

Research Report on Lab Test of Mineral Processing for KIS Ore from Australia

Guangzhou Research Institute of
Non-ferrous Metals

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1 Preface

Guangzhou Research Institute of Non-ferrous Metals (GZRINM, for short later) was commissioned by KIS Management Pty Limited, Australia to carry out the WOF lab test on Scheelite ore from King Island, Australia with the object of providing a basis for plant feasibility study and design. The contract requires carrying out WOF lab test for two kinds of scheelite ore (B-Lens and C-Lens) from King Island and gains the scheelite concentrate which meets the quality requirements with as high as possible recovery by test. Besides, the comprehensive recovery and utilization of valuable elements in the ore should be conducted or their distribution should be traced.

There are three batches of test samples, with the former two groups used for preliminary tests which laid foundations for follow-up tests. The third batch is formal test sample, was sent to GZRINM on June 11, 2009. The lab dressing test had been basically completed by the end of August. The technological flow-sheet and quantitative flow-sheet of lab closed-circuit test were provided to Australia KIS Management Pty Limited in accordance with the contract requirements in early September. The cleaning processes of scheelite flotation rougher concentrate at

elevated temperature and at ambient temperature were compared by test and the former is recommended as the basis of feasibility study and plant design. The final results are shown in Table 1.1.

Table 1.1 the final results

Sample and flow-sheet	Name of Product	Grade WO ₃ %	Recovery WO ₃ %	Remarks
B-Lens ore technological flow-sheet at elevated temp.	Scheelite concentrate	66.58	90.87	B-Lens ore and C-Lens ore are assaying WO ₃ 0.5 % and WO ₃ 1.344% respectively
C-Lens ore technological flow-sheet at elevated temp.	Scheelite concentrate	67.24	91.16	

The above results have fully completed the task of lab test.

2 Preparation and processing of test materials

The processing flow-sheet of test materials is shown in Figure 2-1.

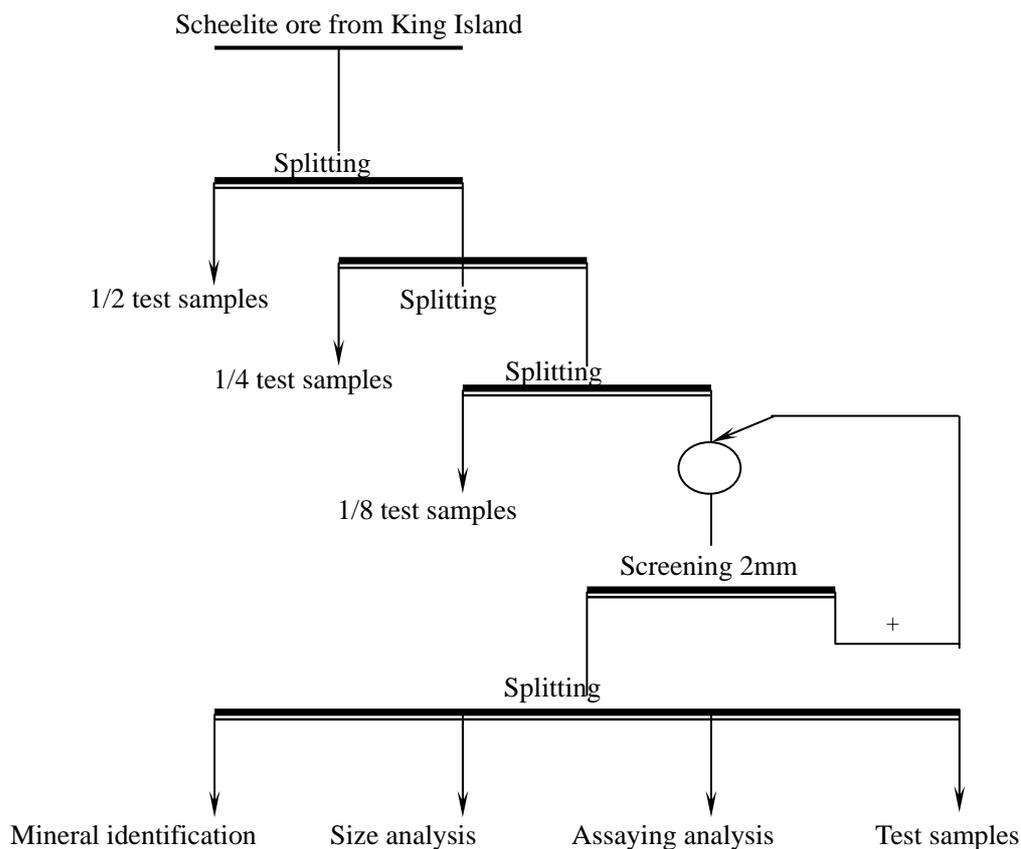


Figure 2-1 the processing flow-sheet of test materials

3 Physical and chemical properties of ore and study on process mineralogy

3.1 The physical and chemical properties of ore

The results of chemical multi-elemental analysis and phase analysis of crude ore are shown respectively in Table 3-1 and Table 3-2.

Table 3-1 the chemical multi-element analysis of crude ore

Element		WO ₃	CaCO ₃	CaF ₂	Cu	S	Pb	Bi	MgO
content %	B-lens	0.49	6.80	2.08	0.011	0.26	0.010	0.008	11.74
	C-lens	1.34	8.65	2.92	0.0059	0.35	0.0084	0.007	11.67
Element		Fe	Mo	SiO ₂	CaO	Al ₂ O ₃	As	Ag g/t	
content %	B-lens	7.95	0.015	42.42	19.01	3.61	<0.005	2.44	
	C-lens	13.11	0.035	36.48	25.38	4.85	<0.005	3.25	

Table 3-2 the phase analysis of crude ore

Mineral		Scheelite	Wolframite	tungstite	Total
B-lens	Content WO ₃ %	0.456	0.014	0.011	0.481
	Distribution WO ₃ %	94.80	2.91	2.29	100.00
C-lens	Content WO ₃ %	1.27	0.015	0.043	1.328
	Distribution WO ₃ %	95.63	1.13	3.24	100.00

3.2 Study on Process Mineralogy of Ores

3.2.1 Study on Process Mineralogy of C-Lens Ore Sample

3.2.1.1 The mineralogical composition of crude ore

Table 3-3 Multi-elemental analysis of crude ore

Element	WO ₃	Mo	Bi	Cu	Pb	S	Ag g/t	MgO
Content(%)	1.34	0.035	0.007	0.059	0.0084	0.35	3.25	11.67
Element	CaCO ₃	CaF ₂	As	Fe	SiO ₂	Al ₂ O ₃	CaO	
Content(%)	8.65	2.92	<0.005	13.11	36.48	4.85	25.38	

3.2.1.2 The mineralogical composition of crude ore

Microscope and the technique of MLA automatic detection were used to check and determine the mineralogical composition of this ore as well as its quantity. The content of major minerals is shown in Table 3-4. The results can be obtained that the tungsten mineral of ore is scheelite other than wolframite. There are a few sulphide minerals with the total amount of less than 1%, which are mainly pyrite、 thimbleful pyrrhotite、 chalcopyrite and molybdenite. The gangue minerals are primarily andradite, followed by diopside、 grossular、 calcite、 quartz、 feldspar、 tremolite, etc. Calcite is the main impurity gangue which has bad effect on tungsten cleaning, the content of fluorite is very low.

Table 3-4 Quantitative composition of the crude ore

Mineral	Content %	Mineral	Content %	Mineral	Content %
Scheelite	1.786	pyrite	0.632	calcite	5.451
Molybdenite	0.024	chalcopirite	0.016	fluorite	0.011
quartz	3.269	sphalerite	0.003	feldspar	1.688
diopside	13.747	pyrrhotite	0.146	muscovite	0.151
andradite	60.890	hematite	0.059	biotite	0.299
grossular	4.843	ilmenite	0.003	chlorite	0.300
tremolite	5.430	apatite	0.145	sphene	1.107

3.2.1.3 The dissemination size of scheelite

The lump ore was made into polished section to measure the dissemination size of scheelite. The results, presented in Table 3-5, show that the dissemination size of scheelite is uneven. The size of coarse grain is more than 1 mm while the fine one is only several microns. The particles of 0.04~1.28mm account for more than 90%, while +0.16mm medium-coarse fractions occupy 35%. The ore is unevenly disseminated in the form of medium-coarse grain.

Table 3-5 The dissemination of scheelite

Size (mm)	Grain-size distribution (%)	
	Share of grain size	Cumulative distribution
+1.28	1.33	1.33
-1.28+0.64	9.99	11.32
-0.64+0.32	10.32	21.64
-0.32+0.16	25.14	46.78
-0.16+0.08	33.96	80.74
-0.08+0.04	11.44	92.14
-0.04+0.02	4.72	96.90
-0.02+0.01	3.00	99.90
-0.01	0.10	100.00
Total	100.00	

3.2.1.4 The liberation degree of scheelite in the crude ore

The results of liberation degree of scheelite are shown in Table 3-6. According to the results, the scheelite has good liberation property. When the ore is ground to 63.7%-0.074mm, the liberation degree of scheelite is more than 96%.

Table 3-6 the liberation degree of scheelite at the grinding fineness of 63.7%-0.074mm

Size(mm)	Wt (%)	WO ₃ (%)	Liberation degree(%)
+0.15	5.57	0.39	73.23
-0.15+0.12	6.54	0.82	89.75
-0.12+0.10	6.68	1.07	90.87
-0.10+0.074	17.49	1.34	91.93
-0.074+0.043	12.39	1.61	95.31
-0.043+0.030	26.59	1.94	99.56
-0.030+0.020	10.58	0.89	100.00
-0.020+0.010	7.78	1.28	100.00
-0.010	6.38	1.13	100.00
Total	100	1.36	96.45

3.2.1.5 The characteristics of mineral processing and dissemination state of main minerals

3.2.1.5.1 Scheelite Ca[WO₄]

The scheelite presents tetragonal bipyramid or equiaxed granular with its crystal colorless and transparent while a minor portion shows

transparent straw yellow due to iron staining (See photo3-1). It appears grease luster, medium hardness (4.5), density 5.8-6.2g/cm³, brittleness and a clear cleavage. The chemical composition of scheelite is shown in Table 3-7 and Figure 3-1、3-2. According to the results, the scheelite and powellite in the ore present limited isomorphism. The scheelite generally contains molybdenum because of powellite's replacement, with the content of molybdenum varying from 0.6% to 5% in the form of MoO₃. At the same time, the content of tungsten in scheelite is about 5% lower than the normal one (WO₃ 80.53%): with the composition of WO₃ 76.06%, Mo1.74%.

Table 3-7 Scheelite's energy spectrum analysis

Sample	elemental content (%)		
	WO ₃	MoO ₃	CaO
1	74.51	5.13	20.36
2	75.06	4.58	20.36
3	75.22	4.33	20.45
4	76.27	4.24	19.49
5	77.11	2.38	20.51
6	77.41	2.57	20.02
7	77.56	2.33	20.11
8	77.83	2.53	19.64

9	78.10	2.43	19.47
10	79.44	0.64	19.92
Average	76.851	3.12	20.03



Photo 3-1 Optical microscope 80X

The scheelite presented in Sample C

C:\SharedData\libo\C_lens_Maps\Scheelite05.spc

Label A:

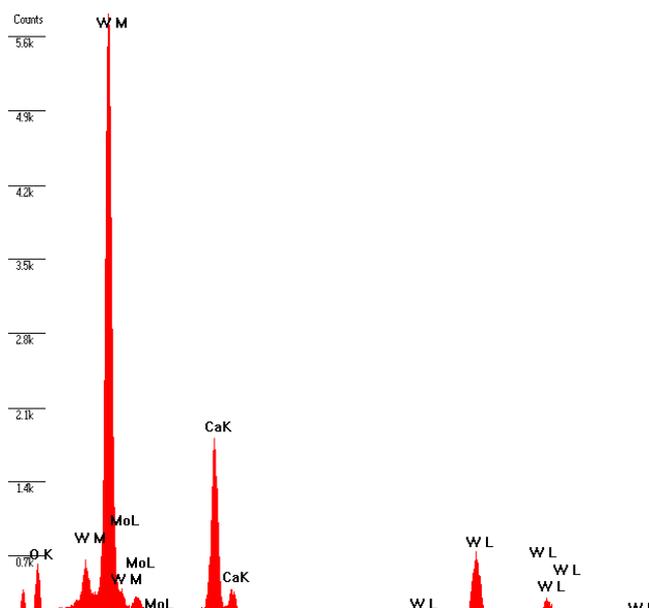


Fig.3-1 Energy spectrum diagram of scheelite containing molybdenum

The energy spectrum analysis of scheelite shows the weak characteristic peaks of Mo L α

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Label A:

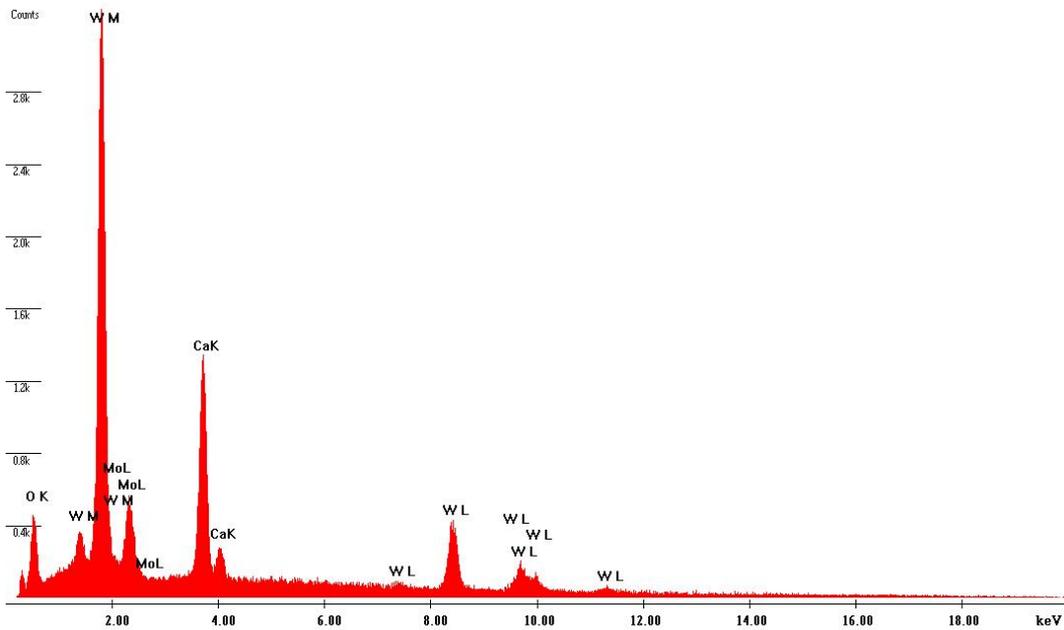


Fig.3-2 Energy spectrum diagram of scheelite containing molybdenum

The energy spectrum analysis of scheelite shows the strong characteristic peaks of Mo L α

Besides, the scheelite generally contains micro-sized diopside、 calcite、 apatite inclusions (See photos 3-2、 3-3、 3-4), which is also one of the reasons leading to the lower content of tungsten in the ore.

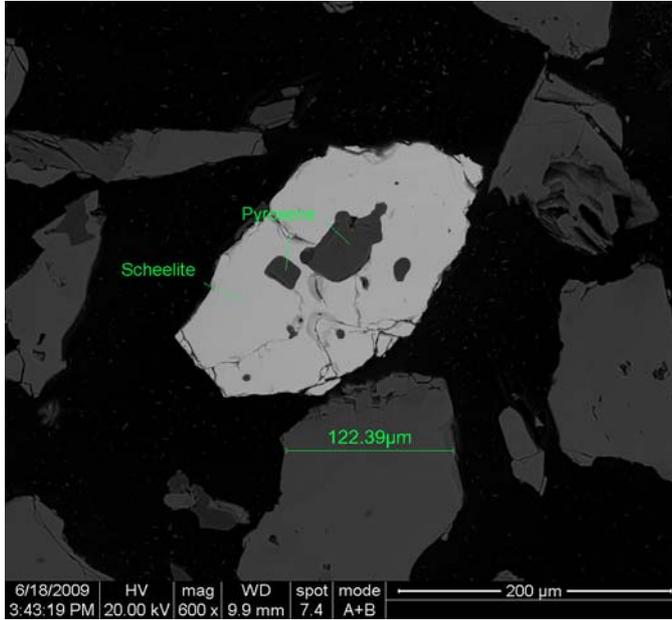


Photo 3-2 SEM 600X
The diopside inclusions in scheelite

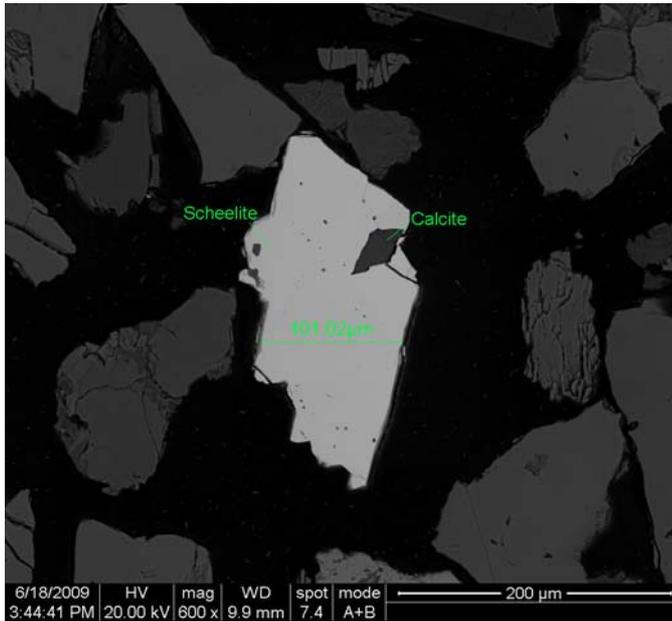


Photo 3-3 SEM 600X
The calcite inclusions in scheelite

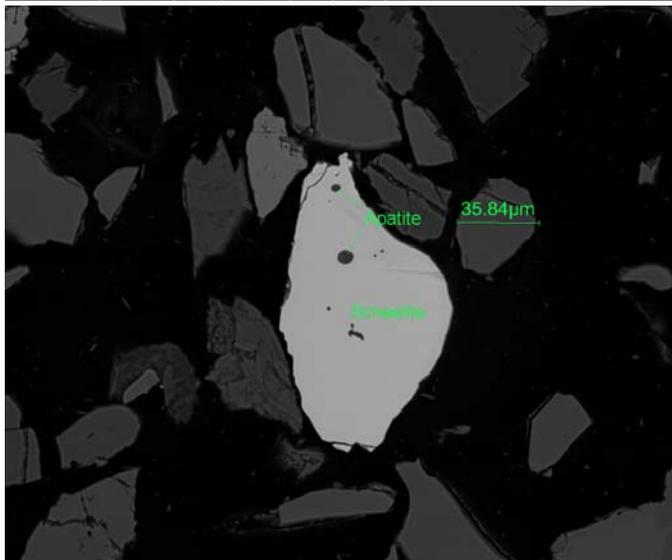
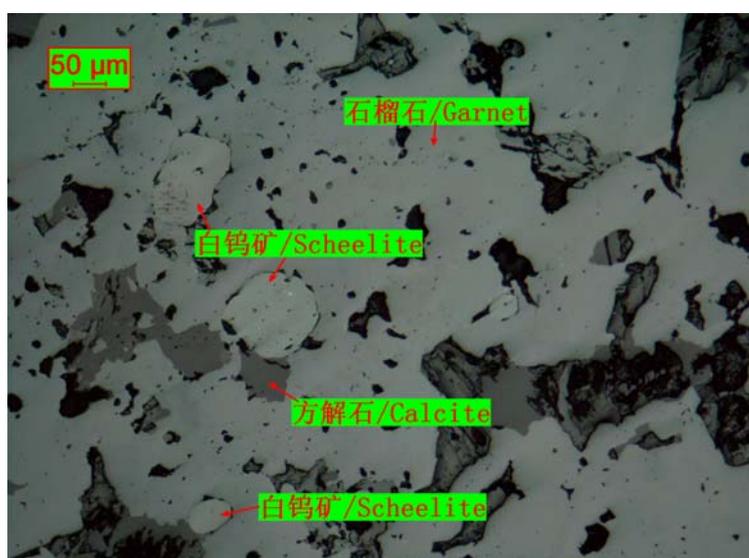


Photo 3-4 SEM 600X
The apatite inclusions in scheelite

The scheelite contained in this sample mainly has the following disseminated forms: ① most scheelite and garnet are closely disseminated with each other. It is common to see poly-particles or single grain scheelite disseminated in garnet, presenting hypidiomorphic crystalline round or sub-round grain (See photos 3-5、3-6、3-7). There is usually calcite or diopside filling between scheelite and garnet. Major scheelite contains micro-sized diopside or calcite inclusions; ② minor scheelite is included in calcite (See photo 3-8) or diopside; ③ a part of scheelite is associates with molybdenite. It is seen that molybdenite is at the neighborhood of scheelite (See photo 3-8), or there is micro fine molybdenite on the edge of scheelite (See photo 3-9).



**Photo 3-5 Reflecting microscope 160X
Poly-particles scheelite is disseminated
in garnet, presenting hypidiomorphic
crystalline sub-round grain**

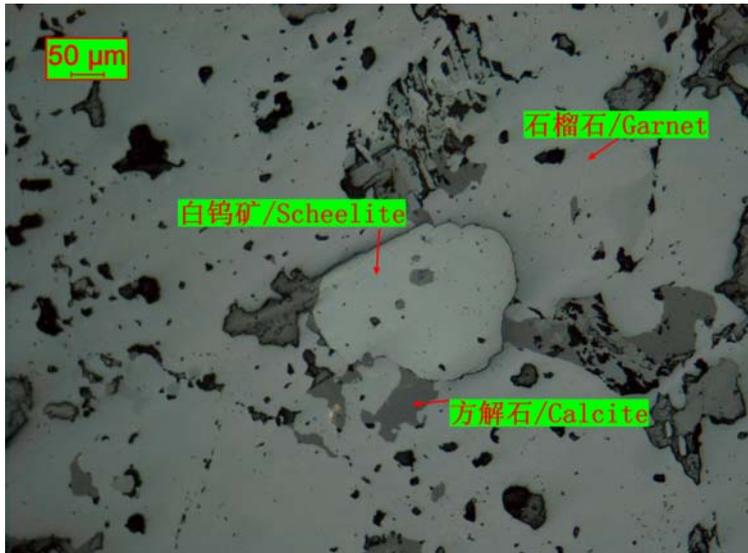


Photo 3-6 Reflecting microscope 160X
 The scheelite is disseminated in garnet, presenting hypidiomorphic crystalline sub-round grain, containing micro-sized diopside inclusions

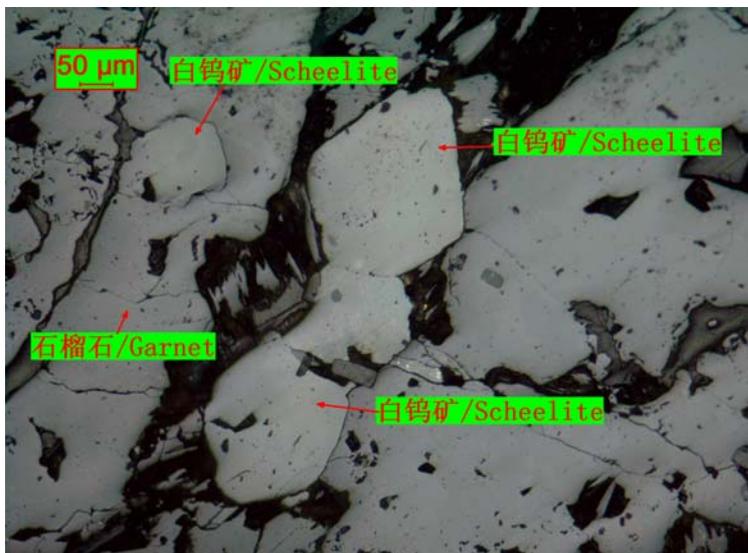


Photo 3-7 Reflecting microscope 160X
 The scheelite is in intergrowth with garnet in the form of bipyramid euhedral crystal.



Photo 3-8 Reflecting microscope 160 X
 The scheelite is included in calcite. The molybdenite is at the neighborhood of scheelite.



