/t. Fig. 3 shows the experimental results. Both grade and recovery were the best when 100 g/t of sodium silicate was used. Also, the dispersing effect of sodium silicate on gangue minerals, was marked when using xanthate and mixed oil. In this case, however, the use of sodium silicate beyond proper quantity should also be avoided strictly. The recovery of molybdenite, as might be expected, was improved by the use of xanthate together with mixed oil, but the MoS_2 grade of the concentrate dropped markedly as

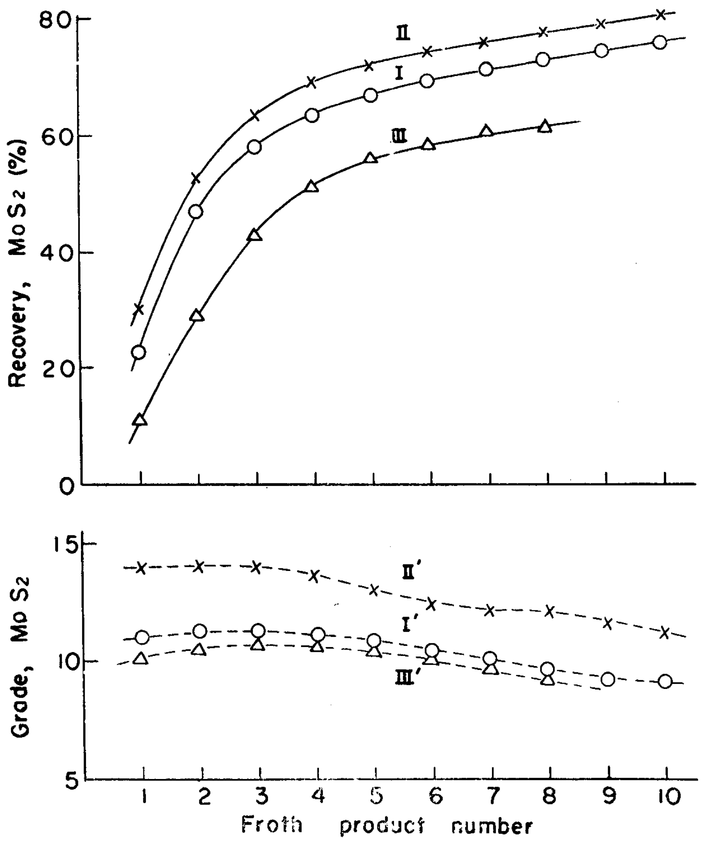

Fig. 3. Influence of the quantities of sodium silicate, using lime (2 kg/t), potassium ethyl xanthate (100g/t), and mixed oil.
Sodium silicate added (g/t): curves I, I′ 100; curves II, II′ 200; curves III, III′ 400.

compared with that by mixed oil alone.

4) Influence of conditioning time after adding sodium silicate

Fig. 4 shows the influence of conditioning time after adding 200 g/t of sodium silicate for sample B. Conditioning time was varied from 0 to 40 minutes. The grade of MoS_2 of froth products was the highest for the conditioning time of zero, but the recovery of MoS_2 decreased with the increase in conditioning time. The SiO_2 assay, which might be regarded as a direct measure of the dispersing effect on gangue minerals, was the highest at the conditioning time of zero and decreased

Table 3. Variation of SiO_2 grade in froth product with conditioning time after adding sodium silicate.

Conditioning time (min)	First froth		Second froth	
	Weight (%)	SiO_2 (%)	Weight (%)	SiO_2 (%)
0	1.34	39.64	1.76	39.24
5	1.82	19.20	2.10	28.07
10	2.04	12.43	1.77	26.04
20	1.69	12.44	1.76	27.17
40	1.76	15.97	1.84	29.92

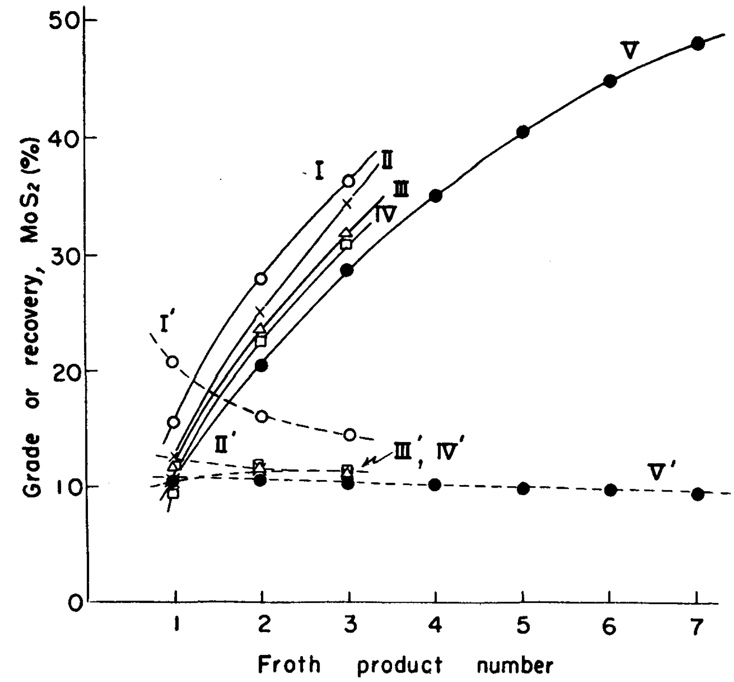

Fig. 4. Influence of the conditioning time after adding sodium silicate. Conditioning time (min): curves I, I′ 0; curves II, II′ 5; curves III, III′ 10; curves IV, IV′ 20; curves V, V′ 40.