Photo 3-9 Reflecting microscope160X
The molybdenite is disseminated on the edge of scheelite

3.2.1.5.2 Molybdenite (MoS)

Apart from the Mo-bearing scheelite, the independent molybdenum mineral is molybdenite. Molybdenite appears lead gray, metallic luster, whose crystal is hexagonal schistose, mostly presenting as schistose aggregates, with a very complete cleavage paralleling to $\{0001\}$ and a flexible sheet. It is soft and feels creamy, with Mohs hardness 1~1.5, density 4.7~5.0 g/cm³, non-conducting. The SEM energy spectrum analysis of Molybdenite: Mo 59.93%, S40.07%.

Molybdenite is scattered in the ore presenting tabular or flake, commonly in the neighborhood of scheelite or is beset on the edge of scheelite (See photos 3-8、3-9、3-10).

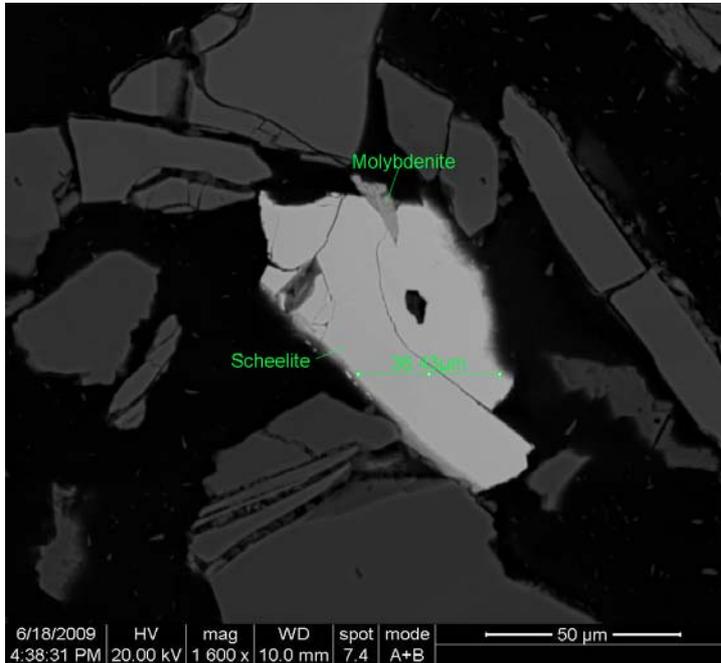


Photo 3-10 SEM 1600X
The molybdenite is disseminated on the edge of scheelite

3.2.1.5.3 Gangue minerals

The gangue minerals in the ore are mainly garnet (most is andradite with a minor grossular), which accounts for about 65% of the total ore. The next are diopside, amphibole minerals, calcite, minor quartz, feldspar, sphene, apatite.

3.2.1.6 The occurrence of tungsten and molybdenum in the ore

3.2.1.6.1 The occurrence of tungsten in the ore

By purification of scheelite and the chemical analysis of gangues,

the distribution of tungsten in the main minerals is shown in Table 3-8. According to the Table, the tungsten exists mainly in the form of scheelite, which accounts for 98.66% of the total tungsten in the crude ore. The tungsten that still exists in the gangue minerals in the fineness of -0.074mm occupies 1.34%. The maximum recovery of tungsten is expected up to 98%.

Table 3-8 Distribution of tungsten in the main minerals (the single mineral is finally purified at the fineness of -0.074mm)

Mineral	Mineral content (%)	WO ₃ (%)	Distribution (%)
Scheelite	1.786	76.06	98.66
Molybdenite	0.024	/	/
Metallic sulfide minerals	0.797	/	/
Metallic Oxides	0.062	/	/
Gangue	97.331	0.019	1.34
Total	100.000	1.377	100.00

3.2.1.6.2 The occurrence of molybdenum in the ore

The distribution of molybdenum in the main minerals is presented in Table 3-9, showing that the molybdenum in the ore primarily is hosted in the scheelite, secondly exists in the form of molybdenite. The

molybdenum contained in the scheelite accounts for 65% of the total molybdenum in the crude ore, while the molybdenum existing in the form of molybdenite occupies 30%. The molybdenum that still exists in the gangue mineral in the fineness of -0.074mm occupies about 5%. The maximum recovery of molybdenum is expected up to 30%.

Table 3-9 The distribution of molybdenum in the main minerals (the single mineral is finally purified in the fineness of -0.074mm)

Ore type	Mineral content (%)	Mo (%)	Distribution (%)
Scheelite	1.786	1.74	65.19
Molybdenite	0.024	59.40	29.91
Metallic sulfide minerals	0.797	/	/
Metallic Oxides	0.062	/	/
Gangue	97.331	0.0024	4.90
Total	100.000	0.048	100.00

3.2.1.7 Summary

(1) The type of valuable metallic minerals in the ore is relatively simple—only scheelite. The content of molybdenum in the ore reaches the grade of comprehensive recovery. However, most of molybdenum

exists in the scheelite and the amount of molybdenite is so small that it is hard to recover. Chalcopyrite and sphalerite are so minor that they don't meet the grade requirement for comprehensive utilization.

(2) There are a few sulphide minerals with the total amount of less than 1% in the ore, which are mainly pyrite, thimbleful pyrrhotite and chalcopyrite. The gangue minerals are characterized by massive garnet, which accounts for 65% of the total minerals. The secondary gangue minerals are diopside, tremolite, calcite, quartz, feldspar, etc. Calcite is the primary gangue which has bad effect on tungsten flotation. The content of fluorite is very low.

(3) The dissemination size of scheelite is uneven. The size of coarse grain is more than 1mm while the fine one is only several microns. The particles of 0.04~1.28mm account for more than 90%, while +0.16mm medium-coarse occupy 35%. The ore is unevenly disseminated in the form of medium-coarse grain.

(4) The scheelite in the ore is closely associated with the garnet. It generally is disseminated among garnet grains or garnet and diopside, calcite grains with relatively coarse dissemination size, loose intergrowth and being easy to dissociate. Therefore, the scheelite has good liberation property. When the ore is grounded to 63.7%-0.074mm, the liberation degree of scheelite is up to 96%.

(5) The investigation on the occurrence state of tungsten indicates the

tungsten exists mainly in the form of scheelite, which accounts for 98.66% of the total tungsten in the crude ore. The tungsten that still exists in the gangue minerals in the fineness of -0.074mm occupies 1.34%. The maximum recovery of tungsten is expected up to 98%.

(6) The content of molybdenum in the ore meets the requirement of comprehensive recovery. It primarily is hosted in the scheelite, which accounts for 65% of the total molybdenum in the crude ore while the molybdenum existing in the form of molybdenite occupies 30%. The molybdenum that is still included in the gangue minerals at the fineness of -0.074mm occupies about 5%. The maximum recovery of molybdenum is expected only to be 30%. Therefore, it is of little value to recover the molybdenum in the ore.

3.2.2 Study on Process Mineralogy of B-Lens ore

3.2.2.1 The mineralogical composition of crude ore

Table 3-10 Multi-elemental chemical analysis of crude ore

Element	WO ₃	Mo	Bi	Cu	Pb	S	Ag g/t	MgO
Content(%)	0.49	0.015	0.008	0.011	0.01	0.26	2.44	11.74
Element	CaCO ₃	CaF ₂	As	Fe	SiO ₂	Al ₂ O ₃	CaO	
Content(%)	6.80	2.08	<0.005	7.95	42.42	3.61	19.01	

3.2.2.1 The mineral composition of crude ore

Microscope and the technique of MLA automatic detection were used to check and determine the mineralogical composition of this ore as well as its quantity. The content of major minerals is shown in Table 3-11. The

results can be obtained that the tungsten mineral of ore is scheelite other than wolframite. There are a few sulphide minerals with the total amount of less than 1%, but the types are more than C-Lens ore, which are mainly pyrite, pyrrhotite, a little chalcopyrite and molybdenite. The gangue minerals are primarily andradite, followed by diopside, grossular, calcite, quartz, feldspar, tremolite, etc. Calcite and apatite are the main impurity gangue minerals which have bad effect on tungsten cleaning, the content of fluorite is very low.

Table 3-11 Quantitative composition of the crude ore

Mineral	Content %	Mineral	Content %	Mineral	Content %
Scheelite	0.595	Pentlandite	0.006	Andradite	11.709
Molybdenite	0.004	Sulfur nickel and cobalt ore	0.002	Diopside- hedenbergite	54.987
Chalcopyrite	0.028	Mica	1.556	Grossular	3.759
Sphalerite	0.007	Quartz	0.841	Tremolite	11.493
Galenobismutite	0.002	Serpentine	1.924	Epidote	0.797
Pyrrhotite	0.330	Chlorite	1.799	Orthoclase	1.404

Pyrite	0.241	Sphene	0.439	Plagioclase	2.987
Fluorite	0.017	Siderite	0.142	Ilmenite	0.007
Calcite	4.200	Magnetite	0.357	Rutile	0.004
Apatite	0.340	Chromite	0.018	Zircon	0.005

3.2.2.3 The dissemination of scheelite

The lump ore was made into polished section to measure the dissemination size of scheelite. The results, presented in Table 3-12, show that the dissemination size of scheelite is relatively even, primarily at the size of 0.08~0.64mm which contains more than 85% scheelite. The ore is evenly disseminated in the form of medium-coarse grain.

Table 3-12 The dissemination of scheelite

Size (mm)	Grain-size distribution (%)	
	Share of grain size	Cumulative distribution
-1.28+0.64	5.84	5.84
-0.64+0.32	16.54	22.38
-0.32+0.16	22.38	44.76
-0.16+0.08	46.46	91.22
-0.08+0.04	7.78	99.00
-0.04+0.02	0.79	99.79
-0.02+0.01	0.18	99.97
-0.01	0.03	100.00

Total	100.00	
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3.2.2.4 The liberation degree of scheelite in the crude ore

The results of liberation degree of scheelite are shown in Table 3-13. According to the results, the dissemination size of scheelite is a little finer than that in C-Lens ore, but relatively even. Therefore, the scheelite also has good liberation property. When the ore is ground to 67.38%-0.074mm, the liberation degree of scheelite is more than 95%.

Table 3-13 The liberation degree of scheelite at the grinding fineness of 67.39%-0.074mm

Size(mm)	Wt. (%)	WO ₃ (%)	Liberation degree (%)
+0.15	4.94	0.17	80.34
-0.15+0.12	5.44	0.34	82.03
-0.12+0.10	5.45	0.49	85.06
-0.10+0.074	16.79	0.51	86.93
-0.074+0.043	14.41	0.6	94.60
-0.043+0.03	27.18	0.7	99.72
-0.03+0.02	11.73	0.58	100.00
-0.02+0.01	6.98	0.39	100.00
-0.01	7.08	0.47	100.00
Total	100	0.54	95.34

3.2.2.5 The characteristics of mineral processing and dissemination state of main minerals

3.2.2.5.1 Scheelite Ca[WO₄]

The scheelite embedded in B-Lens ore is the same with that in Sample C, presenting tetragonal bipyramid or equiaxed granular with its crystal colorless and transparent while the small portion presents transparent straw yellow due to iron staining (See photo3-11). It appears grease luster, medium hardness (4.5), density 5.8-6.2g/cm³, brittleness and a clear cleavage. The chemical composition of scheelite is shown in Table 3-14 and Figure 3-4、3-5. According to the results, the scheelite and powellite present limited isomorphism. The scheelite generally contains molybdenum because of powellite's replacement, with the content of molybdenum varying from 0 to 6% in the form of MoO₃.

Table 3-14 Scheelite energy spectrum analysis

Sample	elemental content (%)		
	WO ₃	MoO ₃	CaO
1	74.35	6.10	19.55
2	75.89	4.08	20.03
3	76.03	4.13	19.84
4	76.62	2.99	20.39
5	77.73	2.06	20.21
6	77.98	2.00	20.02
7	78.46	1.93	19.61

8	78.74	1.48	19.78
9	79.29	0.45	20.26
10	80.44	0.00	19.56
Average	77.55	2.52	19.93

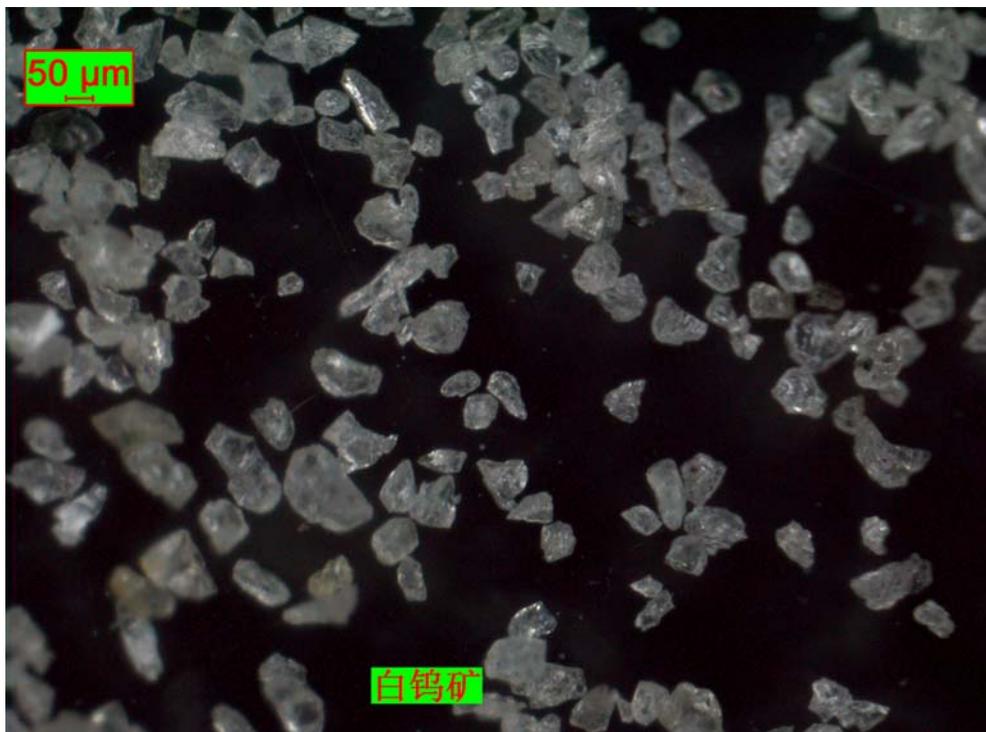


Photo 3-11 Optical microscope 80X
The scheelite presented in B-Lens ore

C:\SharedData\libo\B-Lens_maps\Scheelite06.spc

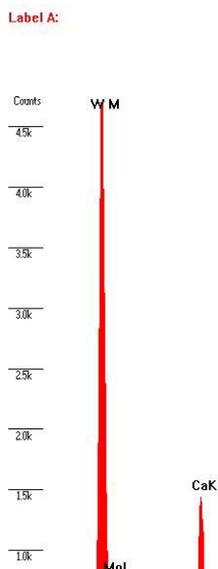


Fig3-3 EDS

The energy spectrum analysis of scheelite shows the weak characteristic peaks of Mo L α

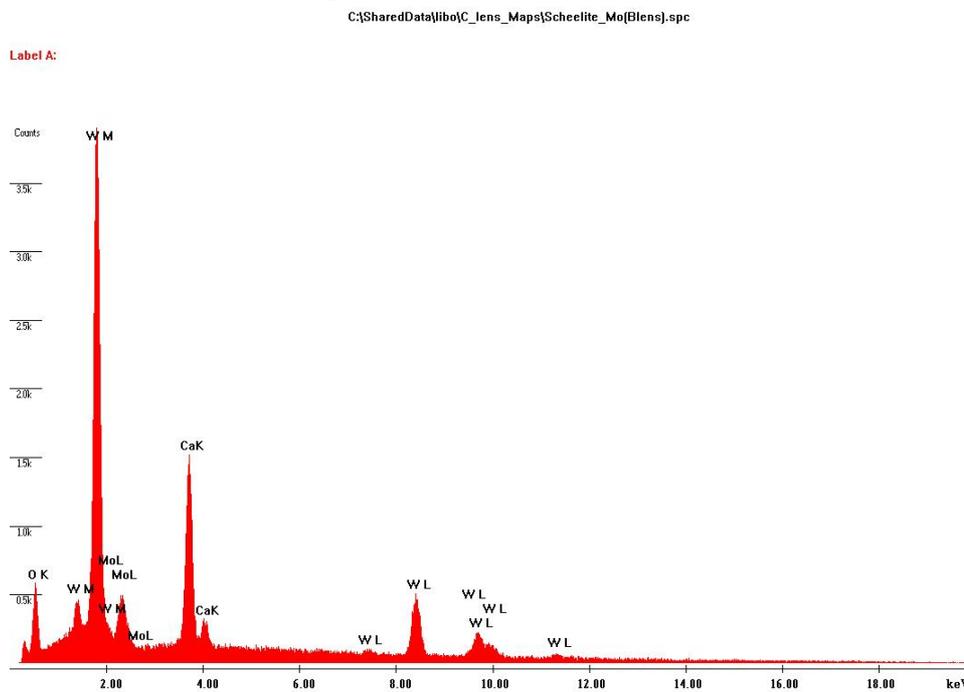


Fig3-3 EDS

The energy spectrum analysis of scheelite shows the strong characteristic peaks of Mo L α , indicating higher content of molybdenum.

The scheelite presented in B-Lens ore also generally contains micro-sized mineral inclusions such as diopside、 calcite、 apatite, etc

(See photos 3-12、3-13). Because of molybdenum's replacement and the inclusions of other minerals, the content of tungsten in scheelite is 4~5% lower than the normal one: with the composition of WO_3 76.19%, Mo2.12%.

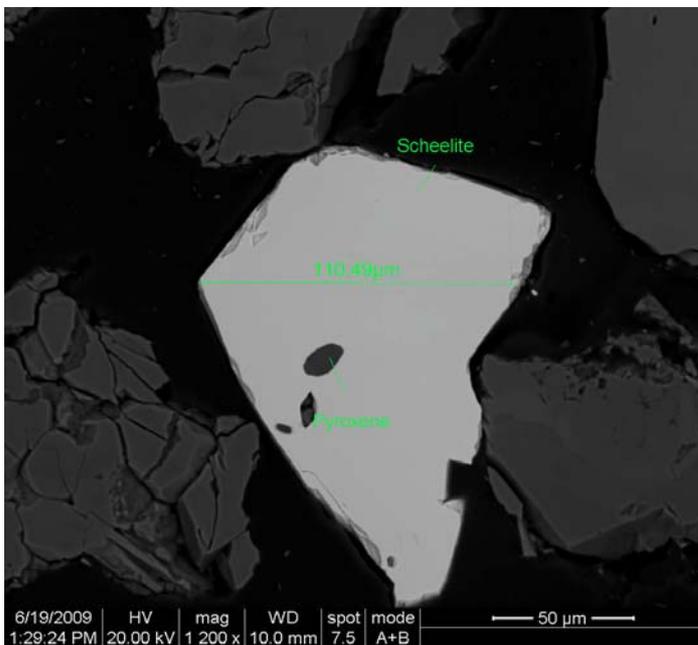


Photo 3-12 SEM 1200X
The diopside inclusions in scheelite.

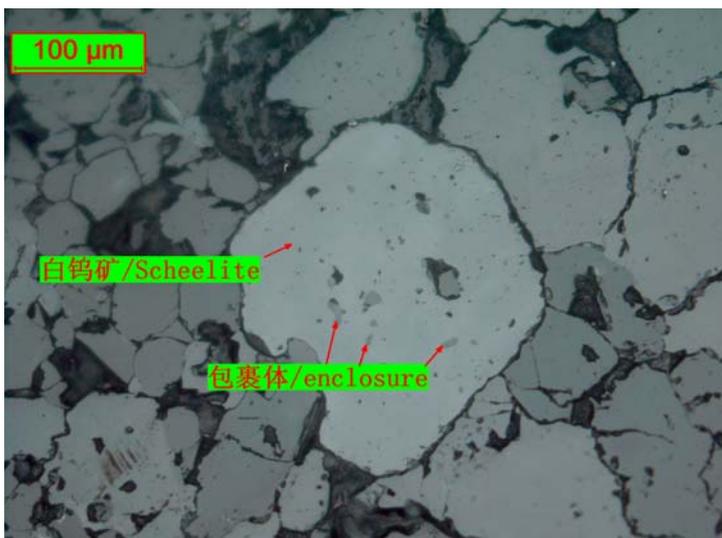


Photo 3-13 Reflecting microscope 160X
The inclusions in scheelite

The scheelite contained in this sample mainly has the following dissemination forms: ① scheelite and garnet are closely disseminated with each other. It is common to see poly-particle or single grain scheelite disseminated in garnet, presenting hypidiomorphic crystalline round or sub-round grain (See photos 3-14、3-15、3-16). There is usually calcite or diopside filling between scheelite and garnet. Some scheelite contains micro-sized diopside or calcite inclusions. This character is similar to C-Lens ore; ② scheelite is disseminated among hedenbergite or diopside grains (See photo 3-17), which is general in B-Lens ore; ③ a part of scheelite is associated with molybdenite. It is seen that molybdenite is at the neighborhood of scheelite and there is micro fine molybdenite on the edge of scheelite (See photo 3-18).

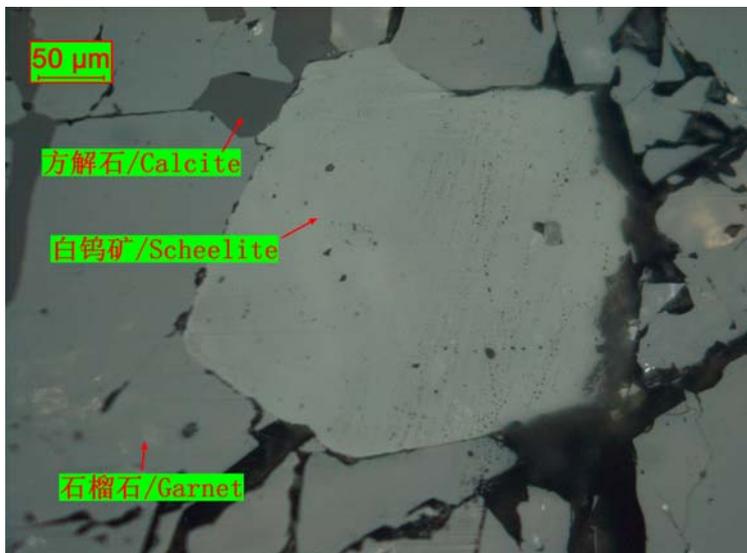


Photo 3-14 Reflecting microscope 160X Scheelite is disseminated in garnet, presenting hypidiomorphic crystalline sub-round grain, calcite filling between scheelite and garnet.

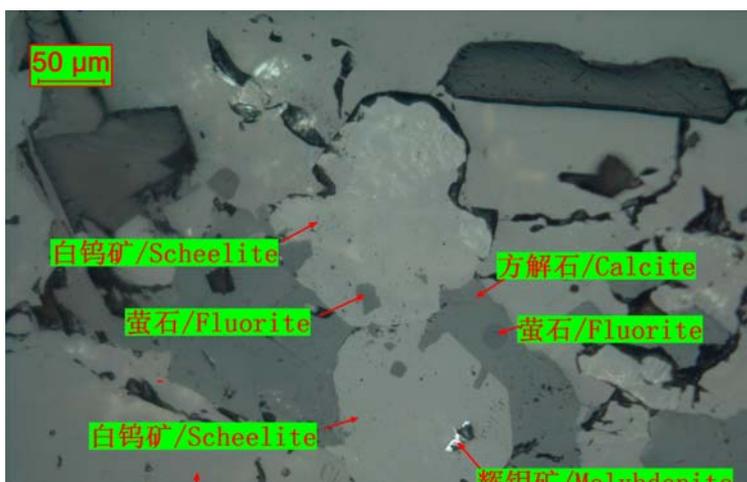


Photo 3-15 Reflecting microscope 160X Crystal stock scheelite disseminates in garnet, presenting hypidiomorphic crystal. Scheelite contains micro-sized molybdenite inclusions.²⁹

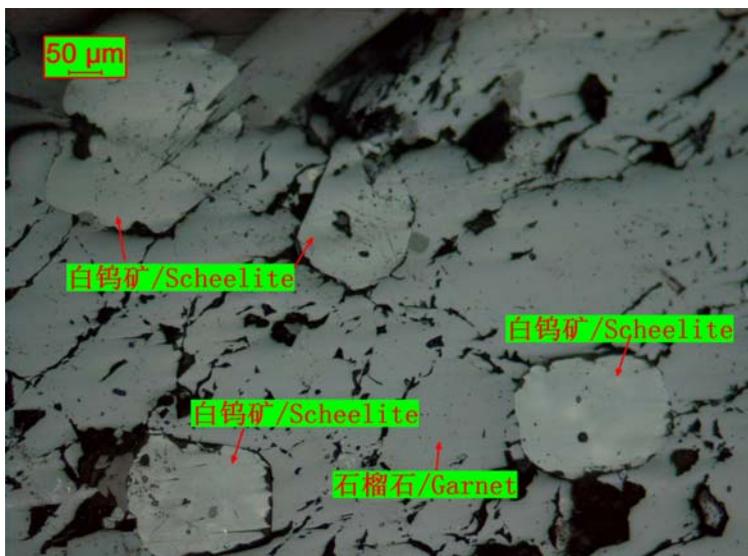


Photo 3-16 Reflecting microscope 160X Poly-particle scheelite is associated with garnet presenting hypidiomorphic crystal.

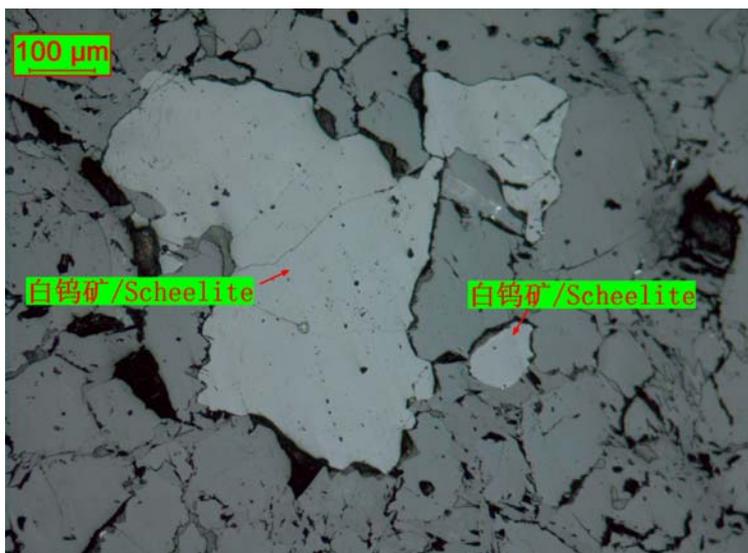
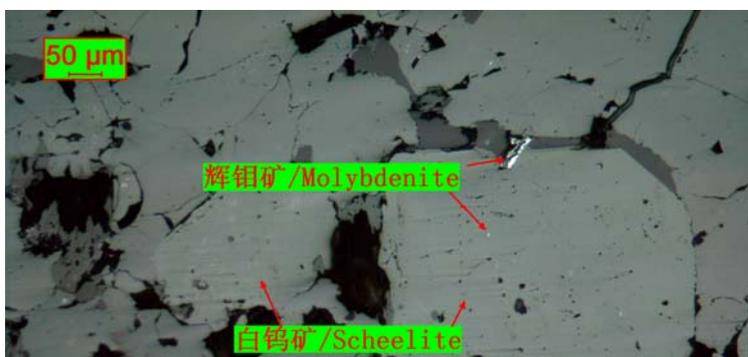


Photo 3-17 Reflecting microscope 160X Scheelite is disseminated among hedenbergite particles in the form of irregular grain



**Photo 3-18 Reflecting microscope 160X
Molybdenite is beset on the edge of scheelite.**

3.2.2.5.2 Molybdenite (MoS)

Most of molybdenum in this ore is occurred in scheelite, only a trace in the form of independent mineral---molybdenite. Molybdenite appears lead gray, metallic luster, whose crystal is hexagonal schistose, mostly presenting as schistose aggregates, with a very complete cleavage paralleling to {0001} and a flexible sheet. It is soft and feels creamy, with Mohs hardness 1~1.5, density 4.7~5.0 g/cm³, non-conducting.

Molybdenite is scattered in the ore presenting tabular or micro-flake (See photo 3-19). It is also seen being beset on the edge of scheelite or being included in scheelite (See photo 3-20).



**Photo 3-19 SEM 1600X
Molybdenite presenting microcrystalline
microcrystalline flake dissemination
among gangues.**



**Photo 3-20 Reflecting microscope
160X
Molybdenite presenting microcrystalline
flake is included in sheelite.**

The gangue minerals in the ore are mainly hedenbergite-diopside. The content of pyroxene minerals accounts for about 55% of the total ore. The second one is garnet (most is andradite with a little grossular), whose content accounts for about 15%. Other gangue minerals are tremolite、calcite、minor quartz、feldspar、epidote、mica、chlorite、sphene、apatite、etc.

3.2.2.6 The state of tungsten and molybdenum in the ore

3.2.2.6.1 The state of tungsten in the ore

By purification of scheelite and the chemical analysis of gangue, the distribution of tungsten in the main minerals is shown in Table 3-15. According to the table, the tungsten exists mainly in the form of scheelite, which accounts for 95.82% of the total tungsten in the crude ore. The tungsten that still exists in the gangue minerals in the fineness of

-0.074mm occupies 4.18%. The maximum recovery of tungsten is expected up to 96%.

Table 3-15 The distribution of tungsten in the main minerals (the single mineral is finally purified in the fineness of -0.074mm)

Mineral	Mineral content (%)	WO ₃ (%)	Distribution rate(%)
Scheelite	0.595	76.19	95.82
Molybdenite	0.004	/	/
Metallic sulfide minerals	0.616	/	/
Metallic Oxides	0.528	/	/
Gangue	98.257	0.020	4.18
Total	100.000	0.473	100.00

3.2.2.6.2 The state of molybdenum in the ore

The distribution of molybdenum in the main minerals is presented in Table 3-16, showing that the molybdenum in the ore primarily hosts in

the scheelite, secondly exists in the form of molybdenite. The molybdenum contained in the scheelite accounts for 76% of the total molybdenum in the crude ore, while the molybdenum existing in the form of molybdenite occupies 14%. The molybdenum that still exists in the gangue mineral in the fineness of -0.074mm occupies about 10%. The maximum recovery of molybdenum is expected to be 14%.

Table 3-16 The distribution of molybdenum in the main minerals (the single mineral is finally purified in the fineness of -0.074mm)

Ore type	Mineral content (%)	Mo(%)	Distribution rate(%)
Scheelite	0.595	2.12	76.12
Molybdenite	0.004	59.40	14.36
Metallic sulfide minerals	0.616	/	/
Metallic Oxides	0.528	/	/
Gangue	98.257	0.0016	9.52
Total	100.000	0.0166	100.00

3.2.2.7 Summary

(1) The type of valuable metallic minerals in the ore is relatively single, only scheelite. The ore contains only 0.016% molybdenum, most of

which exists in the scheelite. The content of molybdenite is so low that it is difficult to recover.

(2) There are a few sulphide minerals with the total amount of less than 1% in the ore, which are mainly pyrite and pyrrhotite, thimbleful chalcopyrite, pentlandite, etc. The gangue minerals are characterized by hedenbergite-diopside, pyroxene minerals accounting for 55% of the total. The secondary gangue minerals are andradite, grossular, tremolite, calcite, etc. Calcite is the primary gangue which has bad effect on tungsten flotation. The content of fluorite is very low.

(3) The dissemination size of scheelite in this ore is a little finer than that in C-Lens ore, but relatively even. The scheelite is mainly disseminated in the range of 0.08~0.64mm, which accounts for more than 85%. The ore is unevenly disseminated in the form of medium-coarse grain.

(4) Although the dissemination size of scheelite in this ore is a little finer than that in C-Lens ore, it has good liberation property because of its homogeneous dissemination. When the ore is ground to 67.38%-0.074mm, the liberation degree of scheelite is more than 95%.

(5) The tungsten in the ore mainly exists in the form of scheelite, which occupies 95.82% of the total, and the tungsten that still exists in the gangue minerals at the size of -0.074mm accounts for 4.18%. The maximum recovery of tungsten is expected up to 96%.

(6) The molybdenum in the ore primarily occurs in the scheelite which occupies 76% of the total. It secondly exists in the form of molybdenite, which accounts for 14%. The molybdenum that is still included in the gangue minerals at the size of -0.074mm occupies about 10%. The maximum recovery of molybdenum is expected up to 14%.

4 Mineral processing tests

4.1 Principle flow-sheet and pre-concentration test

According to the dressing practice of scheelite ores at home and abroad, the coarse-grained scheelite is recovered mainly by means of gravity separation, while the fine-grained by flotation primarily. The scheelite minerals in the ore are liberated basically in the size fraction of $-0.125+0.076\text{mm}$, so it is suitable to recover by flotation. The entrusting party also requires carrying out lab tests by WOF, so the principle flow-sheet is a single flotation process.

The single scheelite flotation mainly adopts fatty acids collector at present, while the gangue minerals bearing calcium such as fluorite, calcite, diopside, etc. also have good floatability. The usual regulator and their combination are: sodium carbonate-sodium silicate, caustic soda-sodium silicate, sodium carbonate-caustic soda-sodium silicate, sodium carbonate-lime-sodium silicate、lime-sodium silicate, etc. The combined regulator of sodium carbonate-sodium silicate is adopted in our scheelite roughing process. The new reagent ZL developed by GZRINM is used as scheelite flotation collector, replacing the current 731 oxidized paraffin soap collector whose selectivity is poorer and consumption is higher.

The rougher concentrate of scheelite flotation still contains many gangue minerals bearing calcium such as fine-grained fluorite, calcite, diopside- hedenbergite, andradite, etc. The floatability of gangue minerals

bearing calcium is more similar to that of scheelite after their interaction with fatty acids collector, so the cleaning separation is very difficult. The methods of attrition of pulp with sodium silicate at ambient temperature and at elevated temperature are tried in the cleaning separation tests of scheelite rougher concentrate. The latter is the improved “Peterov Method”, i.e: a new combination of reagents is added in the attrition process at elevated temperature, which intensifies the depression for gangue minerals, especially for sulfide minerals, eliminates the operation of dilution and reagent-removing and directly floats scheelite from heated pulp, hence a quite good index is achieved. In this study, the cleaning process at ambient temperature also can achieve a relatively good index with a higher recovery, but compared with the heated cleaning process, its efficiency on selective reagent-removal and inhibiting the gangue minerals bearing calcium is relatively poor, while the grade of final concentrate is little lower besides of its poorer stability of processing. Therefore, the tests of heated cleaning process are mainly selected to conduct further.

4.2 Flotation test of sulfide ore

Generally, sulfide minerals such as molybdenite are separated firstly before scheelite flotation, which not only comprehensively recovers the valuable minerals but also benefits scheelite flotation and ensures the quality of final tungsten concentrate. In this study, Na_2SiO_3 is the

regulator in the roughing process of sulfide ore. The flow-sheet and the results are shown respectively in Figure 4-1 and Table 4-1. Both grade and recovery of molybdenum rougher concentrate are lower as a result of 65-76% of molybdenite existing in the scheelite as limited isomorphism, which is consistent with the above-mentioned results of process mineralogy. A number of commercial operation indicate that when the recycled water containing fatty acid collectors is used for sulfide ore flotation, it will not only make sulfide ore separation difficult but also will easily lead to the loss of scheelite. As the new technology of heated cleaning for scheelite has very strong depression effect on sulfide minerals entrained into rough concentrate, the quality of scheelite concentrate will not be affected. In view of the above, the test of molybdenum sulfide recovering will not be carried out further.

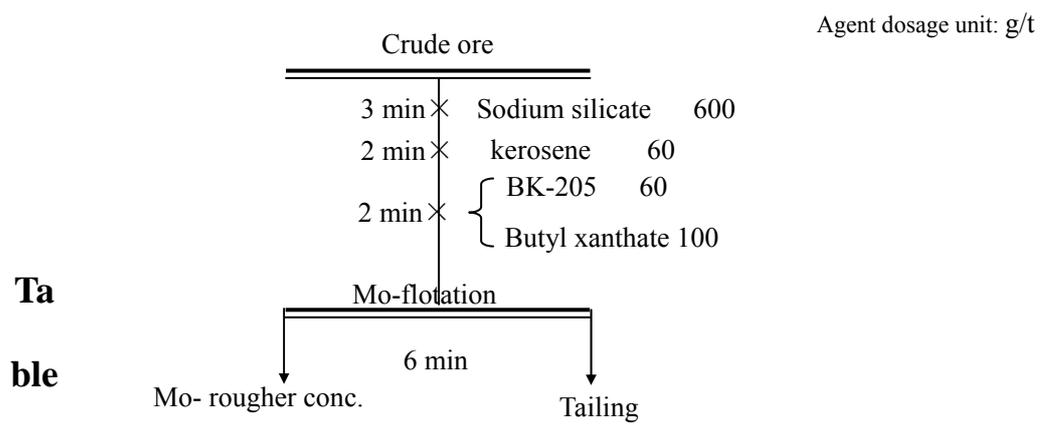


Figure 4-1 the flow-sheet of molybdenite flotation

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the results of molybdenite flotation tests

Sample	Name of Product	Yield %	Grade %		Recovery %	
			Mo	WO ₃	Mo	WO ₃
C-Lens Fineness 80%- 0.10mm	Molybdenum rougher concentrate	1.29	1.00	0.60	38.37	0.56
	Tailing	98.71	0.022	1.38	61.63	99.44
	Crude ore	100.00	0.035	1.37	100.00	100.00
B-Lens Fineness 70%- 0.074mm	Molybdenum rougher concentrate	1.87	0.2	0.60	24.73	2.23
	Tailing	98.13	0.0116	0.502	75.27	97.77
	Crude ore	100.00	0.0152	0.503	100.00	100.00

4.3 Roughing test of scheelite ore

4.3.1 Grinding fineness test

Tests on grinding fineness in the tungsten roughing process for C-Lens ore and B-Lens ore were carried out under the conditions shown in Figure 4-2. The results are presented respectively in Table 4-2 and Table 4-3. Taking comprehensive considerations on rougher concentrate grade, recovery and grinding costs, etc. the grinding finenesses of C-Lens ore and B-Lens ore in the tungsten roughing process are respectively 80%-0.10mm and 70%-0.074mm, which is the basis for follow-up tests.

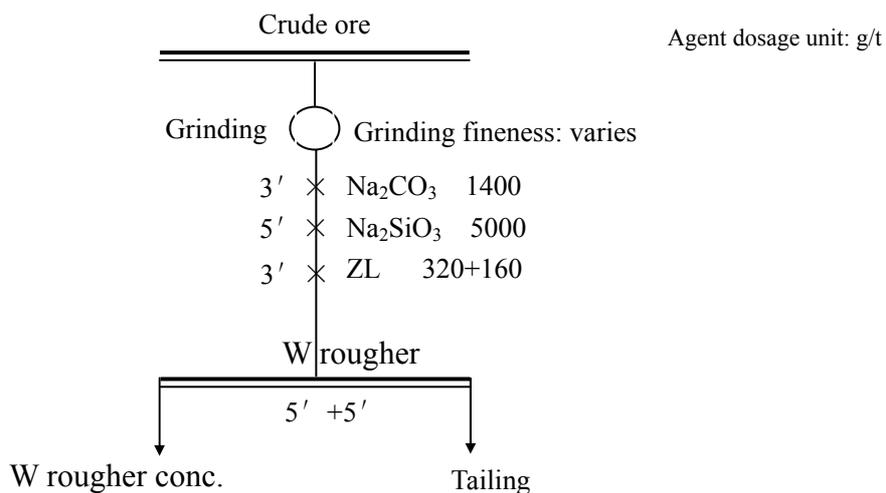


Figure 4-2 the flow-sheet of grinding fineness test

Table 4-2 the results of grinding fineness test for C-Lens ore

Grinding fineness	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
80% -0.12 mm	W rougher conc.	9.32	13.45	93.57
	Tailing	90.68	0.095	6.43
	Crude ore	100.00	1.34	100.00
80% -0.10 mm	W rougher conc.	10.22	12.24	95.48
	Tailing	89.78	0.066	4.52
	Crude ore	100.00	1.31	100.00
70.26% -0.074 mm	W rougher conc.	10.60	11.87	95.33
	Tailing	89.40	0.069	4.67
	Crude ore	100.00	1.320	100.00
74.95% -0.074 mm	W rougher conc.	10.77	11.65	95.65
	Tailing	89.23	0.064	4.35
	Crude ore	100.00	1.312	100.00
80% -0.074 mm	W rougher conc.	12.18	10.40	95.56
	Tailing	87.82	0.067	4.44
	Crude ore	100.00	1.326	100.00

Table 4-3 the results of grinding fineness test for B-Lens ore

Grinding fineness	Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
80 % -0.12 mm	W rougher conc.	3.00	13.58	77.78
	Tailing	97.00	0.12	22.22
	Crude ore	100.00	0.524	100.00
80 % -0.10 mm	W rougher conc.	4.99	9.27	87.12
	Tailing	95.01	0.072	12.88
	Crude ore	100.00	0.531	100.00
65 % -0.074 mm	W rougher conc.	4.86	9.86	89.83
	Tailing	95.14	0.057	10.17
	Crude ore	100.00	0.533	100.00
70 % -0.074 mm	W rougher conc.	5.98	8.14	92.00
	Tailing	94.02	0.045	8.00
	Crude ore	100.00	0.529	100.00
74.60 % -0.074 mm	W rougher conc.	6.24	7.56	92.13
	Tailing	93.76	0.043	7.87
	Crude ore	100.00	0.512	100.00
80 % -0.074 mm	W rougher conc.	6.82	7.19	93.59
	Tailing	93.18	0.036	6.41
	Crude ore	100.00	0.524	100.00

4.3.2 Test on the dosage of regulator Na₂CO₃

Tests on the dosage of regulator Na₂CO₃ in the tungsten roughing process for C-Lens and B-Lens were carried out under the conditions shown in Figure 4-3. The results presented respectively in Table 4-4 and Table 4-5 indicate that Na₂CO₃ has a little benefit to C-Lens ore(C sample) but not obvious, while it has significant benefits to B-Lens ore(B sample). Taking all the considerations, the dosages of Na₂CO₃ for the two samples

are fixed as 1400 g/t.

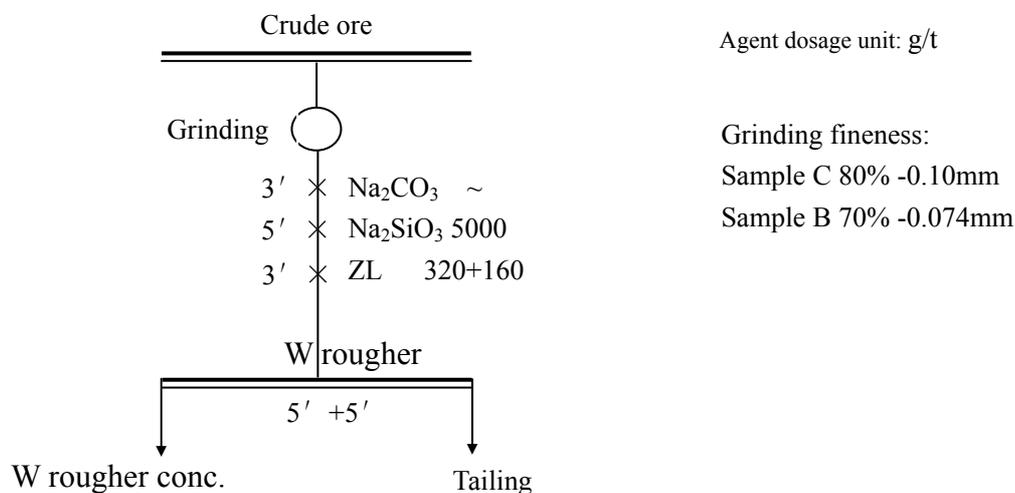


Figure 4-3 the flow-sheet of test on the dosage of Na₂CO₃

Table 4-4 the results of test on Na₂CO₃ dosage for Sample C

Na ₂ CO ₃ dosage (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	W rougher conc.	8.97	13.69	93.88
	Tailing	91.03	0.088	6.12
	Crude ore	100.00	1.308	100.00
1000	W rougher conc.	10.85	11.67	94.99
	Tailing	89.15	0.076	5.01
	Crude ore	100.00	1.334	100.00
1400	W rougher conc.	11.78	10.79	95.87
	Tailing	88.22	0.062	4.13
	Crude ore	100.00	1.326	100.00
2000	W rougher conc.	12.35	10.31	95.72
	Tailing	87.65	0.065	4.28
	Crude ore	100.00	1.330	100.00

Table 4-5 the results of test on Na₂CO₃ dosage for Sample B

Na ₂ CO ₃ dosage (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	W rougher conc.	5.58	6.82	72.88
	Tailing	94.42	0.15	27.12
	Crude ore	100.00	0.522	100.00
1000	W rougher conc.e	10.95	4.50	92.95
	Tailing	89.05	0.042	7.05
	Crude ore	100.00	0.530	100.00
1400	W rougher conc.e	11.30	4.54	94.76
	Tailing	88.70	0.032	5.24
	Crude ore	100.00	0.541	100.00
2000	W rougher conc.e	11.48	4.24	94.02
	Tailing	88.52	0.035	5.98
	Crude ore	100.00	0.518	100.00

4.3.3 Test on the dosage of regulator NaOH

Tests on the dosage of regulator NaOH in the tungsten roughing process for Sample C and Sample B were carried out under the conditions shown in Figure 4-4 with the results presented respectively in Table 4-6 and Table 4-7.

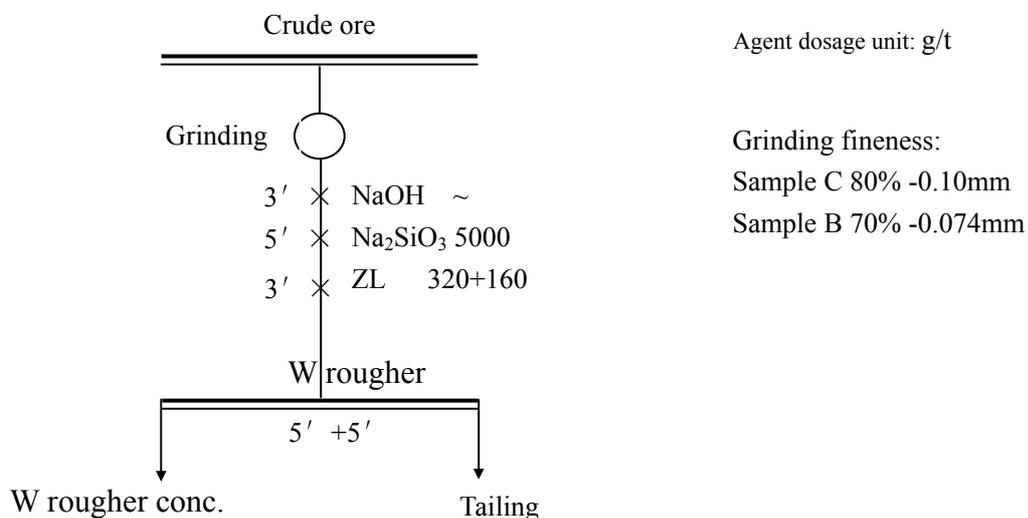


Figure 4-4 the flow-sheet of test on the dosage of NaOH

Table 4-6 the results of tests on NaOH dosage for Sample C

NaOH dosage (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	W rougher conc.	9.79	12.72	94.39
	Tailing	90.21	0.082	5.61
	Crude ore	100.00	1.320	100.00
500	W rougher conc.	9.23	13.15	93.43
	Tailing	90.77	0.094	6.57
	Crude ore	100.00	1.300	100.00
1000	W rougher conc.	12.28	10.24	94.34
	Tailing	87.72	0.086	5.66
	Crude ore	100.00	1.333	100.00
1500	W rougher conc.	10.98	11.17	93.74
	Tailing	89.02	0.092	6.26
	Crude ore	100.00	1.308	100.00

Table 4-7 the results of tests on NaOH dosage for Sample B

NaOH dosage (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	W rougher conc.	6.51	6.36	77.31
	Tailing	93.49	0.13	22.69
	Crude ore	100.00	0.536	100.00
500	W rougher conc.	5.38	9.06	91.97
	Tailing	94.62	0.045	8.03
	Crude ore	100.00	0.530	100.00
1000	W rougher conc.	14.37	3.28	95.16
	Tailing	85.63	0.028	4.84
	Crude ore	100.00	0.495	100.00

According to the Table 4-6 and Table 4-7, the combinative function of NaOH + Na₂SiO₃ is not as good as that for Na₂CO₃+ Na₂SiO₃ with the grade and recovery of its rougher concentrate being poorer.