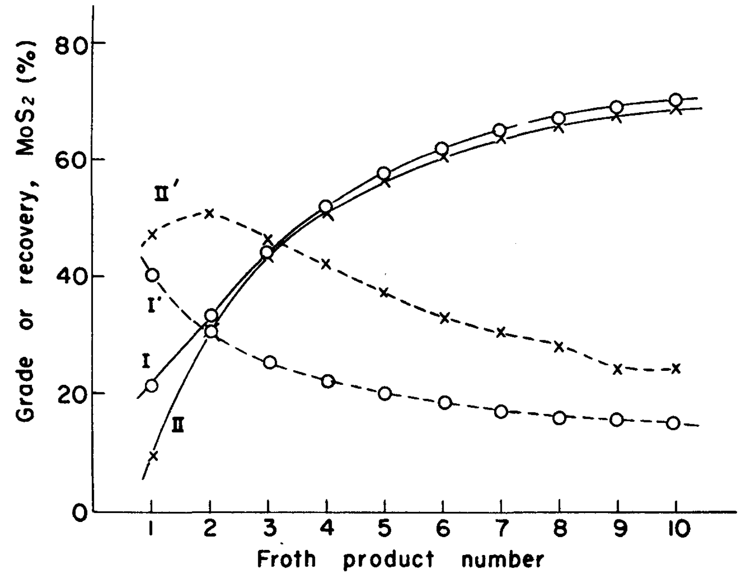

Fig. 5. Influence of lime, using sodium silicate (200 g/t) and mixed oil. Lime added (kg/t): curves I, I′ 0 (pH 4.8-5.4); curves II, II′ 2 (pH. 9.8-8.6)

with the increase in conditioning time. But conditioning over suitable period brought about the high SiO_2 content in froth products, as seen in Table 3. The MoS_2 grade of froth products was influenced slightly by conditioning time; on the other hand, the MoS_2 recovery decreased regularly with the increase in conditioning time. But it may be considered that the drop of recovery of MoS_2 can be relieved by the increase in quantity of mixed oil or of flotation time. Therefore, it may be preferable to take conditioning time for 10–20 minutes to obtain a good flotation result.

5) Influence of lime

Pyrite contained in the present samples may be depressed in the usual manner by lime. Hitherto, at the Daito mine, lime has been used as a pH regulator. But there are found many examples where clayey gangue regulated with lime affect badly the flotation results. Further, it is well known that molybdenite is depressed by lime.(5),(6) Accordingly, it was considered necessary to re-investigate the use of lime.

Fig. 5 shows the flotation results using mixed oil alone. Recovery of MoS_2 is not influenced by the presence of lime, while the MoS_2 grade become higher. Average grades of Fe of the first to the tenth froth products combined were 18.90%

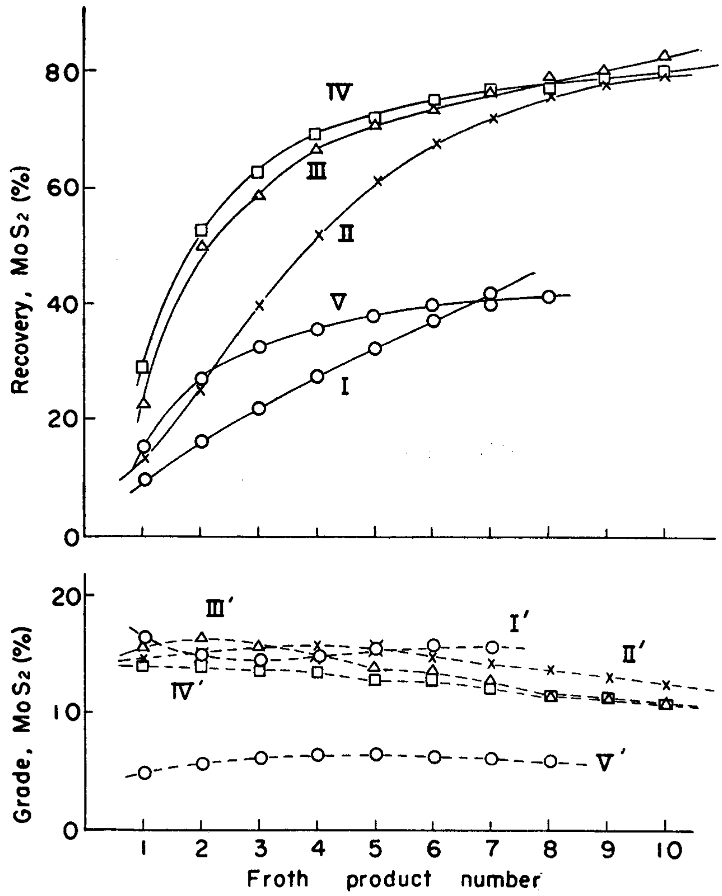

Fig. 6. Influence of lime, using sodium silicate (200 g/t), potassium ethyl xanthate (100 g/t), and mixed oil.
Lime added (kg/t): curves I, I′ 0 (pH4.8-5.5); curves II, II′ 0.5 (pH 6.3-5.9); curves III, III′ 1 (pH 7.4-7.3); curves IV, IV′ 2 (pH 9.7-8.6); curves V, V′ 4 (pH 10.9-9.3).