4.3.4 Test on the dosage of Na₂SiO₃

Tests on the dosage of Na₂SiO₃ in the tungsten roughing process for Sample C and Sample B were carried out under the conditions shown in Figure 4-5 with the results presented respectively in Table 4-8 and Table 4-9. Na₂SiO₃ is the most important gangue depressor. When the dosage of Na₂SiO₃ is too small, the gangue minerals are easy to float, while it is too much, it usually leads to the loss of tungsten. Taking comprehensive considerations on the rougher concentrate grade, recovery and cost .etc. the dosage range of Na₂SiO₃ is 4500-5000 g/t, which is the basis for follow-up tests.

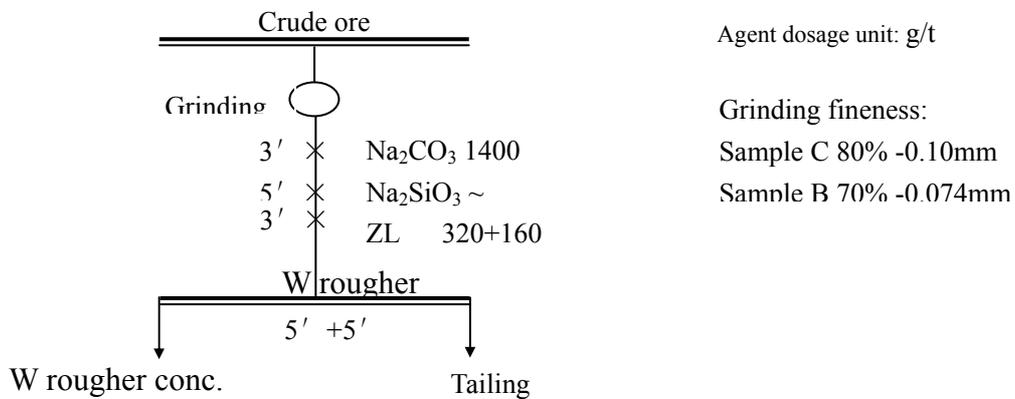


Figure 4-5 the flow-sheet of test on the dosage of Na₂SiO₃

Table 4-8 the results of test on Na₂SiO₃ dosage for Sample C

Na ₂ SiO ₃ dosage (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
3000	W rougher conc.	16.96	7.56	96.91
	Tailing	83.04	0.049	3.09
	Crude ore	100.00	1.316	100.00
4000	W rougher conc.	12.62	10.18	96.52
	Tailing	87.38	0.053	3.48
	Crude ore	100.00	1.331	100.00
4500	W rougher conc.	10.88	11.45	95.56
	Tailing	89.12	0.065	4.44
	Crude ore	100.00	1.304	100.00
5000	W rougher conc.	9.36	13.35	95.17
	Tailing	90.64	0.070	4.83
	Crude ore	100.00	1.313	100.00
6000	W rougher conc.	7.26	16.88	93.82
	Tailing	92.74	0.087	6.18
	Crude ore	100.00	1.306	100.00
7000	W rougher conc.	5.69	20.98	92.00
	Tailing	94.31	0.11	8.00
	Crude ore	100.00	1.298	100.00
8000	W rougher conc.	4.59	24.98	87.61
	Tailing	95.41	0.17	12.39
	Crude ore	100.00	1.309	100.00

Table 4-9 the results of test on Na₂SiO₃ dosage for Sample B

Na ₂ SiO ₃ dosage (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
3500	W rougher conc.	8.40	6.11	93.96
	Tailing	91.60	0.036	6.04
	Crude ore	100.00	0.546	100.00
4000	W rougher conc.	7.48	6.76	93.50
	Tailing	92.52	0.038	6.50
	Crude ore	100.00	0.541	100.00
4500	W rougher conc.	5.58	8.25	91.04
	Tailing	94.42	0.048	8.96
	Crude ore	100.00	0.506	100.00
5000	W rougher conc.	4.12	11.38	87.48
	Tailing	95.88	0.07	12.52
	Crude ore	100.00	0.536	100.00
6000	W rougher conc.	3.26	13.54	80.57
	Tailing	96.74	0.11	19.43
	Crude ore	100.00	0.548	100.00

4.3.5 Test on conditioning time and method of Na₂CO₃ and Na₂SiO₃

Tests on Na₂CO₃ and Na₂SiO₃ conditioning time and method in the tungsten roughing process for Sample C and Sample B were carried out under the conditions shown in Figure 4-6 with the results presented respectively in Table 4-10 and Table 4-11. Taking comprehensive considerations on the rougher concentrate grade, recovery and cost .etc. the way of Na₂CO₃ 3 min and Na₂SiO₃ 5 min is suitable in contrast, which is the basis for follow-up test.

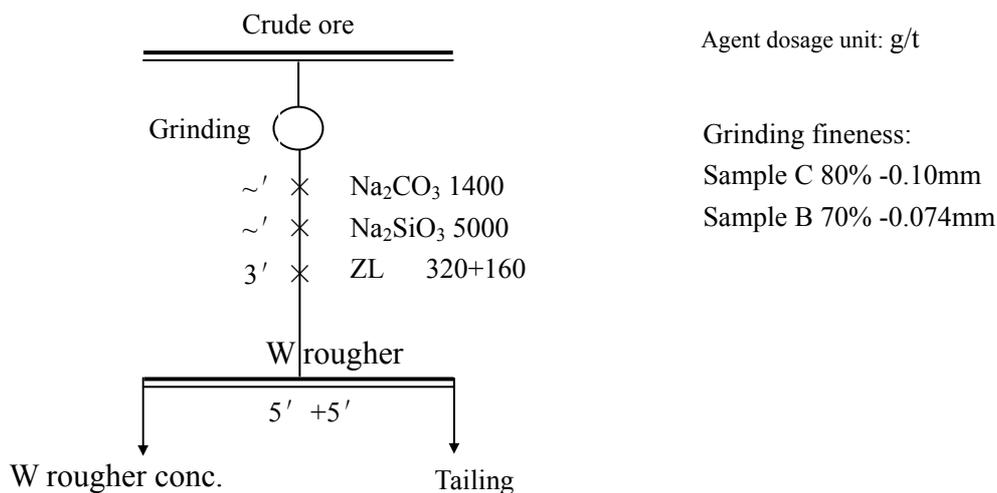


Figure 4-6 the flow-sheet of test on the conditioning time and method of Na_2CO_3 and Na_2SiO_3

Table 4-10 the results of test on the conditioning time and method of Na_2CO_3 and Na_2SiO_3 for Sample C

The conditioning time and method of Na_2CO_3 and Na_2SiO_3	Name of Product	Yield %	Grade $\text{WO}_3\%$	Recovery $\text{WO}_3\%$
Na_2CO_3 , Na_2SiO_3 Conditioning for 5' together	W rougher conc.	9.50	12.98	95.58
	Tailing	90.50	0.064	4.42
	Crude ore	100.00	1.290	100.00
1' Na_2CO_3 5' Na_2SiO_3	W rougher conc.	13.14	9.82	95.99
	Tailing	86.86	0.062	4.01
	Crude ore	100.00	1.344	100.00
3' Na_2CO_3 5' Na_2SiO_3	W rougher conc.	10.98	11.35	95.96
	Tailing	89.02	0.059	4.04
	Crude ore	100.00	1.299	100.00
5' Na_2CO_3 5' Na_2SiO_3	W rougher conc.	14.74	8.59	96.69
	Tailing	85.26	0.051	3.31
	Crude ore	100.00	1.310	100.00

Table 4-11 the results of test the conditioning time and method of Na_2CO_3 and Na_2SiO_3 for Sample B

The conditioning time and method of Na ₂ CO ₃ and Na ₂ SiO ₃	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
Na ₂ CO ₃ , Na ₂ SiO ₃ Conditioning for 5' together	W rougher conc.	5.86	8.14	91.51
	Tailing	94.14	0.047	8.49
	Crude ore	100.00	0.521	100.00
1' Na ₂ CO ₃ 5' Na ₂ SiO ₃	W rougher conc.	6.34	7.88	92.38
	Tailing	93.66	0.044	7.62
	Crude ore	100.00	0.541	100.00
3' Na ₂ CO ₃ 5' Na ₂ SiO ₃	W rougher conc.	6.58	7.59	93.53
	Tailing	93.42	0.037	6.47
	Crude ore	100.00	0.534	100.00
5' Na ₂ CO ₃ 5' Na ₂ SiO ₃	W rougher conc.	6.88	7.35	93.95
	Tailing	93.12	0.035	6.05
	Crude ore	100.00	0.539	100.00

4.3.6 Test on the type of collector for Sample C

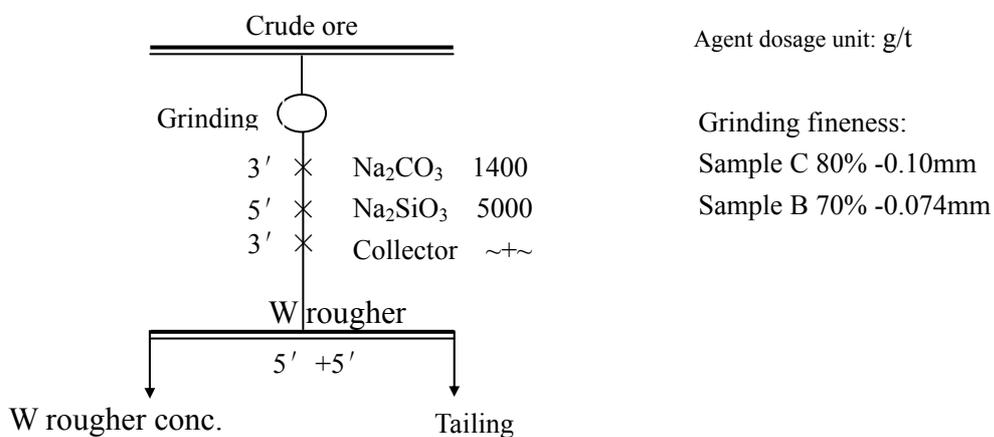


Figure 4-7 the flow-sheet of test on the type of collector

Tests on the type of collector were carried out taking C-Lens ore as sample. Tests on the effect of fatty acid collectors such as 731 # 、 733 # and GYWA were also carried out besides of ZL collector. The results

shown in 4-12 indicate that the effect of GYWA is basically similar to ZL while that of 733 #, especially 731 # are relatively poor when with the same dosage. Good results also could be achieved when their dosage are much higher..

Table 4-12 the results of tests on the type of collector for Sample C

The type and dosage of collector (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
731# 400+200	W rougher conc.	6.38	18.85	91.46
	Tailing	93.62	0.12	8.54
	Crude ore	100.00	1.315	100.00
731# 560+280	W rougher conc.	9.33	13.87	95.13
	Tailing	90.67	0.073	4.87
	Crude ore	100.00	1.360	100.00
733# 400+200	W rougher conc.	9.87	12.53	95.21
	Tailing	90.13	0.069	4.79
	Crude ore	100.00	1.299	100.00
733# 320+160	W rougher conc.	11.70	10.99	95.29
	Tailing	88.30	0.072	4.71
	Crude ore	100.00	1.349	100.00
733# 240+120	W rougher conc.	8.78	13.89	91.14
	Tailing	91.22	0.13	8.86
	Crude ore	100.00	1.338	100.00
GYWA 320+160	W rougher conc.	11.46	11.32	95.56
	Tailing	88.54	0.068	4.44
	Crude ore	100.00	1.357	100.00
ZL	W rougher conc.	10.98	11.35	95.96
	Tailing	89.02	0.059	4.04
	Crude ore	100.00	1.299	100.00

4.3.7 Test on the dosage of ZL collector

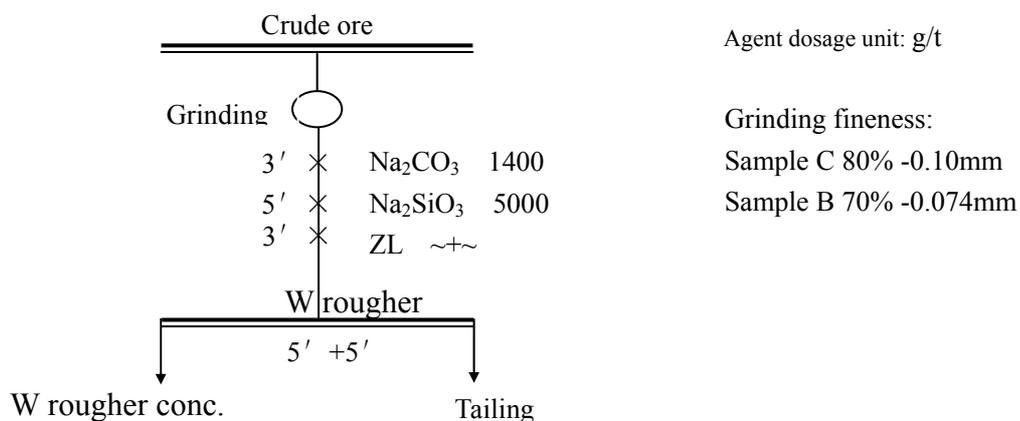


Figure 4-8 the flow-sheet of test on the dosage of ZL

Table 4-13 the results of test on the dosage of ZL for Sample C

The dosage of collector (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
ZL 160+80	W rougher conc.	7.92	15.60	93.13
	Tailing	92.08	0.099	6.87
	Crude ore	100.00	1.327	100.00
240+120	W rougher conc.	10.28	12.09	94.22
	Tailing	89.72	0.085	5.78
	Crude ore	100.00	1.319	100.00
ZL 320+160	W rougher conc.	11.47	11.14	95.31
	Tailing	88.53	0.071	4.69
	Crude ore	100.00	1.341	100.00
ZL 400+200	W rougher conc.	12.95	9.84	96.13
	Tailing	87.05	0.059	3.87
	Crude ore	100.00	1.326	100.00

Tests on the dosage of ZL collector in the tungsten roughing process for Sample C and Sample B were carried out under the conditions shown in Figure 4-8. The results are shown respectively in Table 4-13 and Table

4-14. Taking comprehensive considerations on the rougher concentrate grade, recovery and cost, etc. the suitable dosage of ZL is 320+160g/t.

Table 4-14 the results of test on the dosage of ZL for Sample B

The dosage of collector (g/t)	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
ZL 160+80	W rougher conc.	3.43	10.54	70.07
	Tailing	96.57	0.10	29.93
	Crude ore	100.00	0.516	100.00
ZL 240+120	W rougher conc.	5.57	8.23	86.46
	Tailing	94.43	0.076	13.54
	Crude ore	100.00	0.530	100.00
ZL 320+160	W rougher conc.	6.65	7.26	91.51
	Tailing	93.35	0.048	8.49
	Crude ore	100.00	0.528	100.00
ZL 400+200	W rougher conc.	8.24	5.62	92.83
	Tailing	91.76	0.039	7.17
	Crude ore	100.00	0.499	100.00

4.3.8 Test on the dosage of ZL collector for Sample C at the dosage of Na₂SiO₃ 3000g/t

There is a certain interaction between collector and inhibitor. Tests on the dosage of ZL were carried out for Sample C when the Na₂SiO₃ inhibitor is weak (3000g/t), the results shown in Table 4-15 indicate that a good outcome can also be achieved. But if the amount of inhibitor is too low, the technological process is unstable.

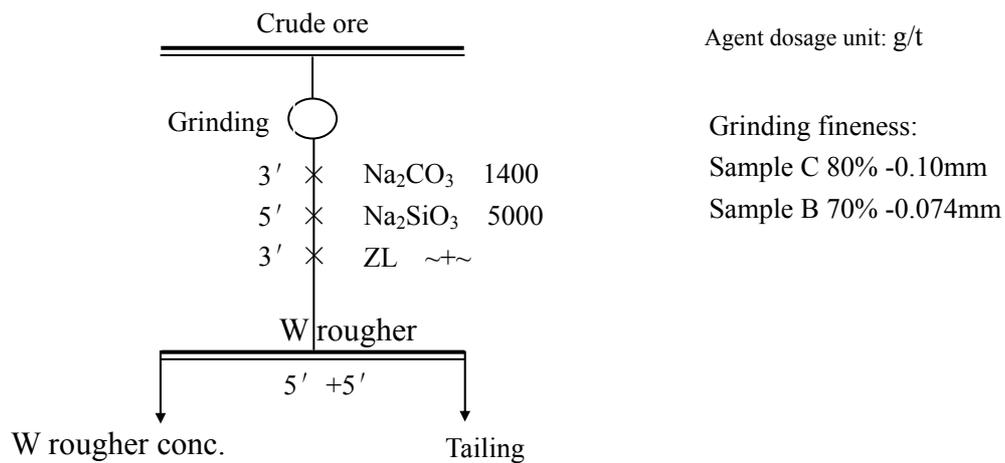


Figure 4-9 the flow-sheet of test on the dosage of ZL with Na_2SiO_3 3000g/t

Table 4-15 the results of test on the dosage of ZL with Na_2SiO_3 3000g/t for Sample C

The dosage of collector (g/t)	Name of Product	Yield %	Grade $\text{WO}_3\%$	Recovery $\text{WO}_3\%$
ZL 240+120	W rougher conc.	16.11	7.94	97.01
	Tailing	83.89	0.047	2.99
	Crude ore	100.00	1.319	100.00
ZL 200+80	W rougher conc.	15.14	8.33	96.49
	Tailing	84.86	0.054	3.51
	Crude ore	100.00	1.307	100.00
ZL 160+40	W rougher conc.	13.53	9.48	96.11
	Tailing	86.47	0.06	3.89
	Crude ore	100.00	1.335	100.00
ZL 120+40	W rougher conc.	11.33	10.80	92.93
	Tailing	88.67	0.105	7.07
	Crude ore	100.00	1.317	100.00

4.3.9 Flotation pulp density test

The flotation pulp density usually has a certain effect on flotation

results. Two kinds of flotation density tests were carried out: ① the dosage of agent g/t is unchanged when the amount of ore varies; ② the volume concentration of agent g/m³ is unchanged when the amount of ore varies.

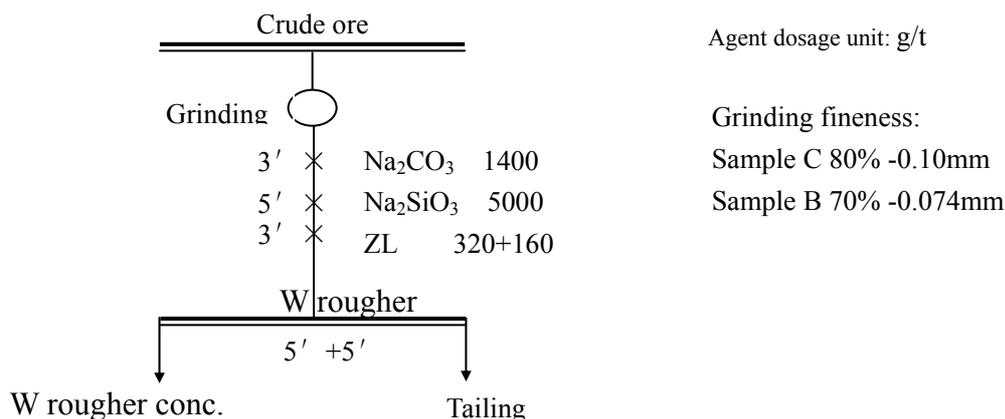


Figure 4-10 the flow-sheet of test on flotation pulp density at rougher stage

Table 4-16 the results of flotation pulp density test for Sample C (1)----the dosage of agent g/t is unchanged when the amount of ore varies

Flotation pulp density R %	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
21.55	W rougher conc.	9.95	11.88	89.74
	Tailing	90.05	0.15	10.26
	Crude ore	100.00	1.317	100.00
30.2	W rougher conc.	10.91	11.29	92.63
	Tailing	89.09	0.11	7.37
	Crude ore	100.00	1.330	100.00
40.91	W rougher conc.	10.00	12.54	95.74
	Tailing	90.00	0.062	4.26
	Crude ore	100.00	1.310	100.00
50.61	W rougher conc.	10.99	11.43	96.51
	Tailing	89.01	0.051	3.49
	Crude ore	100.00	1.301	100.00

The results presented in Table 4-16, Table 4-17, Table 4-18 show that the flotation pulp density has a great impact. The results are relatively good when the pulp density in the roughing stage is 40%±5%. If the pulp density is too high, the particles are easy to settle down to the bottom of flotation cell.

**Table 4-17 the results of flotation pulp density test for Sample C
(2)---- the volume concentration of agent g/m³ is unchanged when the
amount of ore varies**

Flotation pulp density R %	Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
21.55	W rougher conc.	4.79	23.58	84.96
	Tailing	95.21	0.21	15.04
	Crude ore	100.00	1.329	100.00
30.2	W rougher conc.	7.14	16.96	90.62
	Tailing	92.86	0.135	9.38
	Crude ore	100.00	1.336	100.00
40.91	W rougher conc.	10.00	12.54	95.74
	Tailing	90.00	0.062	4.26
	Crude ore	100.00	1.310	100.00
50.61	W rougher conc.	12.91	10.13	96.78
	Tailing	87.09	0.05	3.22
	Crude ore	100.00	1.351	100.00

Table 4-18 the results of flotation pulp density test for Sample B---- the volume concentration of agent g/m³ is unchanged when the amount of ore varies

Flotation pulp density R %	Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
21.55	W rougher conc.	3.64	12.14	83.14
	Tailing	96.36	0.093	16.86
	Crude ore	100.00	0.532	100.00
30.2	W rougher conc.	3.99	11.69	86.48
	Tailing	96.01	0.076	13.52
	Crude ore	100.00	0.540	100.00
40.91	W rougher conc.	7.72	6.49	92.98
	Tailing	92.28	0.041	7.02
	Crude ore	100.00	0.539	100.00
50.61	W rougher conc.	11.63	4.31	96.27
	Tailing	88.37	0.022	3.73
	Crude ore	100.00	0.521	100.00

4.3.10 Test on the flotation residence time for tungsten roughing and scavenging

Tests on the flotation residence time for tungsten roughing and scavenging for Sample C and Sample B were conducted in accordance with Figure 4-11 with the results shown respectively in Table 4-19 and Table 4-20. It is indicated that the roughing (5') + the scavenging 1 (5') + the scavenging 2 (5') is enough for the lab test.