(5) K. Kanazawa, Suiyokwaishi, **13** (1956), 159.
(6) A. Ohba, Thesis of M. Eng., Tohoku Univ., (1955).

Table 4. Effect of lime with mixed oil*

Lime added (kg/t)	Grade (%)	
	Fe	SiO_2
0	19.07	23.92
0.5	20.18	23.77
1	23.44	21.97
2	26.19	19.99
4	28.59	20.55

* The first to the seventh froth products combined were used for assay.

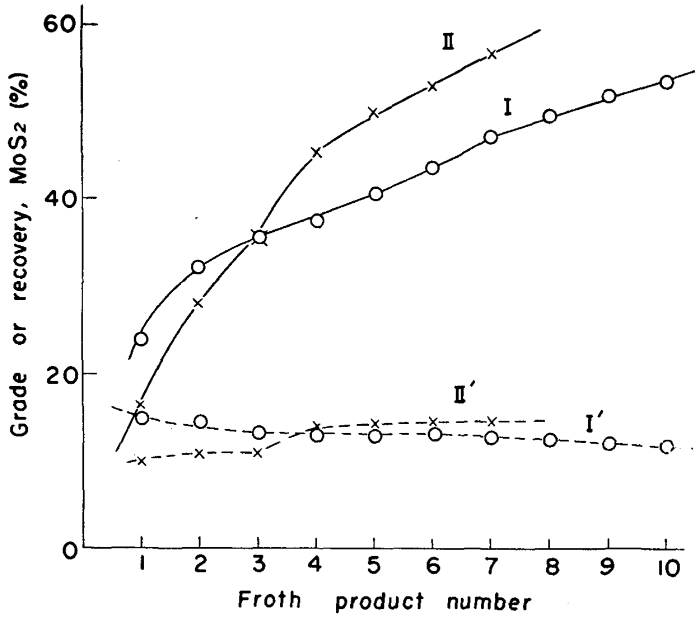

Fig. 7. Influence of lime, using sodium silicate (200 g/t),potassium ethyl xanthate (50 g/t for each froth), and Nikko pine oil (50g/t at the first stage only).
Lime added (kg/t): curves I, I', 0 (pH 6.2-4.9); curves II, II' 2 (pH 9.5-9.0).

without lime and 5.58% with 2 kg/t lime respectively. Thus, it may be considered that pyrite was depressed effectively by lime. Nevertheless, the SiO_2 content in the combined froth product exceeded the value expected from the removal of pyrite by lime. It may be supposed that such high content of SiO_2 is mainly due to the flocculation and activation of gangue minerals with lime.

Fig. 6 shows the results of flotation obtained with potassium ethyl xanthate and mixed oil. The MoS_2 grade decreased with the increase in lime quantity, but it was dropped sharply at 4 kg/t of lime, the pH of pulp after flotation being 9.3. The recovery of MoS_2 increased gradually with the increasing lime quantity, but it deteriorated remarkably by the use of 4 kg/t lime. The variation of Fe and SiO_2 grades of the froth products with the addition of lime is shown in Table 4. The grade of Fe increased with the increase in lime quantity, while SiO_2 grade decreased with it. This tendency is quite different from that of mixed oil alone. In case of using xanthate as a collector, this tendency was increasingly intensified, as will be described later.

Fig. 7 presents the effect of lime with stepwise xanthate additions. The MoS_2 grade of froth products was not be influenced so much with the use of lime, while the recovery increased by 10%. But it should be noted that the recovery of MoS_2 with xanthate was lower than that with mixed oil or with xanthate and mixed oil together. Without lime addition, the grades of Fe and SiO_2 of the first to the seventh froth products combined were 22.68 and 22.07% respectively, whereas with 2 kg/t lime addition, they were 30.44 and 14.71% respectively. That is, the Fe grade becomes higher by the use of lime, while the SiO_2 grade becomes lower. This fact is quite contrary to the case of mixed oil alone. As is well-known, lime acts an depressant in the xanthate flotation of pyrite alone. Although the rise in Fe grade of the froth products is to be somewhat expected from the results with xanthate and mixed oil together, the reasons for which remain unexplained at this stage. It is supposed that this problem is worth studying in future.

6) Influence of sodium hydroxide

Quartz particles are flocculated with lime, but not with sodium hydroxide[7]. Therefore, it may be expected that the effect of sodium hydroxide on the flotation of the present sample differs from that of lime.

Fig. 8 shows the effect of sodium hydroxide with mixed oil. Though MoS_2

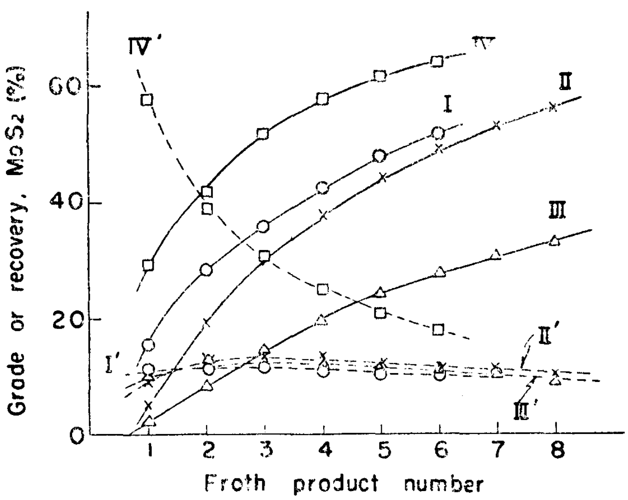

Fig. 8. Influence of sodium hydroxide, using sodium silicate (200 g/t) and mixed oil.
Sodium hydroxide added (kg/t): curves I, I′ 0.5 (pH 5.0-4.7); curves II, II′ 1 (pH 5.8-5.7); curves III, III′ 2 (pH 7.5-7.2); curves IV, IV' 2 (pH 8.5-7.5).

grade of froth products was not to be influenced by the additions of 0.5–2 kg/t lime, the recovery of MoS_2 decreased markedly with the increase in lime quantity. But,

(7) T. Oyama and S. Usui, Nippon Kogyo Kaishi, **73** (1957), 551.

Table 5. Effect of sodium hydroxide with mixed oil.*

Sodium hydroxide added (kg/t)	Grade (%)	
	Fe	SiO_2
0.5	18.02	34.01
1	13.28	43.46
2	12.38	48.85
4	4.16	60.20

* The first to the sixth froth products combined were used for assay.

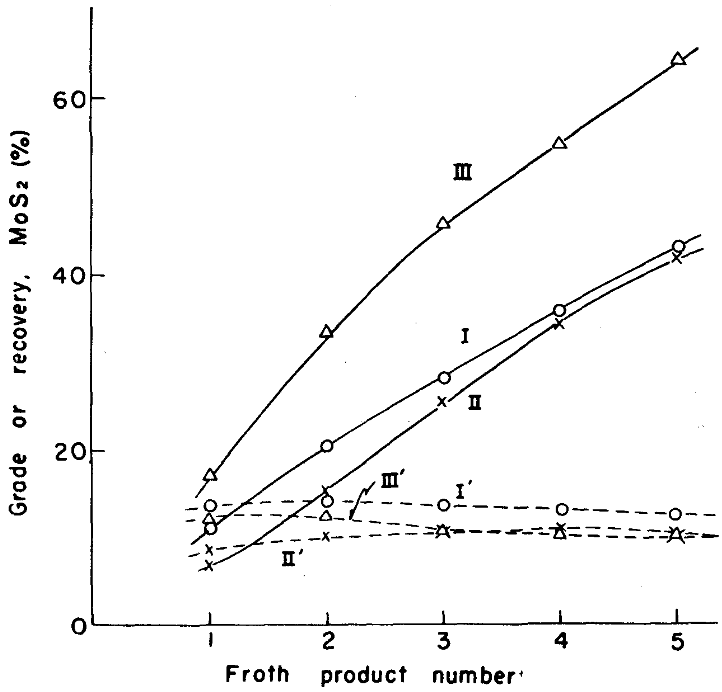

Fig. 9. Influence of sodium hydroxide, using sodium silicate (200 g/t), potassium ethyl xanthate (100 g/t), and mixed oil.
Sodium hydroxide added (kg/t): curves I, I' 0.5 (pH 5.0-4.7); curves II, II' 1 (pH 5.8-5.7); curves III, III' 2 (pH 7.3-7.2).

both grade and recovery of MoS_2 increased sharply with the addition of 4 kg/t lime. The comparison of the flotation results obtained with 2 kg/t lime and with 4 kg/t sodium hydroxide shows that the MoS_2 grade of froth products for the former is higher than that for the latter, while the recovery of MoS_2 for the former is lower than that for the latter.

Table 5 shows the effect of sodium hydroxide on the Fe or SiO_2 grade of the first to sixth froth products combined. The Fe content in the combined product dropped remarkably with sodium hydroxide but SiO_2 content, e.g. the contamination with siliceous gangue, was much higher than that with lime.

As shown in Fig. 9, a similar tendency was observed when xanthate and mixed oil were used together. The use of 0.5–1 kg/t sodium hydroxide did not affect the grade and recovery of MoS_2 of froth products, but the use of 2 kg/t sodium hydroxide gave rise to a considerably large increase in the recovery of MoS_2. The comparison of the flotation results obtained with 1 kg/t lime and with 2 kg/t sodium hydroxide shows that the MoS_2 grade of froth products for the former is somewhat higher than that for the latter while the recovery of MoS_2 for the former is remarkably lower than that for the latter.