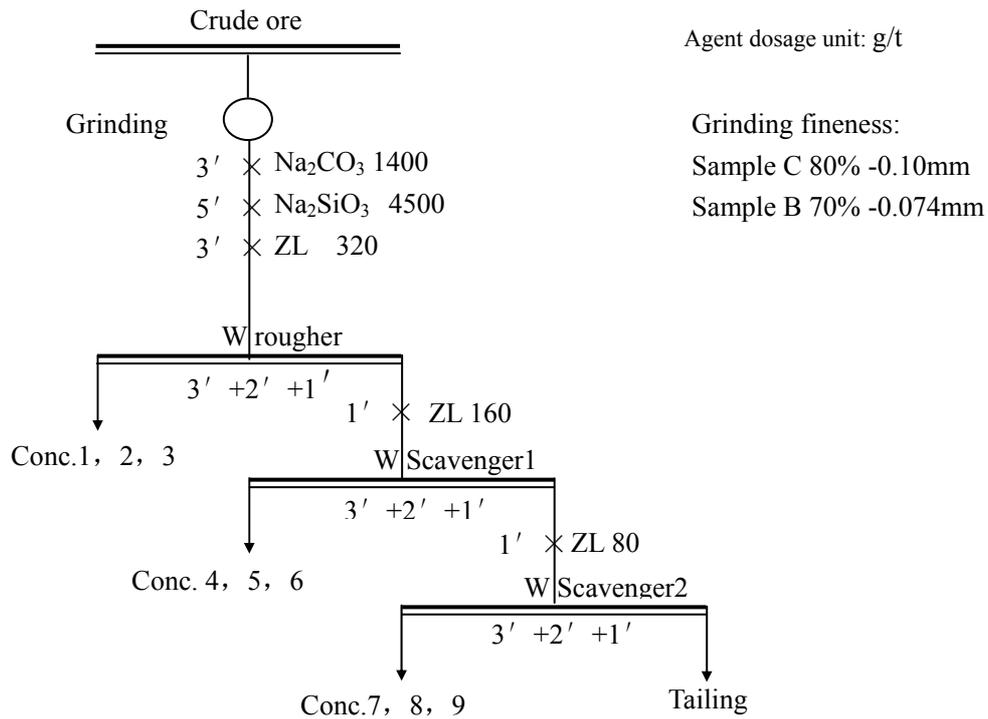


Figure 4-11 Test on the flotation residence time of scheelite roughing and scavenging

Table 4-19 the results of test on the flotation residence time of the tungsten roughing and scavenging for Sample C

Name of Product	Yield %		Grade WO ₃ %		WO ₃ Recovery %	
	Indiv.	Acum..	Indiv.	Acum..	Indiv.	Acum..
Conc.K1	8.75		14.12		93.70	
Conc.K2	0.48	9.23	2.09	13.49	0.76	94.46
Conc.K3	0.19	9.42	1.86	13.25	0.27	94.73
Conc.K4	1.27	10.69	0.99	11.79	0.96	95.69
Conc.K5	0.38	11.07	0.91	11.42	0.26	95.95
Conc.K6	0.19	11.26	0.86	11.24	0.12	96.08
Conc.K7	0.77	12.03	0.62	10.56	0.36	96.44
Conc.K8	0.40	12.43	0.55	10.25	0.16	96.60
Conc.K9	0.41	12.84	0.51	9.94	0.16	96.76
Tailing	87.16	100.00	0.049	1.32	3.24	100.00
Total (head ore)	100.00		1.32		100.00	

Table 4-20 the results of test on the flotation residence time of the tungsten roughing and scavenging for Sample B

Name of Product	Yield %		Grade WO ₃ %		WO ₃ Recovery %	
	Indiv.	Acum..	Indiv.	Acum..	Indiv.	Acum..
Conc.K1	3.78		12.00		90.61	
Conc.K2	0.52	4.30	1.72	10.74	1.81	92.42
Conc.K3	0.19	4.49	1.11	10.33	0.43	92.85
Conc.K4	2.88	7.37	0.47	6.48	2.71	95.55
Conc.K5	0.53	7.90	0.29	6.06	0.31	95.86
Conc.K6	0.25	8.15	0.27	5.89	0.13	95.99
Conc.K7	0.99	9.14	0.21	5.27	0.42	96.41
Conc.K8	0.45	9.59	0.21	5.04	0.19	96.60
Conc.K9	0.47	10.06	0.17	4.81	0.16	96.76
Tailing	89.94	100.00	0.018	0.50	3.24	100.00
Total (feed ore)	100.00		0.50		100.00	

4.3.11 Test on the retreatment of W scavenger concentrate in the tungsten roughing stage

At the request of KIS Management Pty Limited, the tests on the retreatment of W scavenger concentrate in the tungsten roughing process for Sample C and Sample B were carried out. The technological process is shown in Figure 4-12, and the results are presented in Table 4-21.

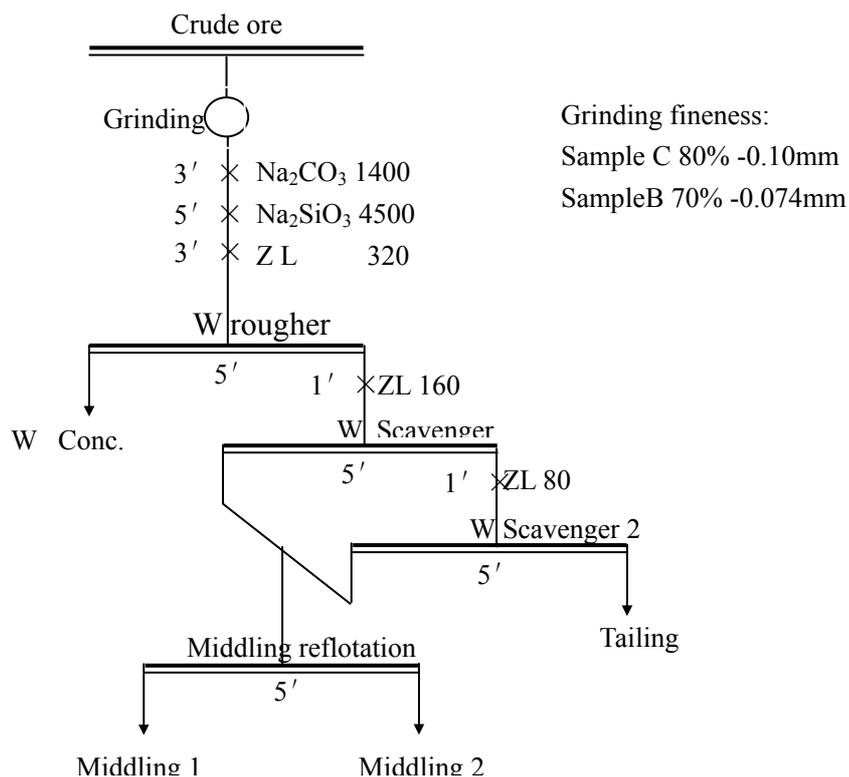


Figure 4-12 the flow-sheet of re-flotation test of W scavenger concentrate in the tungsten roughing process

Table 4-21 the results of retreatment tests of W scavenger concentrate in the tungsten roughing for Sample C and Sample B

Sample	Name of product	Wt. %		Grade W O ₃ %		Recovery W O ₃ %	
		Indiv.	Acum.	Indiv.	Acum.	Indiv.	Acum.
Sample c	W-rough conc.	7.59		16.88		92.12	
	Mid 1	1.31	8.9	2.72	14.80	2.56	94.68
	Mid 2	1.06	9.96	0.43	13.27	0.33	95.02
	Rougher tailing	90.04		0.077		4.99	
	Head ore	100.00		1.391		100.00	
Sample B	W-rough conc.	3.45		13.69		88.63	
	Mid 1	2.07	5.52	1.24	9.02	4.82	93.45
	Mid 2	1.78	7.30	0.19	6.87	0.63	94.09
	Rougher tailing	92.70		0.034		5.91	
	Head ore	100.00		0.533		100.00	

4.3.12 Na₂SiO₃ dosage test for cleaning of W rougher froth for Sample C

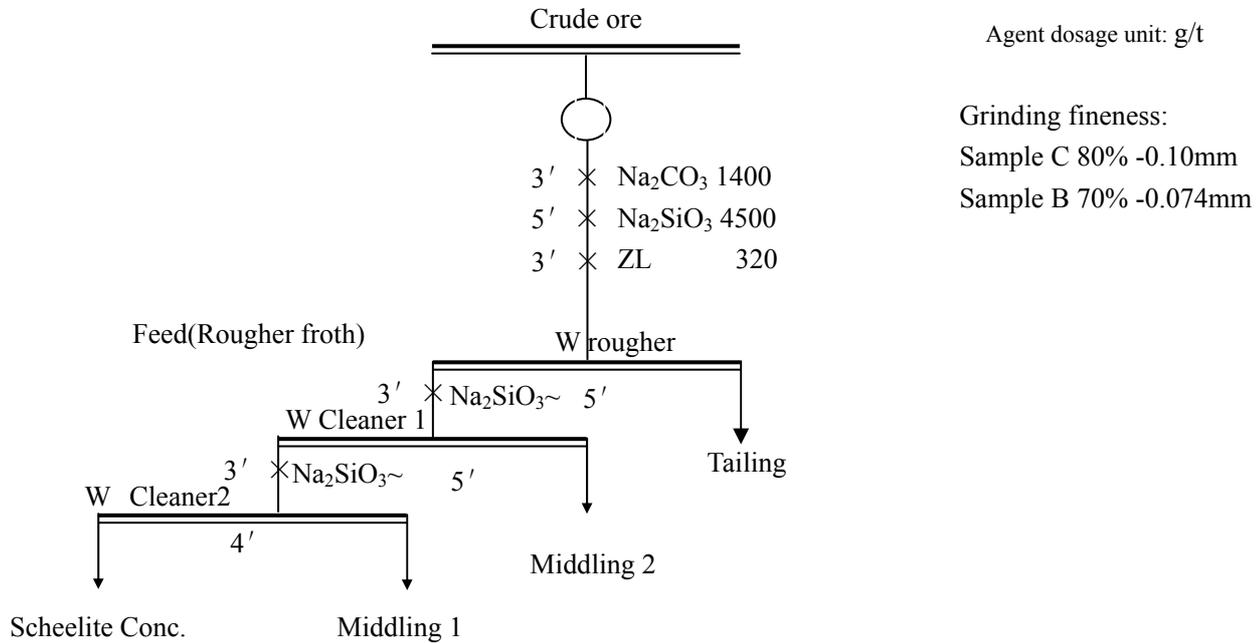


Figure 4-13 the cleaning flow-sheet of scheelite rougher froth

Na₂SiO₃ dosage test for cleaning of rougher froth for Sample C was carried out with the flow-sheet shown in Figure 4-13. The results are presented in Table 4-22. It is indicated that a suitable amount of Na₂SiO₃ is of help to upgrading scheelite rough concentrate.

Table 4-22 the results of Na₂SiO₃ dosage test of cleaning of scheelite rougher froth for Sample C

Dosage of Na ₂ SiO ₃ (g/t)	Name of Product	Operation Yield %	Grade WO ₃ %	Operation Recovery WO ₃ %
Cleaner.1: 0 Cleaner.2: 0	W rougher conc.	78.86	19.05	97.92
	Middling 1	5.90	2.41	0.93
	Middling 2	15.24	1.16	1.15
	Feeding ore	100.00	15.34	100.00
Cleaner1: 500 Cleaner2: 0	W rougher conc.	75.13	22.69	97.88
	Middling 1	5.62	2.43	0.78
	Middling 2	19.25	1.21	1.34
	Feeding ore	100.00	17.42	100.00
Cleaner1: 0 Cleaner2:500	W rougher conc.	76.34	22.05	97.85
	Middling 1	6.38	2.48	0.92
	Middling 2	17.28	1.22	1.23
	Feeding ore	100.00	17.20	100.00
Cleaner1: 500 Cleaner2: 500	W rougher conc.	74.08	23.62	97.76
	Middling 1	6.71	2.53	0.95
	Middling 2	19.21	1.21	1.29
	Feeding ore	100.00	17.90	100.00

4.3.13 Whole open-circuit test for scheelite roughing stage

The whole open-circuit tests for scheelite roughing for Sample C and Sample B were carried out in accordance with Figure 4-14. The results are shown in Table 4-23 and Table 4-24.

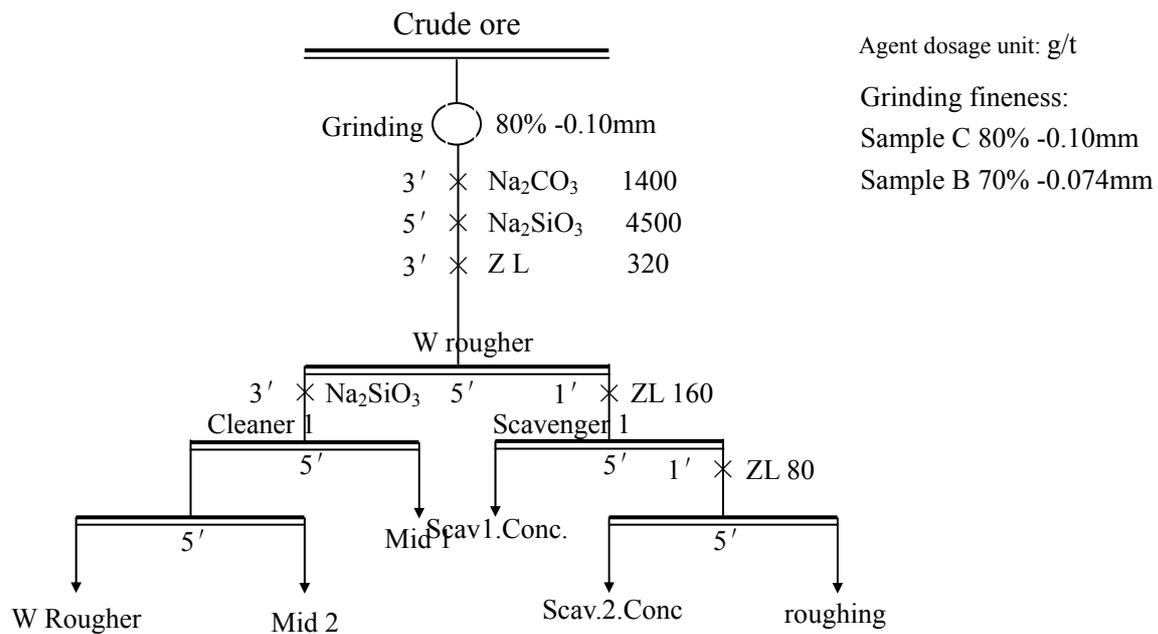


Figure 4-14 the flow-sheet of whole open-circuit tests of scheelite roughing for Sample C

Table 4-23 the results of whole open-circuit tests of scheelite roughing for Sample C

Name of Product	Yield %		Grade WO ₃ %		Recovery WO ₃ %	
	Indiv.	Acum.	Indiv.	Acum.	Indiv.	Acum.
W rougher Conc.	5.82		17.04		91.87	
Middling 2	0.46	7.28	3.48	16.18	1.25	93.03
Middling 1	1.42	8.70	1.10	13.72	1.24	94.27
Scav.1 Conc.	1.61	10.31	1.23	11.77	1.57	95.84
Scav.2 Conc.	0.94	11.25	0.80	10.86	0.59	96.43
Rougher Tailing	88.75	100.00	0.051	1.266	3.57	100.00
Feeding ore	100.00		1.266		100.00	

**Table 4-24 the results of whole open-circuit tests of scheelite
roughing for Sample B**

Name of Product	Yield %		Grade WO ₃ %		Recovery WO ₃ %	
	Indiv.	Acum.	Indiv.	Acum.	Indiv.	Acum.
W rougher Conc.	2.08		19.57		84.42	
Middling 2	0.62	2.70	2.49	15.63	3.22	87.64
Middling 1	1.76	4.46	1.27	9.96	4.64	92.28
Scav.1 Conc.	2.82	7.28	0.59	6.33	3.45	95.73
Scav.2 Conc.	1.48	8.76	0.29	5.31	0.86	96.59
Rougher Tailing	91.24	100.00	0.018	0.485	3.41	100.00
Feeding ore	100.00		0.485		100.00	

4.3.14 Closed-circuit test for scheelite roughing stage

The closed-circuit tests for scheelite roughing stage for Sample B and Sample C were carried out respectively in accordance with Figure 4-15 and Figure 4-16. The corresponding quantitative flow-sheets are shown in Figure 4-17 and Figure 4-18 and the results are presented in Table 4-25 together.

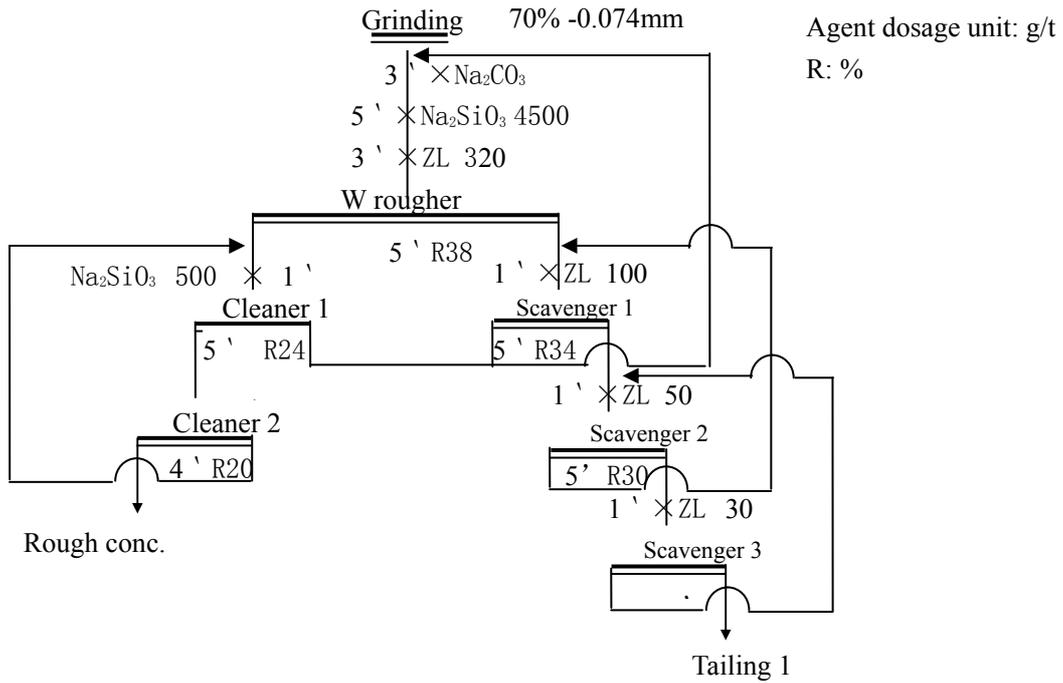


Fig.4-15 Closed circuit Flow-sheet of W-Rougher for B-Lens Ore

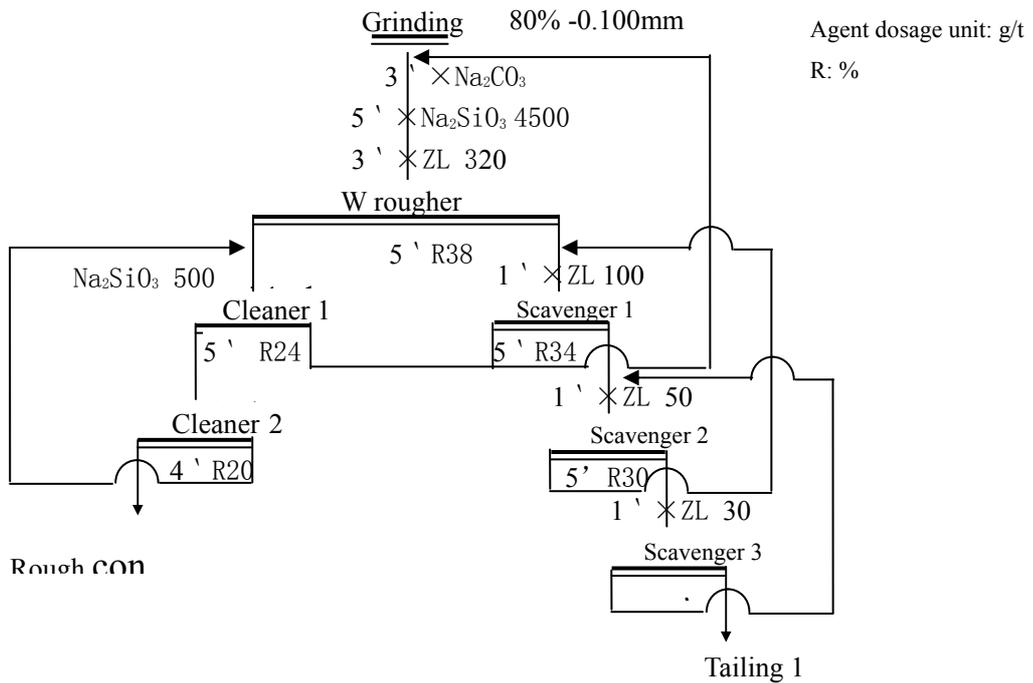


Fig.4-16 Closed circuit Flow-sheet of W-Rougher for C-Lens Ore

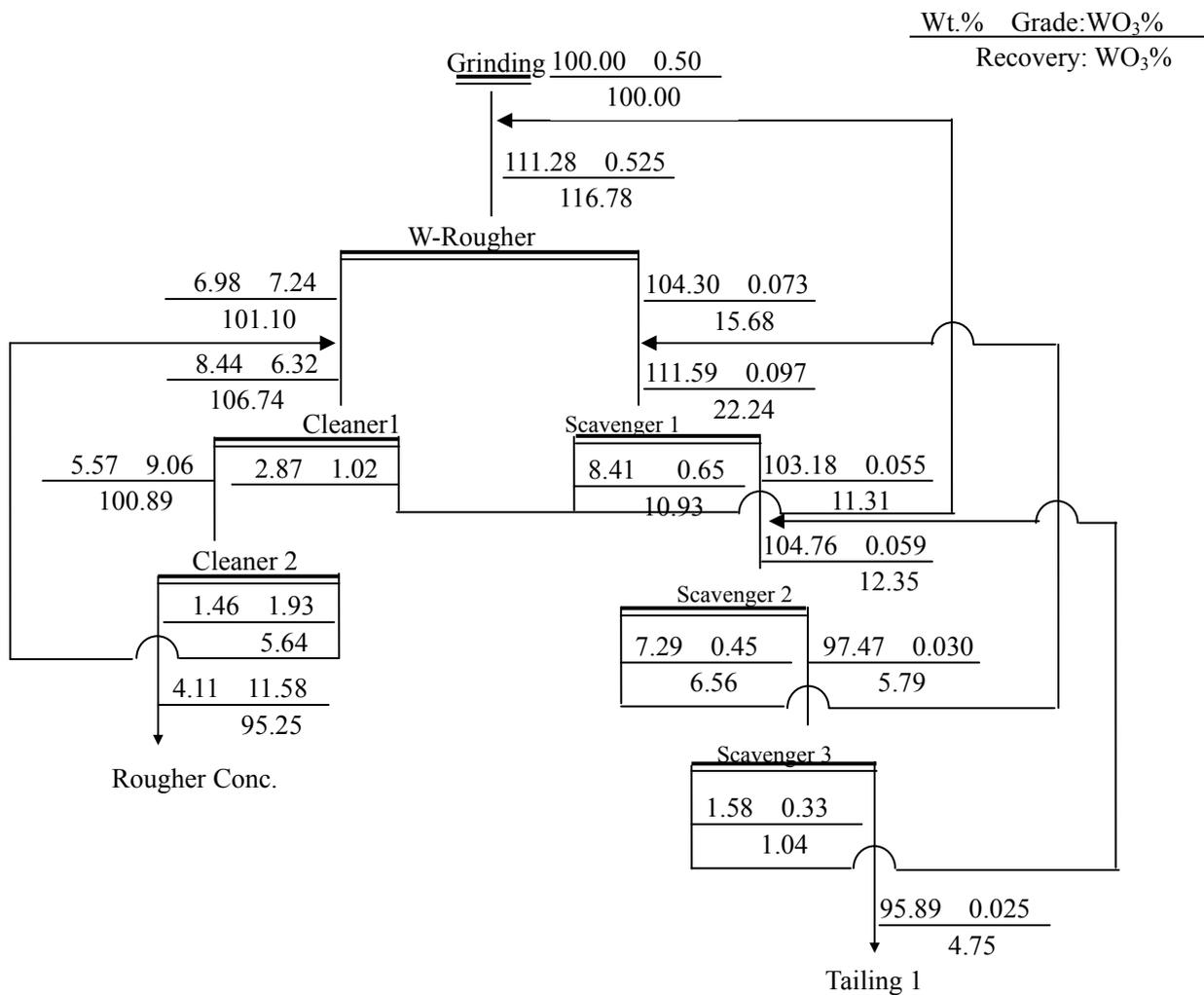


Fig.4-17 Quantitative Flow-sheet of Closed Circuit of W-Rougher for B-Lens Ore

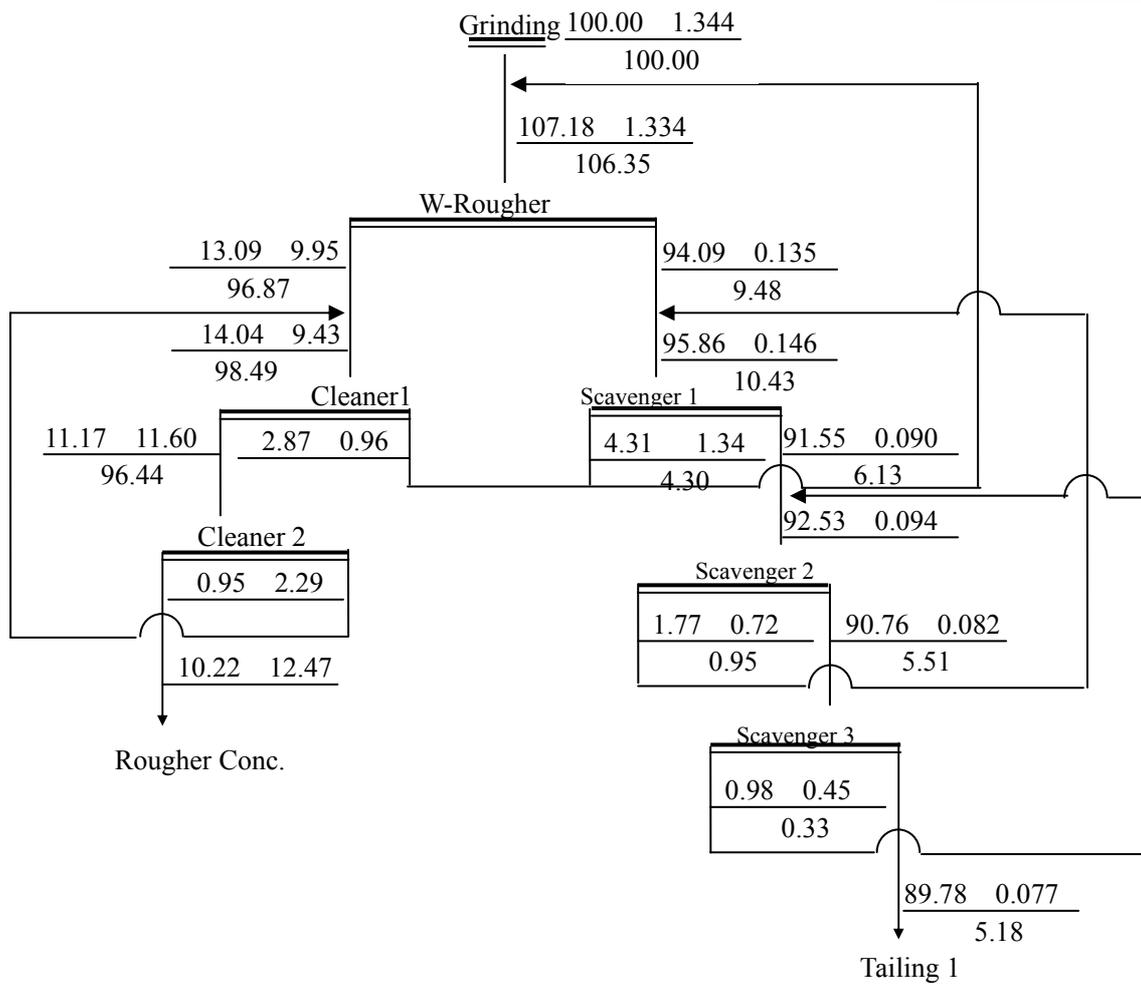


Fig.4-18 Quantitative Flow-sheet of Closed Circuit of W-Rougher for C-Lens Ore

Table 4-25 the results of closed-circuit tests for W-Rougher for

Sample C and Sample B

Sample	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
Sample B	W rougher Conc.	4.11	11.58	95.25
	Tailing	95.89	0.025	4.75
	Crude ore	100.00	0.50	100.00
Sample C	W rougher Conc.	10.22	12.47	94.82
	Tailing	89.78	0.077	5.18
	Crude ore	100.00	1.344	100.00

4.4 Cleaning test of scheelite rougher concentrate

The WO_3 grade of scheelite rougher froth product is up to $12\%\pm$ in the rougher stage. It still contains lots of gangue minerals bearing calcium dominated by fluorite, calcite and pyroxene and a small amount of sulfide minerals with good floatability so that it still has difficulty in obtaining scheelite concentrate with WO_3 grade over 65% and high recovery.