Thus in these tests, sodium hydroxide did not show any particularly excellent

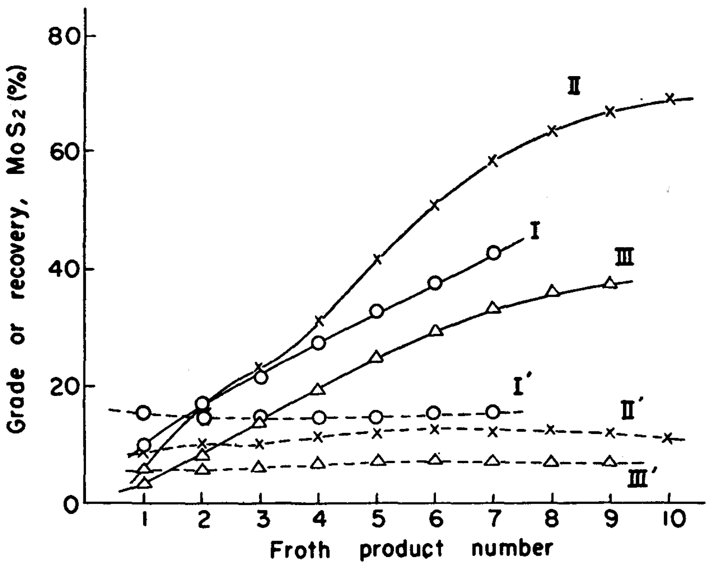

Fig. 10. Influence of the quantities of potassium ethyl xanthate, using sodium silicate (200 g/t) and mixed oil.
Xanthate added (g/t): curves I, I′ 100; curves II, II′ 200; curves III, III 400.

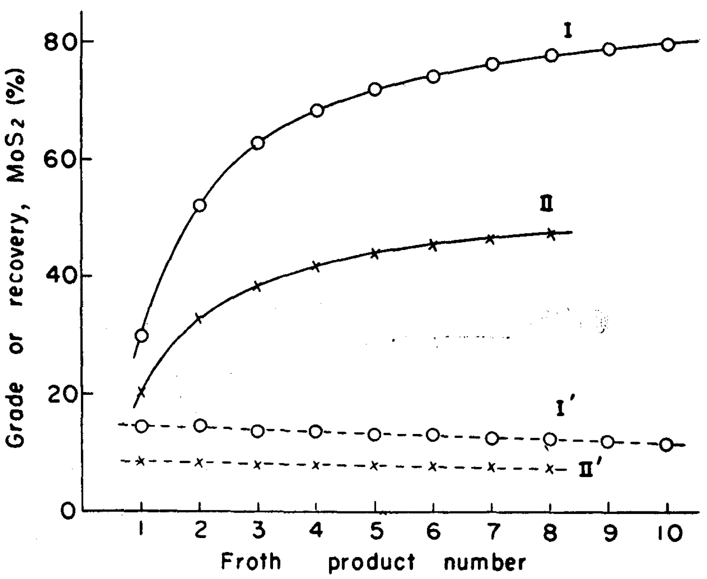

Fig. 11. Influence of the quantities of potassium ethyl xanthate, using sodium silicate (200 g/t), lime (2k g/t), and mixed oil.
Xanthate added (g/t): curves I, I′ 100; curves II, II' 200.

effect in comparison with lime. However, it shows an excellent effect on slimy ore, as will be described later.

7) Influence of xanthate

The use of xanthate in proper quantities with mixed oil at the same time results in the increase in the recovery of MoS_2, as described previously. But it may be supposed that the excessive use of xanthate causes a bad flotation effect. Therefore, the influence of quantities of xanthate was investigated.

Fig. 10 shows the flotation results obtained without lime, and Fig. 11 those with 2 kg/t lime. As shown in Fig. 10, the increase in quantities of xanthate led to the lowering of MoS_2 grade. Maximum recovery of MoS_2 was obtained with the addition of 200 g/t xanthate. The use of xanthate of over 200 g/t gave rise to the sharp drop in recovery of MoS_2.

When lime was added, the use of xanthate of over 100 g/t caused the lowering of grade and recovery of MoS_2, as seen in Fig. 11. The use of amyl xanthate instead of ethyl xanthate made no difference to the flotation results.

8) Influence of mixed oil

In all flotation tests described above, mixed oil was added at the rate of 100 g/t to each froth product. It may be readily supposed that flotation results become different from those of the previous tests, if the amount of mixed oil applied to each froth product is varied. In a mill operation, middling is usually retreated, so the optimum quantity of mixed oil given in this study will not be applied directly to a mill operation. But it is interesting to obtain the fundamental data necessary for elucidation of flotation characteristics of molybdenite.

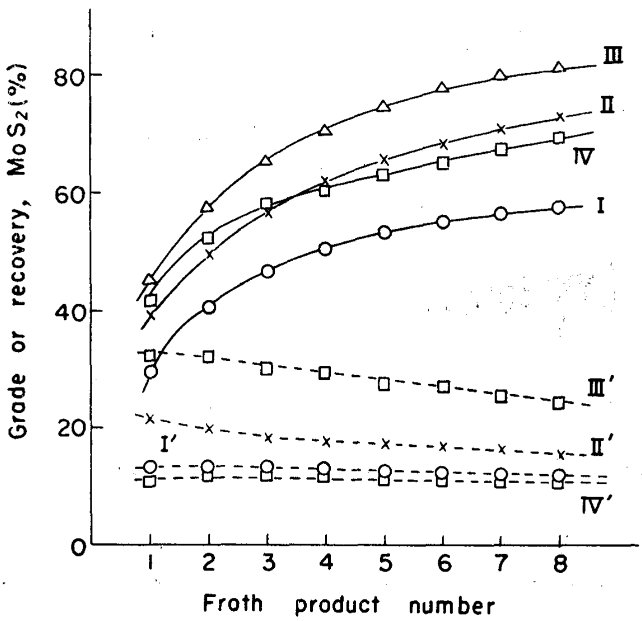

Fig. 12. Influence of the quantities of mixed oil, using sodium silicate (200g/t).
Mixed oil added for each froth product (g/t): curves I, I′ 100; curves II, II′ 200; curves III, III′ 400; curves IV, IV′ 800.

Fig. 12 shows the experimental results obtained with sample B. As is obvious from the figure, the best recovery and grade of MoS_2 could be obtained with the addition of 400 g/t mixed oil to each froth product. The addition of 800 g/t mixed oil to each froth product caused a bad flotation effect. The assay of MoS_2, Fe, and SiO_2 of the first to the eighth froth product combined are presented in Table 6. It is found that the product of higher MoS_2 grade contains much SiO_2 and little Fe.

9) Flotation properties of the size fractions with and without primary slime

To understand the flotation behavior of slime of the present ore, the sample was prepared as follows: 1 kg of ore crushed minus 4-mesh through a Blake crusher

Table 6. Effect of the quantity of mixed oil.*

Mixed oil added (kg/t)	Grade (%)		
	MoS_2	Fe	SiO_2
0.8	11.68	20.66	31.00
1.6	15.72	13.35	37.95
3.2	25.03	5.90	48.38
6.4	11.08	22.12	34.24

* The first to the eighth froth products combined were used for assay.

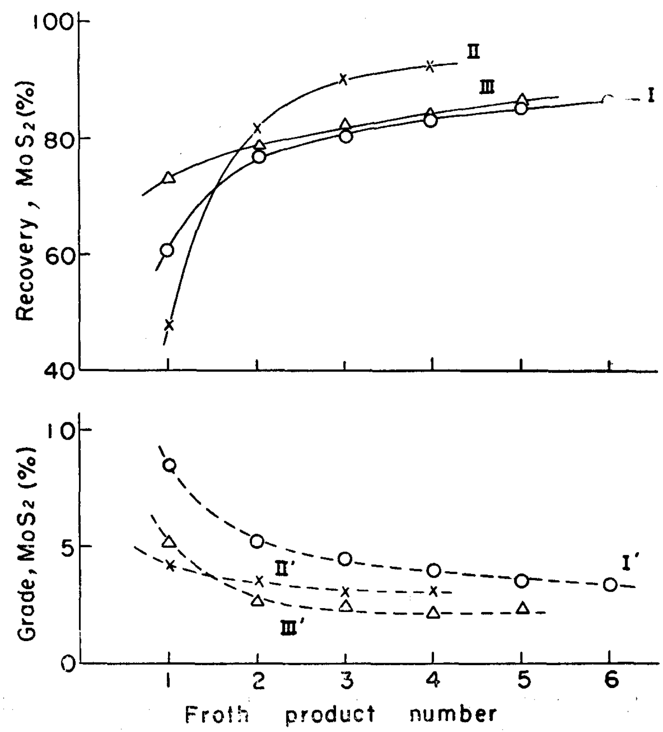

Fig. 13. Flotation results of the sample of oversize re-ground through 65-mesh.
I, I′: using mixed oil alone (100g/t for each froth product); II, II′: using lime (1 kg/t), potassium ethyl xanthate (100 g/t); and mixed oil (100 g/t for each froth product), III, III: using sodium hydroxide (4 kg/t), potassium ethyl xanthate (100 g/t), and mixed oil (100 g/t for each froth product).

and a roll jaw crusher was agitated in a Fagergren type flotation machine for 30 minutes at the pulp density of 25% solid, and then screened wet through 65-mesh. A portion of the undersize was used as it was and a portion of the oversize was reground in a porcelain mill until all material passed through 65-mesh and then offered as samples. The former contained 2.2% MoS_2 and the latter 0.2% MoS_2. Flotation tests were carried out for each sample under the following conditions: (a) using mixed oil alone, (b) using xanthate with mixed oil together after conditioning with 1 kg/t calcium hydroxide, and (c) using xanthate together with mixed oil after conditioning with 4 kg/t sodium hydroxide.

Fig. 13 shows the flotation results obtained for the size fraction without primary slime, and Fig. 14 those for the size fraction with primary slime. With