Presently, in commercial practice both at home and abroad, there are two methods to separate the scheelite rougher concentrate containing the gangue minerals bearing calcium dominated by fluorite, calcite and pyroxene, which are heated cleaning (also known as "Peterov Method") and cleaning at ambient temperature. The heated cleaning is to attrite high density pulp with large amount of sodium silicate at elevated temperature, which is still an efficient method to separate scheelite and the gangue minerals bearing calcium such as fluorite, calcite, etc. Normally, the heated pulp is required to be diluted several times to remove reagents followed by cleaning flotation finally.

For the refractory ore with complex properties, GZRINM has improved the "Peterov Method" to ensure the quality of scheelite concentrate by taking new technical measures such as modifying sodium silicate and adding sodium silicate mixture, etc. to greatly strengthen the depression of sodium silicate on gangue minerals bearing calcium and sulfide minerals and the selective activation as well as collecting function for

scheelite. That the W rougher concentrate is directly sent to scheelite flotation without dilution and reagents-removing after heating process can not only greatly simplify the technological process of scheelite heated cleaning and reduce the loss of tungsten in the process of dilution and reagents-removing, but also eliminate the process of dephosphorization for final scheelite concentrate. The method of cleaning at ambient temperature is also to attrite the pulp for a long time with large amount of sodium silicate mixtures, but for this method, its inhibition on gangue minerals bearing calcium and activation on scheelite are weaker than that for heated cleaning process, hence the quality of its final concentrate and the stability of operation is a little poor. Batch test and closed-circuit test of cleaning processes for scheelite rougher concentrate both at elevated temperature and at ambient temperature were carried out in accordance with the contract requirements.

4.4.1 Batch test of scheelite rougher concentrate by cleaning at elevated temperature

4.4.1.1 Test on the dosage of Na_2SiO_3 in rougher separation of heated cleaning process (heated roughing for short)

The dosage of Na_2SiO_3 in heated roughing has a great effect on the grade and recovery of concentrate. The tests were carried out under the conditions shown in Figure 4-19 and the results are presented in Table 4-26 and Table 4-27. The grade of concentrate is low if the dosage of

Na₂SiO₃ is insufficient while excessive Na₂SiO₃ also makes scheelite to be inhibited. Considered comprehensively, the dosages of Na₂SiO₃ 4500g/t and 3500g/t respectively for C and B samples are working. Besides, the role of Na₂S in the process was examined at the presence of Na₂SiO₃, which was not obvious.

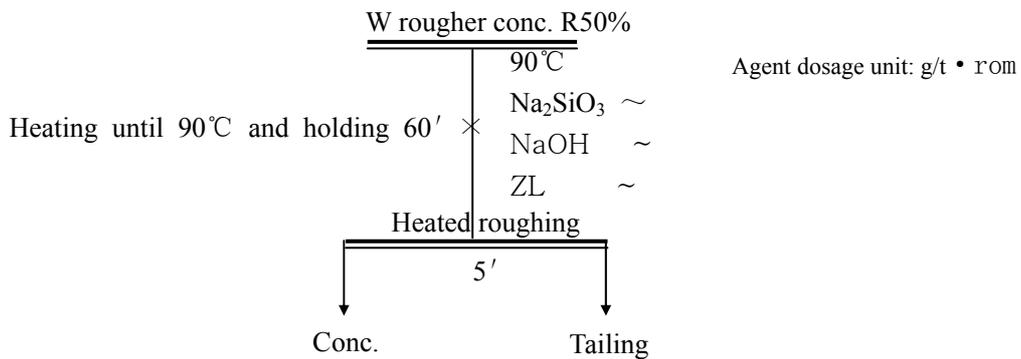


Figure 4-19 the flow-sheet of test on the dosage of Na₂SiO₃ in heated roughing

Table 4-26 the results of tests on the dosage of Na₂SiO₃ in heated roughing for C-Lens ore (NaOH 400 g/t, ZL40 g/t)

Dosage of Na ₂ SiO ₃ (g/t.rom)	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
3000	Concentrate	27.23	44.61	96.14
	Tailing	72.77	0.67	3.86
	Feed	100.00	12.634	100.00
4500	Concentrate	21.25	56.75	93.58
	Tailing	78.75	1.05	6.42
	Feed	100.00	12.886	100.00
6000	Concentrate	19.36	58.96	90.82
	Tailing	80.64	1.43	9.18
	Feed	100.00	12.568	100.00
4500 with Na ₂ S 150(g/t)	Concentrate	20.23	57.54	94.25
	Tailing	79.77	0.89	5.75
	Feed	100.00	12.350	100.00

Table 4-27 the results of tests on the dosage of Na₂SiO₃ in heated roughing for B-Lens ore (NaOH 200 g/t, ZL20 g/t)

Dosage of Na ₂ SiO ₃ (g/t.rom)	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
2500	Concentrate	26.15	40.89	94.39
	Tailing	73.85	0.86	5.61
	Feed	100.00	11.314	100.00
3500	Concentrate	19.23	54.98	93.10
	Tailing	80.77	0.97	6.90
	Feed	100.00	11.356	100.00
4500	Concentrate	18.13	59.74	91.24
	Tailing	81.87	1.27	8.76
	Feed	100.00	11.871	100.00
3500 with Na ₂ S 150(g/t)	Concentrate	18.89	55.86	93.40
	Tailing	81.11	0.92	6.60
	Feed	100.00	11.298	100.00

4.4.1.2 Test on the dosage of NaOH in heated roughing

The technological flow-sheet and the results of tests are shown respectively in Figure 4-20, Table 4-28 and Table 4-29. According to the results, NaOH has enhanced the inhibitory effect of sodium silicate on gangues and sulfide minerals. The suitable dosage of NaOH for C-Lens ore and B-Lens ore are respectively 400g/t and 200g/t.

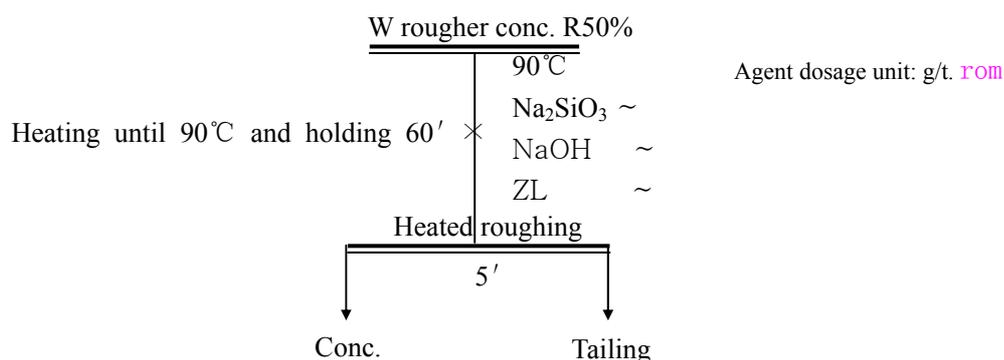


Figure 4-20 the flow-sheet of test on the dosage of NaOH in heated roughing

Table 4-28 the results of tests on the dosage of NaOH in heated roughing for C-Lens ore (Na₂SiO₃ 4500g/t, ZL 40 g/t)

Dosage of NaOH (g/t.rom)	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	Concentrate	22.02	51.24	89.21
	Tailing	77.98	1.75	10.79
	Feed	100.00	12.648	100.00
200	Concentrate	21.86	53.54	91.73
	Tailing	78.14	1.35	8.27
	Feed	100.00	12.759	100.00
400	Concentrate	21.25	56.75	93.58
	Tailing	78.75	1.05	6.42
	Feeding ore	100.00	12.886	100.00
600	Concentrate	20.58	57.65	92.28

	Tailing	79.42	1.25	7.72
	Feed	100.00	12.857	100.00

Table 4-29 the results of tests on the dosage of NaOH in heated roughing for B-Lens ore (Na₂SiO₃ 3500g/t, ZL 40 g/t)

Dosage of NaOH (g/t)	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	Conc.	20.65	51.26	90.50
	Tailing	79.35	1.40	9.50
	Feed	100.00	11.696	100.00
200	Conc	19.23	54.98	93.10
	Tailing	80.77	0.97	6.90
	Feed	100.00	11.356	100.00
400	Conc.	18.46	55.85	91.12
	Tailing	78.54	1.28	8.88
	Feed	100.00	11.665	100.00

4.4.1.3 Test on the dosage of ZL in heated roughing

The conditions and results of tests are shown respectively in Figure 4-21, Table 4-30 and Table 4-31. According to the results, moderate ZL is helpful to improve the recovery. The suitable dosage of ZL for C-Lens ore and B-Lens ore are respectively 40g/t•rom and 20g/t•rom.

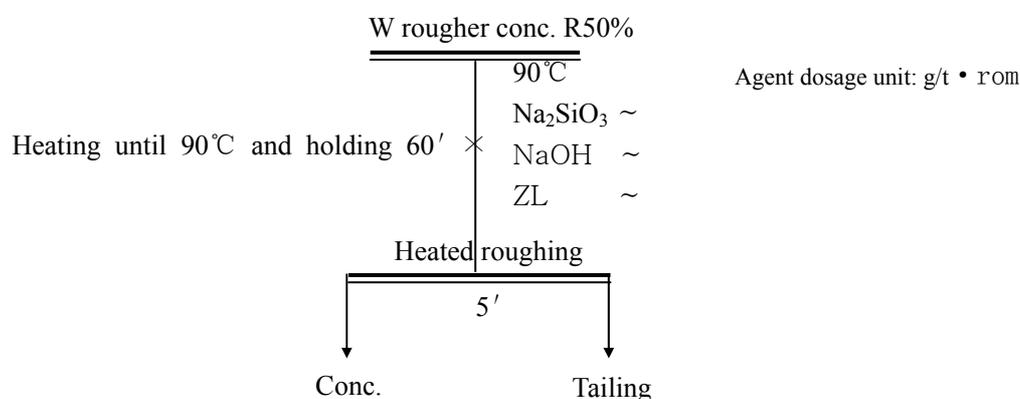


Figure 4-21 the flow-sheet of test on the dosage of ZL in heated roughing

Table 4-30 the results of tests on the dosage of ZL in heated roughing for C-Lens ore (Na₂SiO₃ 4500g/t, NaOH 400 g/t)

Dosage of ZL(g/t)	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	Conc.	20.07	57.21	89.64
	Tailing	79.93	1.66	10.36
	Feed	100.00	12.809	100.00
40	Conc.	20.88	56.23	92.81
	Tailing	79.12	1.15	7.19
	Feed	100.00	12.651	100.00
80	Conc.	21.84	53.58	93.33
	Tailing	78.16	1.07	6.67
	Feed	100.00	12.538	100.00

Table 4-31 the results of tests on the dosage of ZL in heated roughing for B-Lens ore (Na₂SiO₃ 3500g/t, NaOH 200 g/t)

Dosage of ZL(g/t)	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
0	Conc.	18.49	55.32	89.07
	Tailing	81.51	1.54	10.93
	Feed.	100.00	11.484	100.00
20	Conc.	19.45	54.16	92.44
	Tailing	80.55	1.07	7.56
	Feed.	100.00	11.396	100.00
40	Conc.	19.76	53.65	92.70
	Tailing	80.24	1.04	7.30
	Feed.	100.00	11.436	100.00

4.4.1.4 Test on pulp temperature in heated roughing

The influence of pulp temperature at attrition on scheelite heated flotation was examined. The flow-sheet is shown in Figure 4-22 and the

results are presented in Table 4-32 and Table 4-33. Although a good result can be achieved at 60°C, but the result at 80~90°C is better. The result at 30°C is poor, while the effect of Na₂S at this temperature is not obvious.

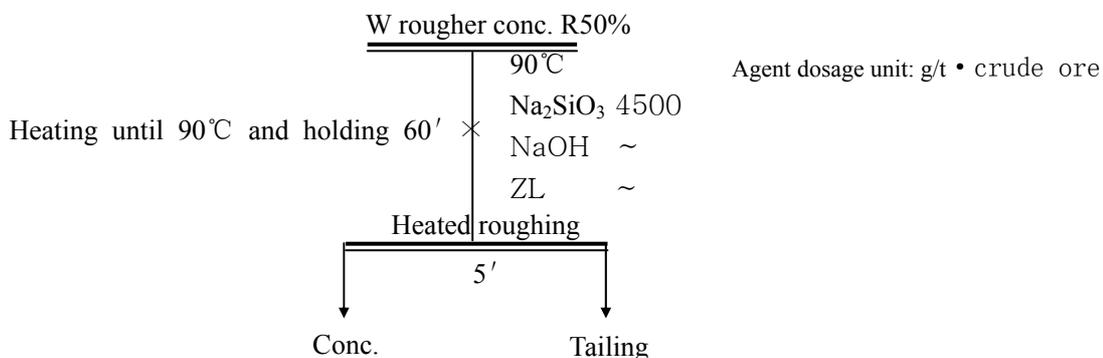


Figure 4-22 the flow-sheet of test on pulp temperature in heated roughing

Table 4-32 the results of tests on pulp temperature at attrition in heated roughing for C-Lens ore (Na₂SiO₃ 4500 g/t, NaOH 400 g/t, ZL 40 g/t)

Temperature °C	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
30	Conc.	22.96	49.76	89.61
	Tailing	77.04	1.72	10.39
	Feed.	100.00	12.750	100.00
60	Conc.	21.69	54.02	91.11
	Tailing	78.31	1.46	8.89
	Feed.	100.00	12.860	100.00
90	Conc.	20.88	56.23	92.81
	Tailing	79.12	1.15	7.19
	Feed.	100.00	12.651	100.00
30 adding Na ₂ S 150(g/t)	Conc.	22.04	51.65	89.68
	Tailing	77.96	1.68	10.32
	Feed.	100.00	12.693	100.00

Table 4-33 the results of tests on pulp temperature at attrition in heated roughing for B-Lens ore (Na₂SiO₃ 3500 g/t, NaOH 200 g/t, ZL 20 g/t)

Temperature °C	Name of product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
30	Conc.	23.04	45.14	88.94
	Tailing	76.96	1.68	11.06
	Feed.	100.00	11.693	100.00
60	Conc.	20.76	50.03	89.79
	Tailing	79.24	1.49	10.21
	Feed.	100.00	11.567	100.00
90	Conc.	19.45	54.06	92.44
	Tailing	80.55	1.07	7.56
	Feed.	100.00	11.396	100.00
30 adding Na ₂ S 150(g/t)	Conc.	21.54	48.08	88.24
	Tailing	78.46	1.76	11.76
	Feed.	100.00	11.737	100.00

4.5 Flow-sheet of whole open circuit test for heated cleaning

Whole open circuit flow-sheet tests of heated cleaning for W rougher concentrate were carried out with the flow-sheet and the results shown respectively in Figure 4-23, Table 4-34 and Table 4-35.

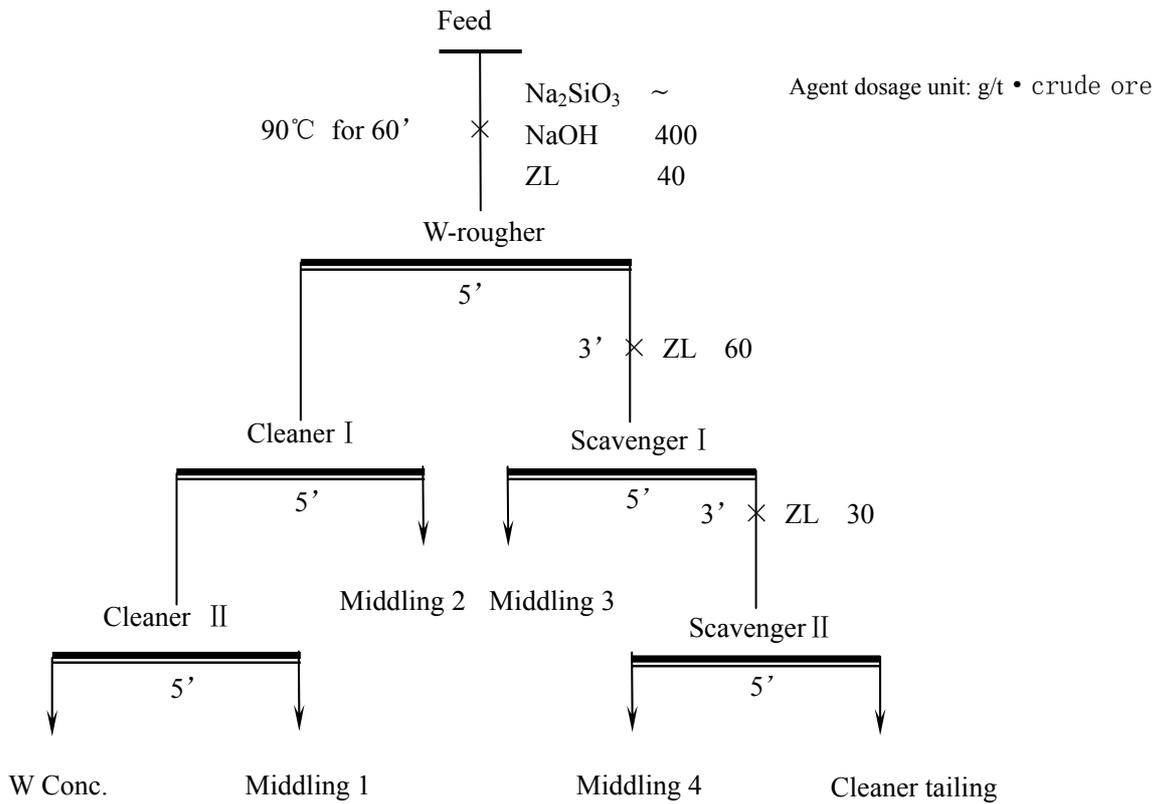


Figure 4-23 whole open circuit test flow-sheet of heated cleaning for W rougher conc.

Table 4-34 the results of whole open circuit tests of heated cleaning for C-Lens ore (Na_2SiO_3 4500 g/t)

Name of product	Yield %		Grade %		Recovery %	
	Indiv.	Acum.	Indiv.	Acum.	Indiv.	Acum.
Scheelite Conc.	15.20		69.81		85.46	
Middling 1	2.25	17.45	32.16	64.96	5.83	91.29
Middling 2	2.83	20.28	14.06	57.85	3.20	94.49
Middling 3	3.84	24.12	6.19	49.63	1.91	96.40
Middling 4	2.37	26.49	4.56	45.60	0.88	97.28
Cleaner tailing	73.51	100.00	0.46	12.42	2.72	100.00
Feed	100.00		12.42		100.00	

**Table 4-35 the results of whole open circuit tests of heated cleaning
for B-Lens ore (Na₂SiO₃ 3500 g/t)**

Name of product	Yield %		Grade %		Recovery %	
	Indiv.	Acum.	Indiv.	Acum.	Indiv.	Acum.
Scheelite Conc.	14.04		69.38		84.61	
Middling 1	1.58	15.62	28.79	65.27	3.95	88.57
Middling 2	2.88	18.50	14.23	57.33	3.56	92.13
Middling 3	6.25	24.75	6.75	44.56	3.66	95.79
Middling 4	4.02	28.77	4.26	38.93	1.49	97.28
Cleaner tailing	71.23	100.00	0.44	11.512	2.72	100.00
Feed	100.00		11.512		100.00	

4.6 Closed circuit test for heated cleaning process

The closed circuit tests of heated cleaning process were carried out for C-Lens ore and B-Lens ore in accordance with the flow-sheets shown in Figure 4-24 and Figure 4-25. Their quantitative flow-sheets are shown in Figure 4-26 and Figure 4-27 respectively and the results are presented in Table 4-36 together.