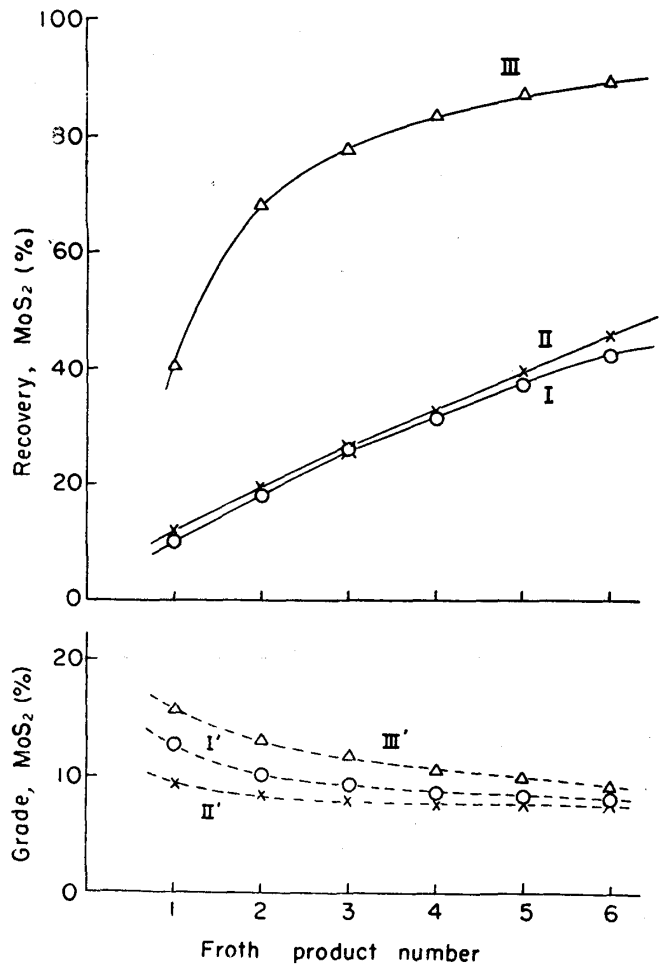

Fig. 14. Flotation results of the sample of 65-mesh undersize. Conditions of flotation: the same as in Fig. 13.

the re-ground product of the oversize fraction, the MoS_2 grade of froth product was the highest under the condition of (a), but the ratio of enrichment was considerably large in spite of the flotation conditions. The best recovery of MoS_2 was obtained under the condition of (b), but the cumulative recovery exceeded 80% for the fourth froth product even under unfavorable conditions.

Though MoS_2 grade of this sample was 0.2%, that of the tailing after extracting the fourth froth product became 0.02% under the condition of (b). On the other hand, MoS_2 grade of froth product recovered from the undersize sample decreased in order of (c), (a), and (b), as seen in Fig. 14. The MoS_2 recoveries of the first to the sixth froth product combined were 40% under (a) and (b), and 90% under (c) respectively.

Thus, the effect of sodium hydroxide on slime flotation is excellent.

From these results it may be considered that the use of lime is preferable in regulating the pH value of the pulp containing no primary slime while the use of sodium hydroxide for the pulp containing much primary slime is effective in recovering more MoS_2. So, it became possible to treat the fraction of ore containing primary slime in a separate circuit after classifying at a suitable size.

IV. Modification of flotation method at the Daito mine

Hitherto, at the Daito mine, the mill operation had been carried out according to the flowsheet presented in Fig. 15. But the application of the ore containing clayey gangue from the Hinotani pit to such a circuit gave place to the rubs as previously mentioned. Therefore, it became necessary to re-examine the method of mill operation. From the flotation results obtained in the present studies, it is

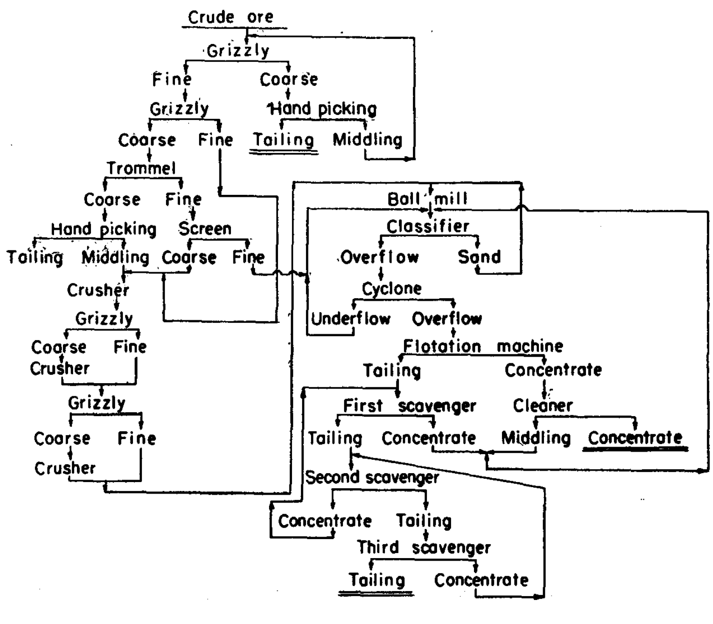

Fig. 15. Flowsheet of the dressing mill at the Daito mine. (Before improvement)

considered difficult that merely simple replacement of reagents is not useful enough as a means of settling the rubs. For instance, the use of sodium silicate having the ratio of silica to soda 2:1 or of sodium hydroxide is surely effective in a mill operation, but that much is still insufficient. One of the remedies expected through the experimental results is the treatment of a portion of ore containing primary slime, whose behavior in flotation is different from the bulk ore without primary slime, in a separate circuit.

However, economical restrictions to the increase of equipments should be taken into consideration as a matter of course, so the treatment of ore containing primary slime in a completely separate circuit is hardly to be expected. Therefore, it may be considered that the fines classified are treated in a separate flotation circuit to remove much primary slime as possible and then the froths are returned to the main circuit. According to such point of view, the flowsheet was modified as shown in Fig. 16. Crude ore from the lump ore bin is first screened wet in a trommel and then in a low-head screen, and a portion of the undersize is classified in a drag classifier. The overflow from classifier is treated in two Fahrenwald No. 18 SP type flotation cells and the froths are returned to a Dorr classifier. The pH value of pulp in a rougher flotation circuit is held at 8.5 using sodium hydroxide. Reagents used are as follows: 6 g/t sodium cyanide and 340 g /t Nikko No. 120-T flotation oil in the main roughing flotation circuit, 6 g/t sodium cyanide in the cleaning circuit, 190 g/t mixed oil prepared by mixing Nikko No. 120-T flotation

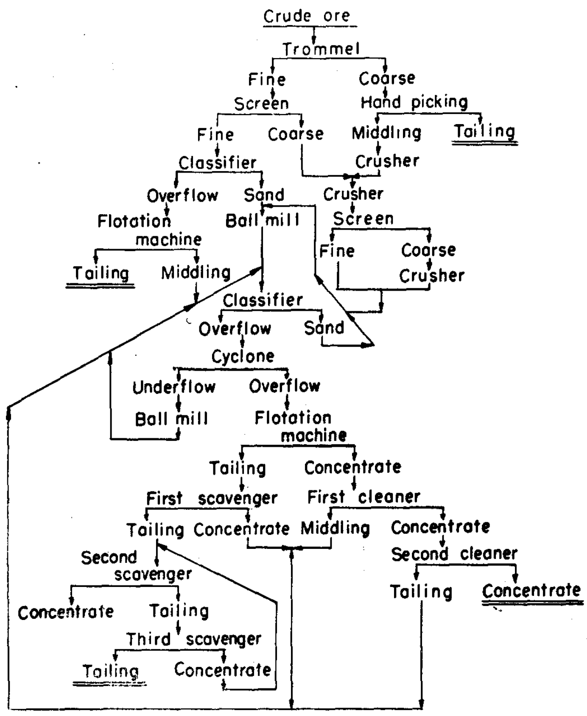

Fig. 16. Flowsheet of the dressing mill at the Daito mine. (After improvement)

oil with Nikko No. 5 pine oil in the ratio of one to one (added stepwise) in the scavenging flotation circuit, and 36 g/t Nikko No. 120-T flotation oil in the slime flotation circuit. Thus, at the Daito mine, no difficulty has been experienced in producing a molybdenite concentrate assaying 86.3–87.4% MoS_2 with a recovery of 95.5–97.9% from a flotation feed assaying 1.06–1.13% MoS_2 within 6 months from

January to June in 1961.

Describing for reference, ore assaying 2.58% MoS_2 was fed to the slime circuit, and tailing assaying 0.08% MoS_2 was rejected, the froth containing 39.37% MoS_2 being floated with a recovery of 97%.

Summary

Flotation of molybdenite ore containing clayey gangue is not so easy. Therefore, in the present study, some points to be considered in the flotation of molybdenite ore containing clayey gangue were investigated. Then, based upon the results obtained, the mill operation at the Daito mine, where troubles encountered in the treatment of ore accompanying clayey gangue, was re-examined and the flowsheet was modified. Consequently, the flotation results have been improved and no difficulty has been experienced in producing a molybdenite concentrate of sufficient grade and in recovering MoS_2.

The results obtained may be summarized as follows:

1. The use of suitable quantities of sodium silicate is effective to disperse the clayey gangue minerals. Particularly sodium silicate having the silica to soda ratio of 2: 1 shows the best depressing action with that having the ratio of 1: 1 or 3: 1.

2. The addition of excess quantity of sodium silicate harms remarkably the floatability of molybdenite.

3. The minimum content of SiO_2 in a froth product is obtained when conditioning time after adding sodium silicate is 10–20 minutes.

4. It is preferable to use sodium hydroxide instead of lime to regulate the pH value of the pulp containing much primary slime. On the contrary, lime is effective for the flotation of molybdenite ore containing no primary slime.

5. Though it is usual to use oily collectors as collecting agents for molybdenite, the quantities to be added to obtain good flotation results are unexpectedly large. In some cases molybdenite can be recovered with high recoveries by using xanthate with oily collector, but we should be cautious of using much xanthate. However, a good flotation result cannot be expected with xanthate only.

6. At the Daito mine, the flotation circuit has been modified. Slime is treated by a separate flotation circuit and the froths are returned to the main circuit. Sodium hydroxide is used to regulate the pH value of the pulp. Consequently, the flotation results have been improved and no difficulty has been experienced in producing a molybdenite concentrate assaying 86.3–87.4% MoS_2 with a recovery of 95.5–97.9% from a flotation feed assaying 1.06–1.13% MoS_2.

Acknowledgments

The authors express their appreciation to Messrs. T. Hashimoto, Managing Director, T. Asano, Head of the Sendai Factory, and S. Toda, Chief of the Mineral Dressing Section of the Daito mine of the Taiyo Mining and Industrial Co., for their benevolent supports.

The authors also wish to acknowledge the assistance in the experimental work of Messrs. N. Seki and N. Abe of the Taiyo Mining and Industrial Co., and Misses H. Sasaki and K. Kikuta of the Research Institute of Mineral Dressing and Metallurgy, Tohoku University.