**Table 4-36 the results of closed circuit tests of heated cleaning
process of C-Lens ore and B-Lens ore**

Sample	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
C-Lens ore	W conc.	17.83	67.24	96.14
	Tailing 2	82.17	0.586	3.86
	Feed	100.00	12.47	100.00
B-Lens ore	W conc.	16.59	66.58	95.40
	Tailing 2	83.41	0.639	4.60
	Feed	100.00	11.58	100.00

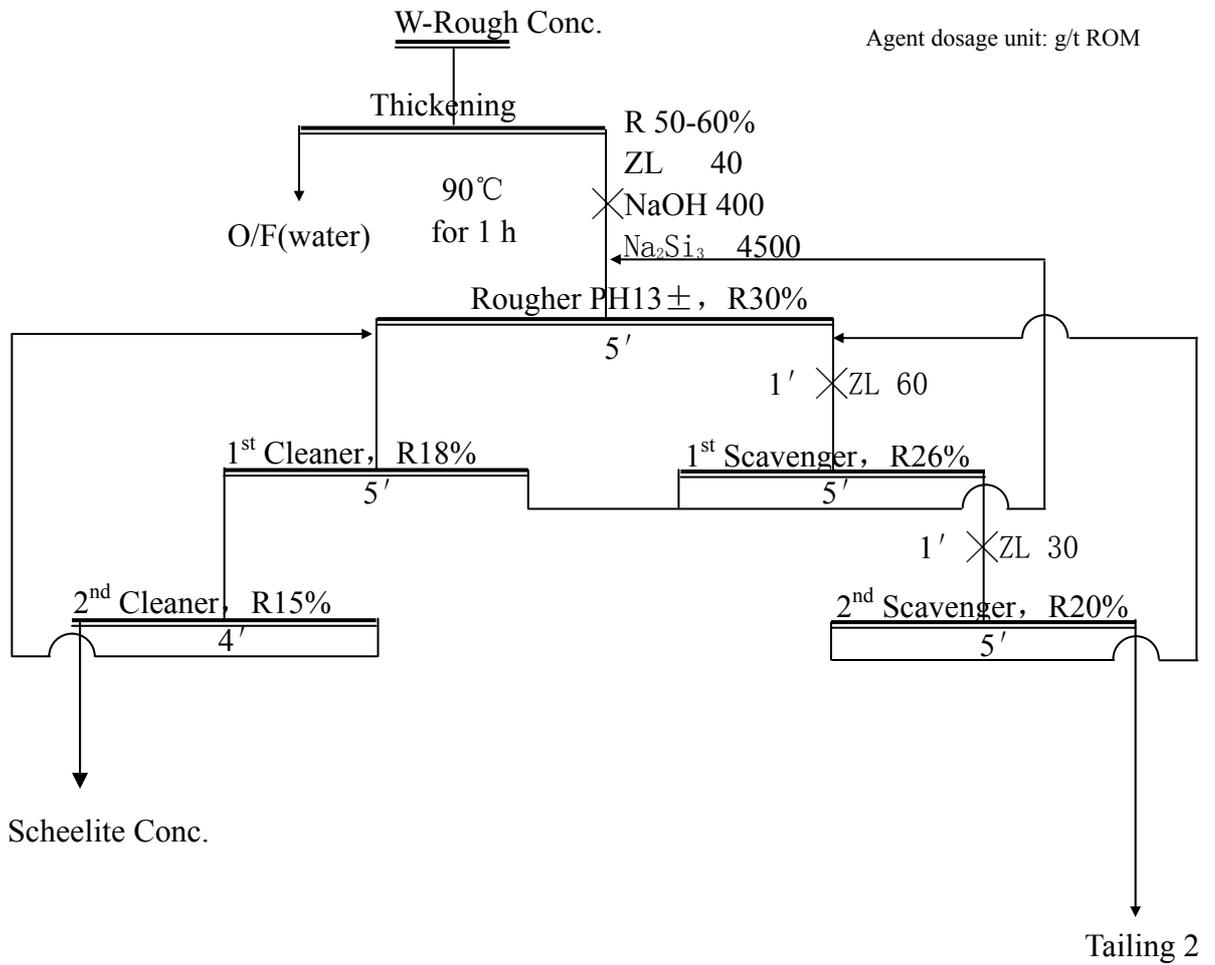


Fig.4-24 Closed circuit flow-sheet of heated cleaning of rough conc. for C-lens ore

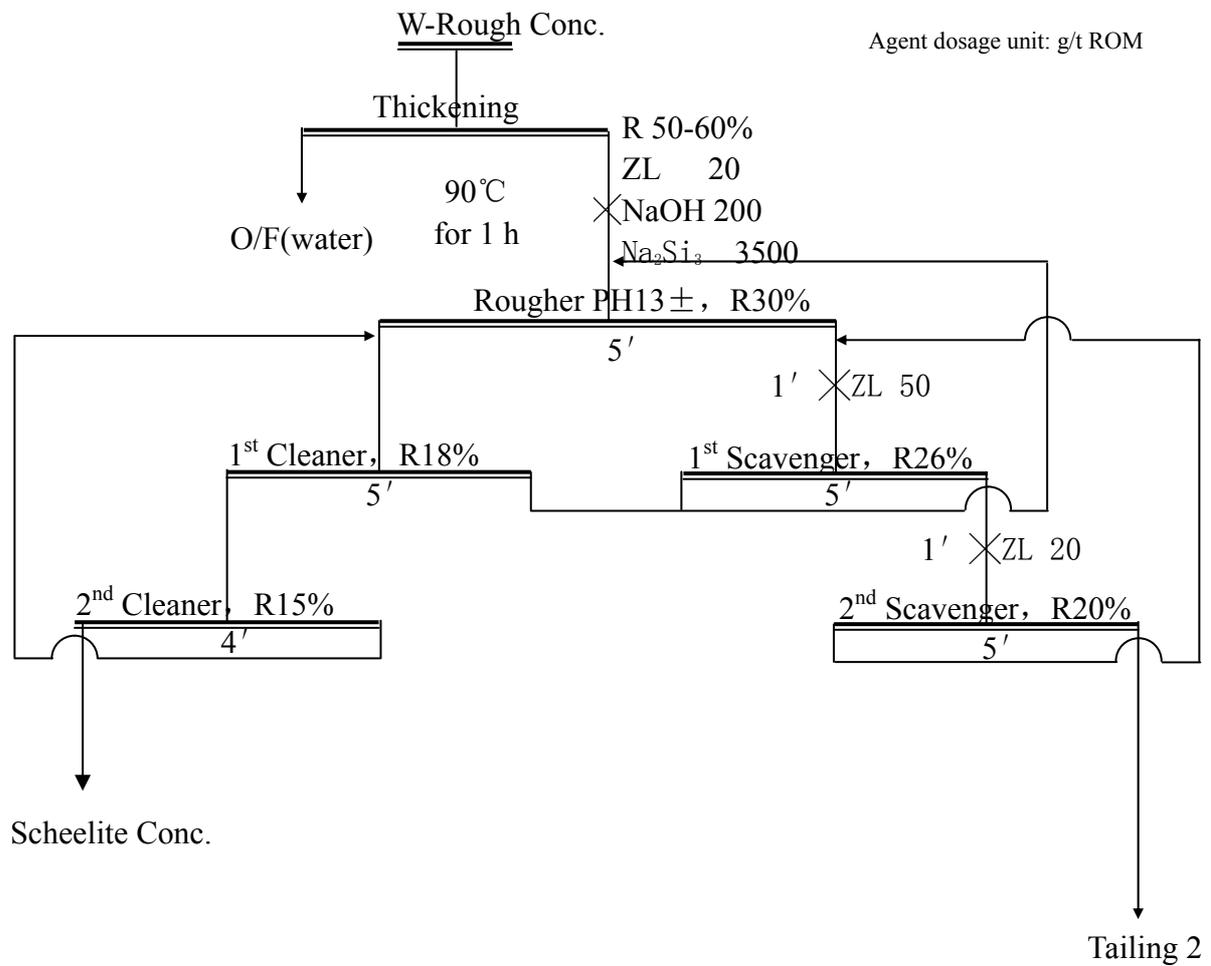


Fig.4-25 Closed circuit flow-sheet of heated cleaning of rough conc. for B-lens ore

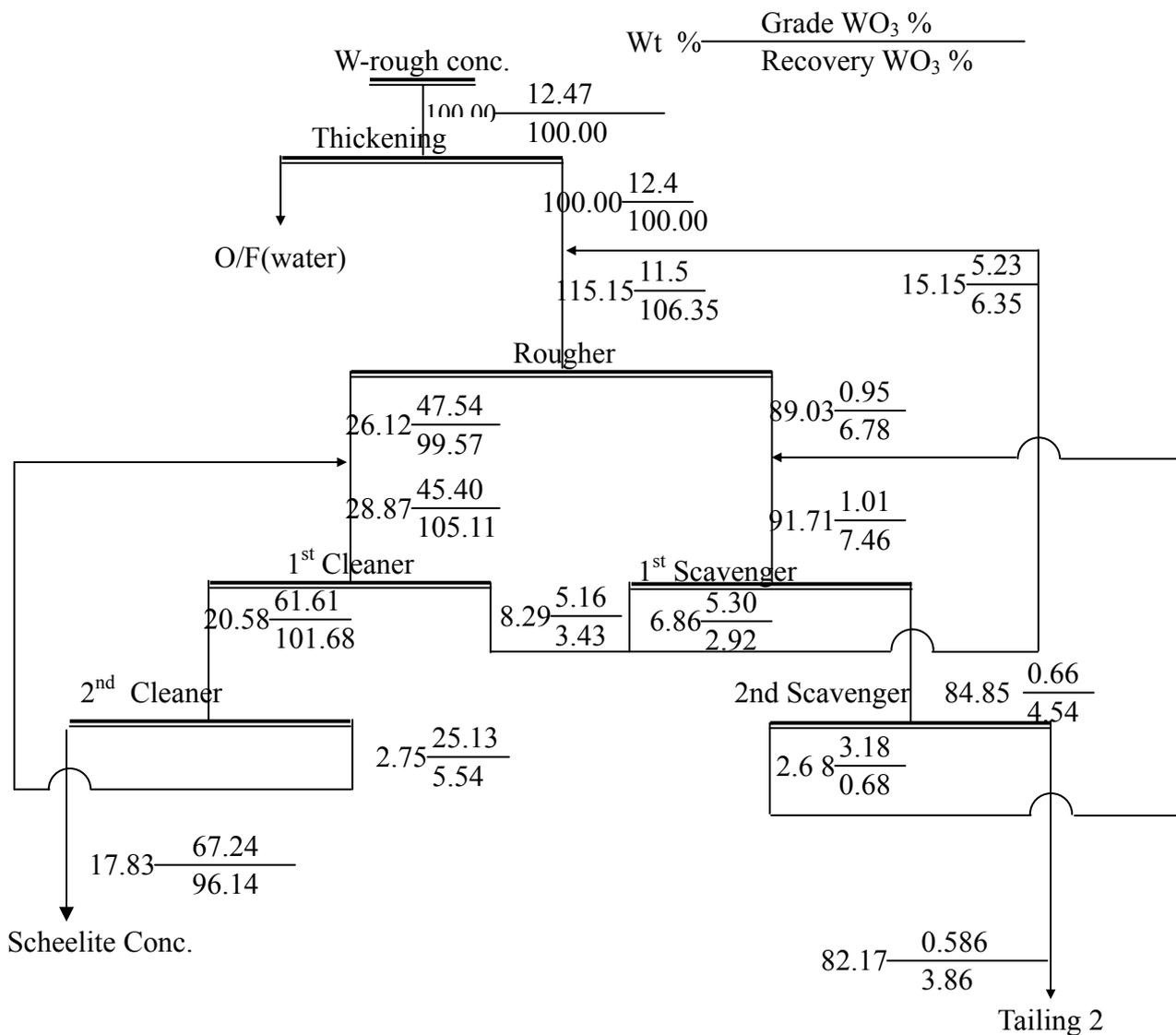


Fig. 4-26 Quantitative flow-sheet of closed circuit test of heated cleaning of W-rougher conc. for C-Lens ore

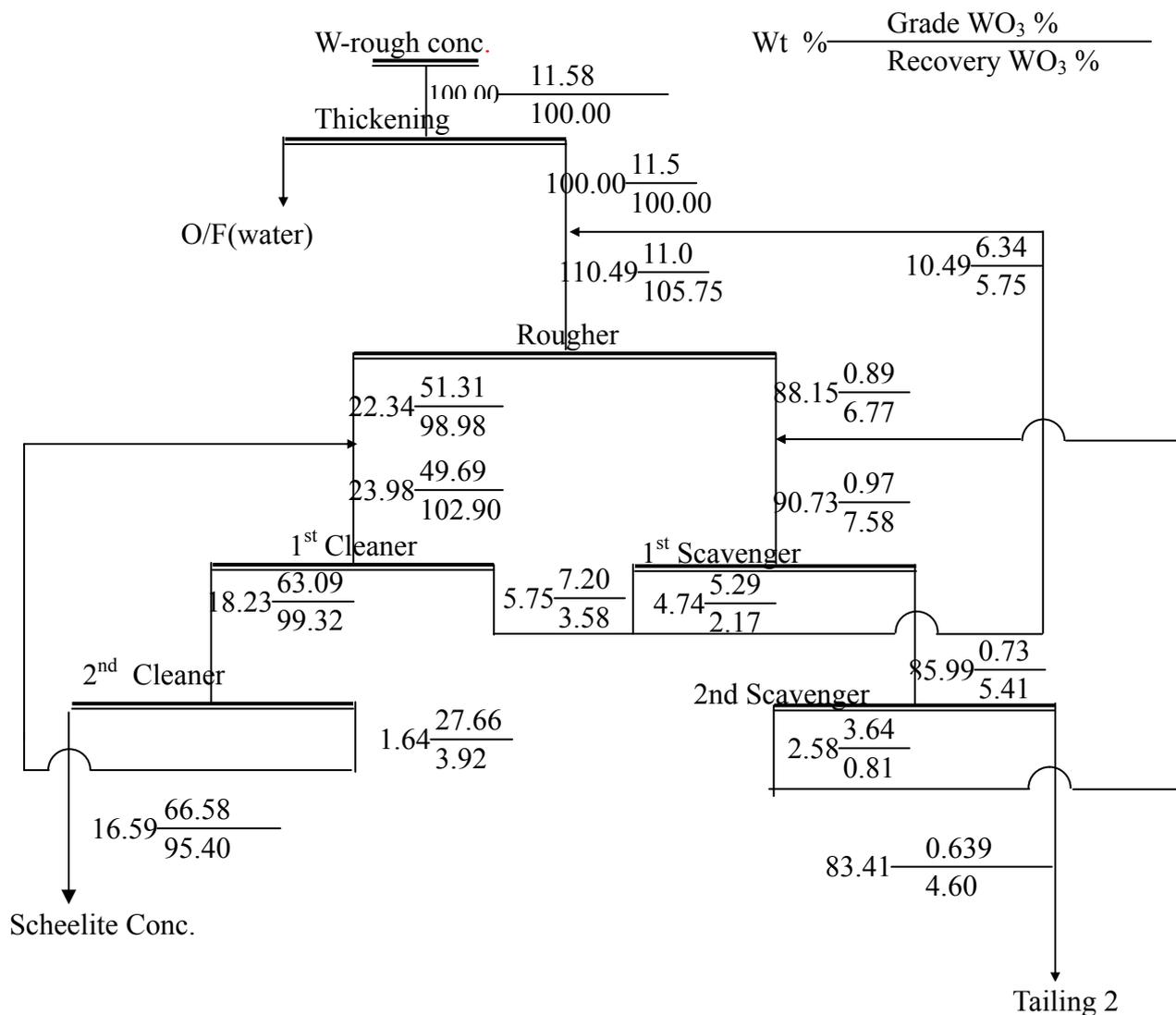


Fig.4-27 Quantitative flow-sheet of closed circuit test of heated cleaning of W-rougher conc. for B-Lens Ore

4.7 Cleaning test at ambient temperature for scheelite cleaning stage

4.7.1 Batch test of cleaning at ambient temperature

The batch tests of cleaning at ambient temperature were carried out for C-Lens ore and B-Lens ore under the corresponding technological conditions. The results are shown in Table 4-37.

Table 4-37 the results of batch tests of cleaning at ambient**temperature(30°C) in scheelite cleaning stage (30°C)**

Conditioning time and sample	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
1 h C-Lens ore	W rougher Conc.	22.96	49.76	89.61
	Tailing	77.04	1.72	10.39
	feed	100.00	12.75	100.00
2 h C-Lens ore	W rougher Conc.	21.85	52.88	90.90
	Tailing	78.15	1.48	9.10
	feed	100.00	12.71	100.00
1 h B-Lens ore	W rougher Conc.	23.04	45.14	88.94
	Tailing	76.96	1.68	11.06
	feed	100.00	11.693	100.00
2 h B-Lens ore	W rougher Conc.	21.22	49.21	89.65
	Tailing	78.78	1.53	10.35
	feed	100.00	11.648	100.00

4.7.2 Closed circuit test of cleaning at ambient temperature

The closed circuit tests of cleaning at ambient temperature were carried out for C-Lens ore and B-Lens ore in accordance with the flow-sheets shown in Figure 4-28 and Figure 4-29 and the results presented in Table 4-38 together. Compared with heated cleaning process, the results of cleaning at ambient temperature (2 hour's attrition) are a little poor, especially for B-Lens ore, their obvious difference can be seen, and the technological operation is easy to fluctuate.

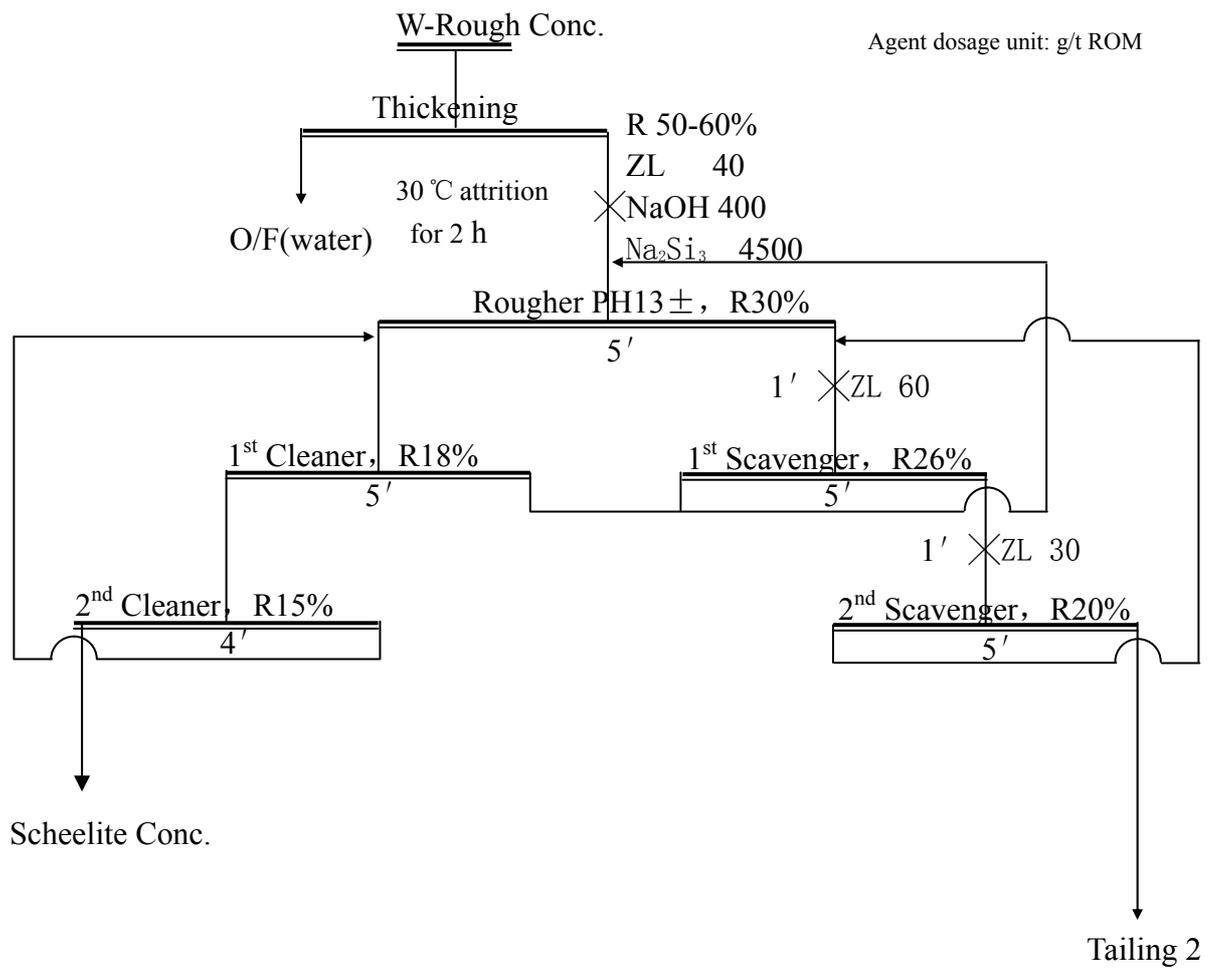


Fig.4-28 the flow-sheet of closed circuit tests of cleaning at ambient temperature of W rougher Conc. for C-lens ore

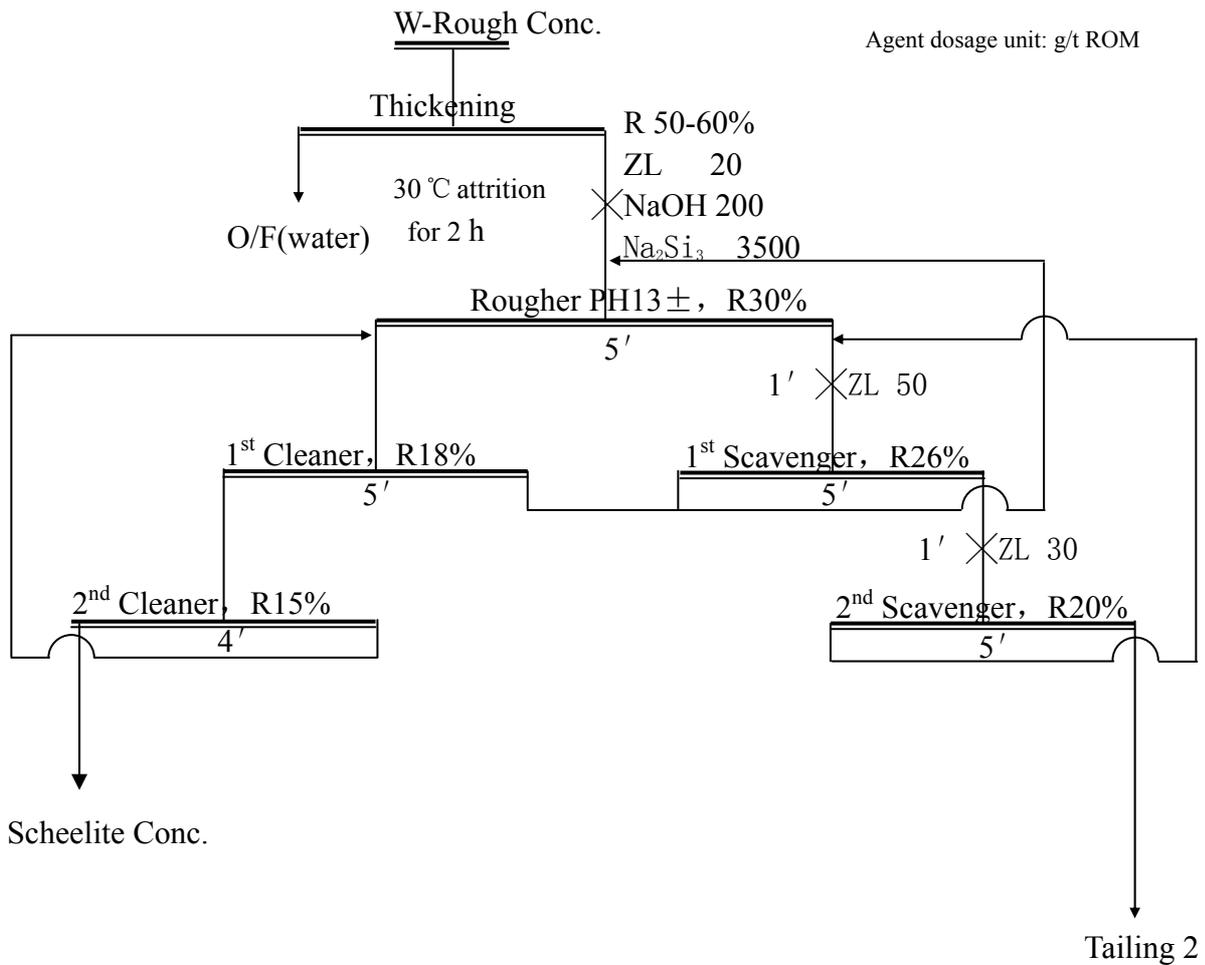


Fig.4-29 the flow-sheet of closed circuit tests of cleaning at ambient temperature of W rougher Conc. for B-lens ore

Table 4-38 the results of closed circuit tests of cleaning at ambient temperature for C-Lens ore and B-Lens ore

Sample	Name of Product	Yield %	Grade WO ₃ %	Recovery WO ₃ %
C-Lens ore	W conc.	17.94	65.48	94.20
	Tailing 2	82.06	0.88	5.80
	Feed	100.00	12.47	100.00
B-Lens ore	W conc.	17.35	62.39	93.47
	Tailing 2	82.65	0.915	6.53
	Feed	100.00	11.58	100.00

4.8 Whole flow-sheet closed circuit tests with heated cleaning technology

Whole flow-sheet closed circuit tests with heated cleaning technology were carried out respectively for B-Lens ore and C-Lens ore. The flow-sheets are shown in Figure 4-30 and Figure 4-31 while the results are presented in Table 4-39 together.

Table 4-39 the results of whole flow-sheet closed circuit tests with heated cleaning technology for C-Lens ore and B-Lens ore

Sample	Name of Product	Yield %		Grade %	Recovery %	
		For feed	For ROM		For feed	For ROM
B-Lens ore	W conc.	16.39	0.68	66.58	95.40	90.87
	Tailing 2	83.41	3.43	0.639	4.60	4.38
	Rougher Conc.	4.11	4.11	11.58	95.25	95.25
	Tailing 1	95.89	95.89	0.025	4.75	4.75
	Feed	100.00	100.00	0.50	100.00	100.00
C-Lens ore	W conc.	17.83	1.82	67.24	96.14	91.16
	Tailing 2	82.17	8.40	0.586	3.86	3.66
	Rougher Conc.	10.22	10.22	12.47	94.82	94.82
	Tailing 1	89.78	89.78	0.077	5.18	5.18
	Feed	100.00	100.00	1.344	100.00	100.00

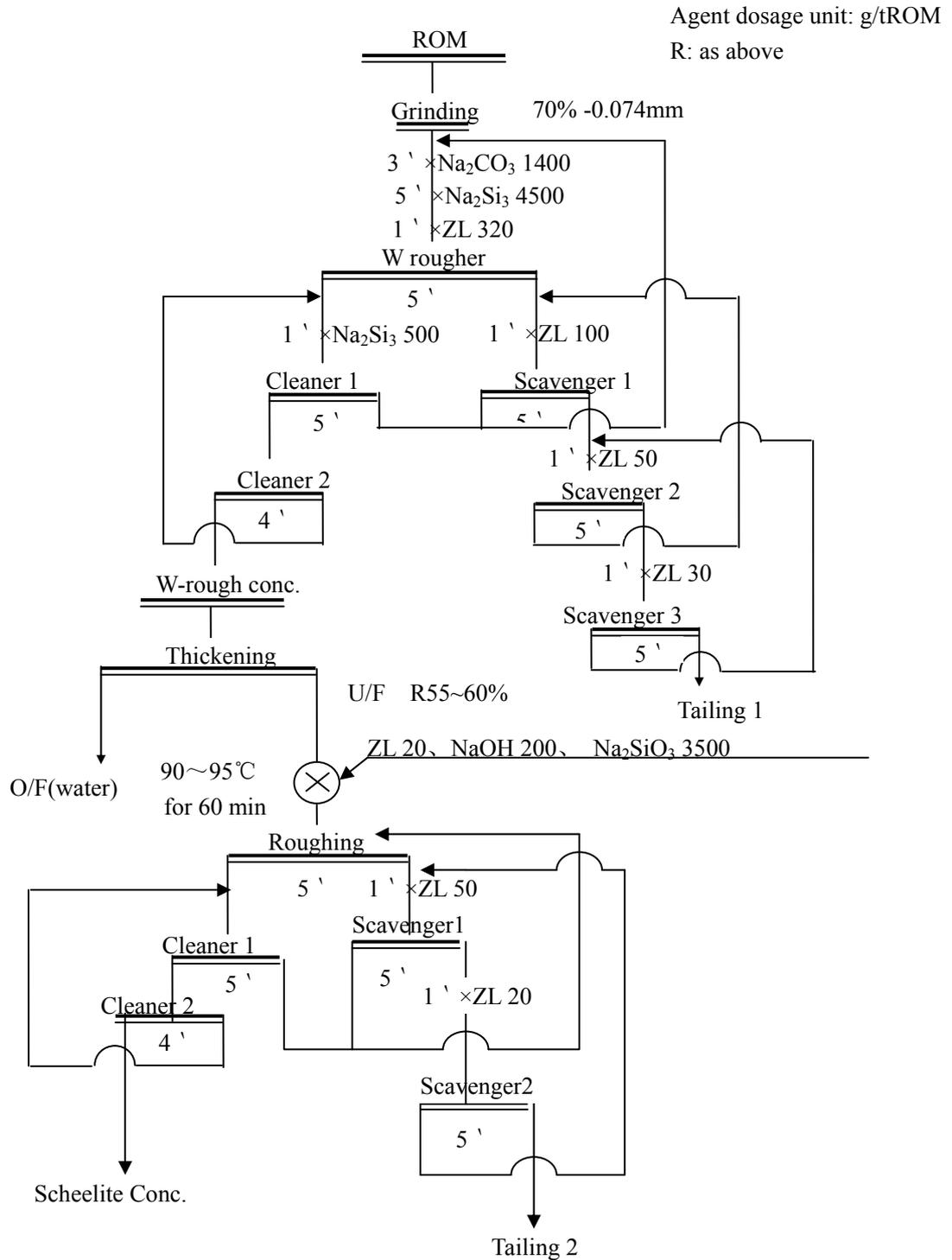


Fig.4-30 Whole Ore Flotation Flow-sheet for B-Lens Ore

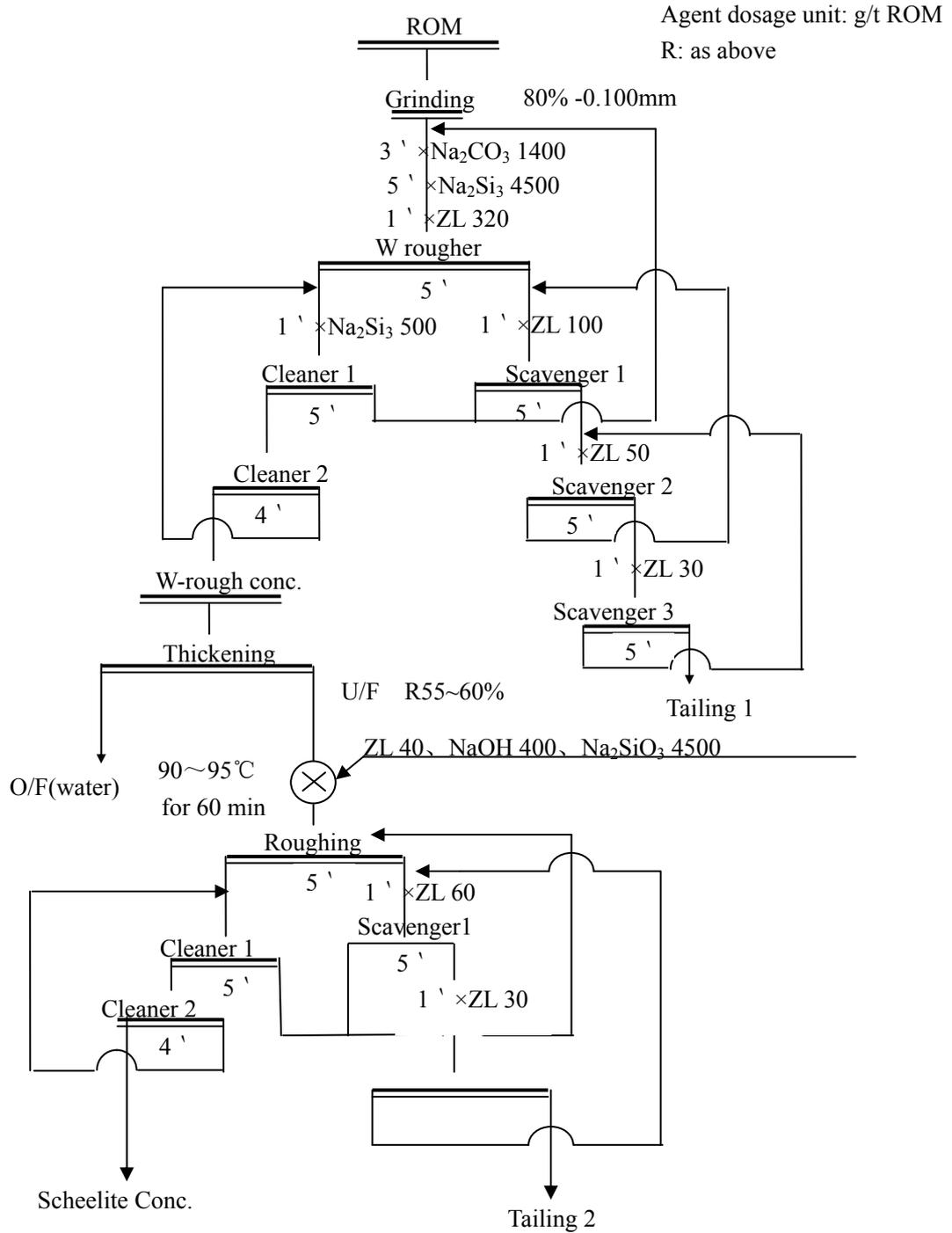


Fig. 4-31 Whole Ore Flotation Flow-sheet for C-Lens Ore

5 Treatment and recycling of tailings water

Tailing slurry contains a large amount of sodium silicate, the coarse-grained minerals in the tailings slurry sink basically in 1 hour, but sinking of the micro-fine minerals is very difficult, even if placed for 3 or 4 days, the tailings water is still unclear. If the tailing water is treated by suitable amount of lime (4.8kg /t.), it can be clarified, but its pH value is still very high (pH value 11-13). If amount of sulfuric acid (1.4 - 2 kg / t.) is added, the pH value of water will go down to 8.0-9.0. Tailings water is colorless and odorless after treatment, and all detecting indices are lower than the national emission standards, so it could be discharged directly and the clear tailing water could also be recycled. In addition, further test results show that though containing a large number of water glass and reagents, the muddy water obtained after coarse-grained minerals' sinking can also be used for recycling.

5.1. Experiment on tailing slurry settling

The slurry can be settled basically in 0.5 - 1 hours by adding lime of 1200 g / m³ to the tailings slurry, tailing water pH value is 11 ~ 13 or so. Figure 5-1 is setting curve for the tailing slurry.

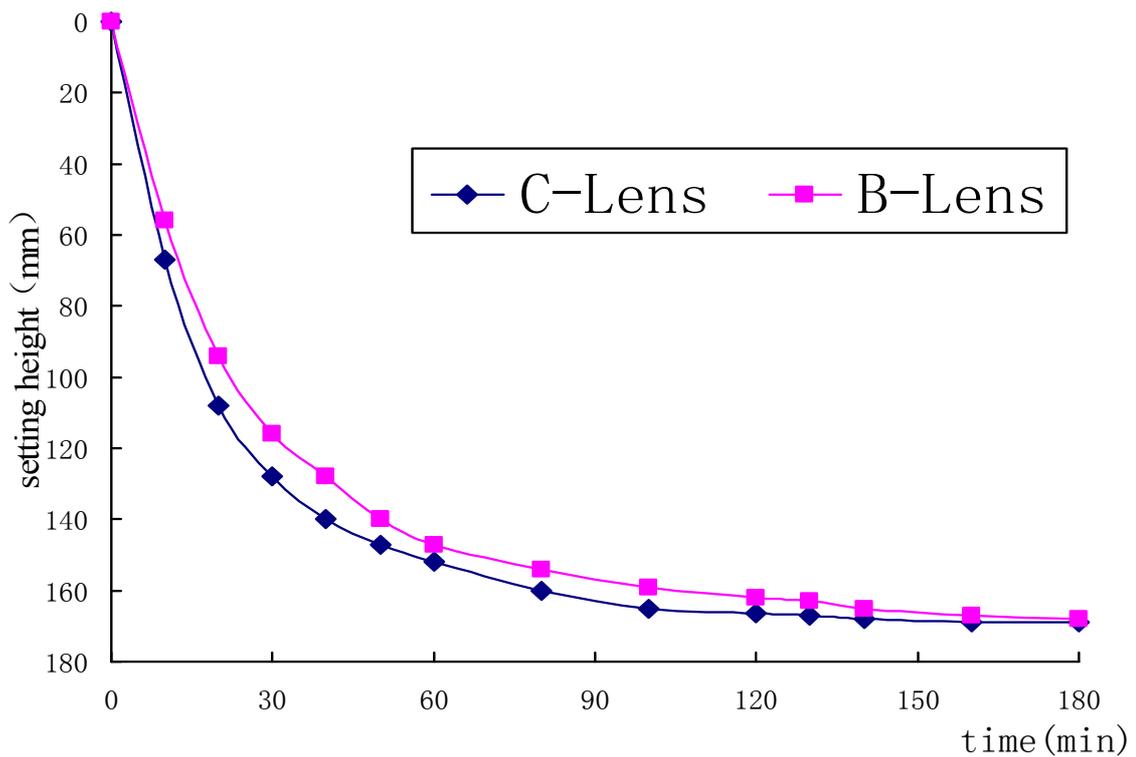


Figure5-1 Setting curve of tailing slurry with lime of 1200g/m

5.2 Water quality detection of floatation tailing slurry

If sulfuric acid 300 (C samples) -500 (B samples) g/m^3 is added into clear tailing water treated already by addition of lime of 1200 grams/m^3 , its pH value will declined to below 9 . The detection results of the neutralized tailing water are shown in Table 5-1.

**Table 5-1 Results of clear tailing water quality analysis after its
treatment**

Serials number	Item or related substance	National relevant standard mg/l	Clear tailing water after treated mg/l	Clear tailing water after treated mg/l
			C-Lens ore	B-Lens ore
1	pH	6~9	8.7	8.3
2	Suspensions	250	74	65
3	Chemical Oxygen Demand (COD)	100	67	78
4	Lead and its compounds	1 (counted by Pb)	0.035	0.028
5	Zinc and its compounds	4 (counted by Zn)	0.08	0.06
6	Copper and its compounds	1 (counted by Cu)	0.07	0.05
7	Arsenic and its compounds	0.5 (counted by As)	0.006	0.005
8	Sulfide	1	0.54	0.39
9	Inorganic compounds of fluorine	10	1.1	0.9

After treatment, tailings water is colorless, odorless and all detection indices are lower than the national emission standards, it could be allowed for direct discharge.

In addition, the tests show that if all tailings slurry is thickened by thickener firstly, its overflow is untreated muddy water (which can be directly recycled in flotation), and the underflow is the pulp with density 60%. This kind of the pulp can be treated by a small amount of lime and sulfuric acid (the required amount of lime and sulfuric acid is only about

30% of the original), the treated overflow can be directly discharged

5.3 Flotation test of recycling tailing water

5.3.1. Type of recycling water:

C-1[#]: total tailing pulp is treated only by suitable amount of lime (4.8kg/t.ROM, pulp is clear) ----C-Lens ore

C-2[#]: C-1[#] is treated by sulfuric acid further (2kg/t.ROM, pulp is clear and its pH value is 8.5-9) ----C-Lens ore

C-3[#]: muddy water (upper portion of total tailing pulp after natural settlement without any treatment----C-Lens ore

B-1[#]: total tailing pulp is treated only by suitable amount of lime (4.8kg/t.ROM, pulp is clear) ----B-Lens ore

B-2[#]: B-1[#] is treated by sulfuric acid further (1.4kg/t.ROM, pulp is clear and its pH value is 8.5-9) ----B-Lens ore

B-3[#]: muddy water (upper portion of total tailing pulp after natural settlement without any treatment----B-Lens ore

5.3.2. Test flow-sheet and results

Obviously, the flotation conditions should be adjusted accordingly when recycled water is used. The results showed that all of the tailings slurry clarified by the treatment of appropriate amount of lime and sulfuric acid and untreated slurry water (the upper part of all the tailings slurry after natural settling) may be recycled and the results are also basically good.

5.3.2.1. Test of recycled water for C-Lens ore

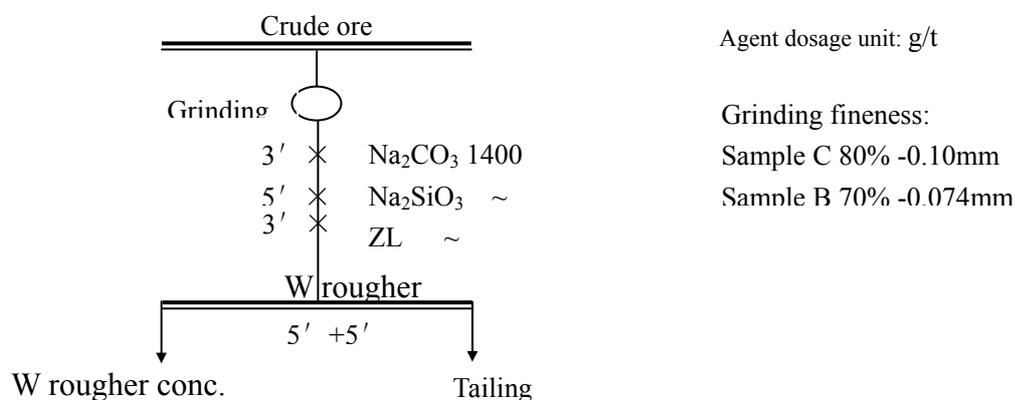


Fig5-2 the flow-sheet of test of recycled water for C-Lens ore

Table 5-2 test result of recycled water for C-Lens ore

Flotation Conditions	Name of products	Yield/%	Grade, WO ₃ %	Distribution WO ₃ %
Na ₂ SiO ₃ 4500 g/t ZL 320 + 160 g/t Tap water	Crude conc.	12.54	10.12	95.52
	Tailings	87.46	0.068	4.48
	Head ore	100.00	1.329	100.00
Na ₂ SiO ₃ 3000 g/t ZL 320 + 160 g/t C-1 [#]	Crude conc.	12.12	10.23	94.00
	Tailings	87.88	0.09	6.00
	Head ore	100.00	1.319	100.00
Na ₂ SiO ₃ 3800 g/t ZL 320 + 160 g/t C-2 [#]	Crude conc.	16.30	7.89	95.88
	Tailings	83.70	0.066	4.12
	Head ore	100.00	1.341	100.00
Na ₂ SiO ₃ 4500 g/t ZL 280+ 120 g/t C-3 [#]	Crude conc.	15.20	8.06	94.75
	Tailings	84.80	0.08	5.25
	Head ore	100.00	1.293	100.00

5.3.2.2 Test of recycled water for B-Lens ore

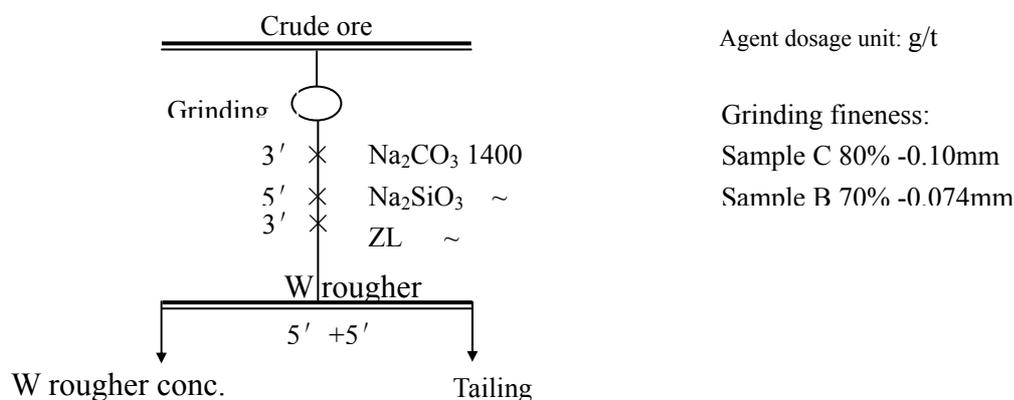


Fig5-3 the flow-sheet of test of recycled water for B-Lens ore

Table 5-3 test result of recycled water for B-Lens ore

Flotation Conditions	Name of products	Yield/%	Grade/WO ₃ %	Distribution WO ₃ %
Na ₂ SiO ₃ 4500 g/t ZL 320 + 160 g/t Tap water	Crude conc.	8.45	5.36	92.52
	Tailings	91.55	0.04	7.48
	Feed	100.00	0.490	100.00
Na ₂ SiO ₃ 3800 g/t ZL 320 + 160 g/t B-2 [#]	Crude conc.	9.47	4.87	94.44
	Tailings	90.53	0.03	5.56
	Feed	100.00	0.488	100.00
Na ₂ SiO ₃ 3800 g/t ZL 320 + 160 g/t B-3 [#]	Crude conc.	8.70	5.25	92.43
	Tailings	91.30	0.041	7.57
	Feed	100.00	0.494	100.00

6 Dosage and cost estimates of dressing agents

The dosage and cost estimates of dressing agents are shown in Table 6-1, which were calculated by the agent dosage of C-Lens ore. The agent dosage of B-Lens ore is basically the same with that of C-Lens ore.

Table 6-1 the dosage and cost estimates of dressing agents

Name of Agent	Dosage (g/t)	Price (Yuan/kg)	Cost (Yuan/t)
sodium carbonate	1400	1.30	1.82
Sodium Silicate	9500	0.70	6.65
ZL	630	12.0	7.56
Sulfuric Acid 1	2000	0.5	1.00
Sulfuric Acid 2**	600	0.5	0.30
Lime 1	4800	0.30	1.20
Lime 2**	1440	0.30	0.43
Total 1			18.23
Total 2**			16.76

** indicates the data obtained by treating the underflow (the pulp density is 60%) of thickener which is adopted to thicken all tailing slurry firstly.

7. Product detection

7.1 Scheelite concentrate analysis

The scheelite concentrate grade and impurity analysis are shown in Table 7-1. The size distribution of scheelite concentrates is presented in Table 7-1.1.

Table 7-1 the scheelite concentrate grade and impurity analysis

Element		WO ₃	Sn	As	S	Mo	Cu	CaF ₂	CaCO ₃	SiO ₂	P
B-Lens ore	Content %	66.81	0.15	0.008	0.35	1.05	0.12	5.25	1.49	3.42	0.048
C-Lens ore	Content %	67.32	0.16	0.009	0.55	1.14	0.11	6.42	2.51	3.25	0.053

Table 7-1.1 the size distribution of scheelite concentrate for C-Lens ore and B-Lens ore

Size mm	C-Lens ore		B-Lens ore	
	Indiv. %	Acum. %	Indiv. %	Acum. %
+0.10	9.54		4.16	
-0.10+0.074	10.77	20.31	10.50	14.66
-0.074+0.050	16.50	36.81	24.32	38.98
-0.050+0.043	16.34	53.15	28.82	67.80
-0.043+0.030	7.97	61.12	10.99	78.79
-0.030+0.020	13.78	74.90	12.90	91.69
-0.020+0.010	18.05	92.95	7.59	99.26
-0.010	7.05	100.00	0.74	100.00
Total	100.00		100.00	

7.2 The size distribution of grinding products

Table 7-2 and Table 7-3 are respectively the size distribution of C-Lens ore with grinding fineness P80-0.10mm and B-Lens ore with grinding fineness 70%-0.074mm.

Table 7-2 the size distribution of C-Lens ore with grinding fineness P80-0.10mm

Size mm	Yield %		Grade WO ₃ %		Recovery WO ₃ %	
	Indiv.	Acum.	Indiv.	Acum.	Indiv.	Acum.
+0.15	5.57		0.39		1.59	
-0.15+0.12	6.54	12.11	0.82	0.62	3.94	5.53
-0.12+0.10	6.68	18.78	1.07	0.78	5.25	10.78
-0.10+0.074	17.49	36.28	1.34	1.05	17.20	27.98
-0.074+0.043	12.39	48.67	1.61	1.19	14.64	42.62
-0.043+0.03	26.59	75.26	1.94	1.46	37.86	80.49
-0.03+0.02	10.58	85.84	0.89	1.39	6.91	87.40
-0.02+0.01	7.78	93.62	1.28	1.38	7.31	94.71
-0.01	6.38	100.00	1.13	1.362	5.29	100.00
Total	100.00		1.362		100.00	

Table 7-3 the size distribution of B-Lens ore with grinding fineness

70%-0.074mm.

Size mm	Yield %		Grade WO ₃ %		Recovery WO ₃ %	
	Indiv.	Acum.	Indiv.	Acum.	Indiv.	Acum.
+0.15	3.10		0.17		1.04	
-0.15+0.12	4.08	7.18	0.34	0.27	2.73	3.77
-0.12+0.10	4.65	11.83	0.47	0.35	4.31	8.08
-0.10+0.074	17.85	29.68	0.48	0.43	16.89	24.97
-0.074+0.043	12.65	42.33	0.55	0.46	13.72	38.69
-0.043+0.03	26.68	69.01	0.62	0.52	32.61	71.30
-0.03+0.02	12.96	81.97	0.54	0.53	13.80	85.10
-0.02+0.01	9.25	91.22	0.39	0.51	7.11	92.21
-0.01	8.78	100.00	0.45	0.507	7.79	100.00
Total	100.00		0.507		100.00	

7.3 The size distribution of scheelite rougher tailings

Table 7-4 the size distribution of scheelite rougher tailing for

B-Lens ore

Size mm	Yield %	Grade WO ₃ %	Recovery WO ₃ %
+0.12	8.48	0.023	7.05
-0.12+0.10	5.22	0.022	4.15
-0.10+0.074	14.29	0.012	6.20
-0.074+0.043	13.35	0.013	6.27
-0.043	58.66	0.036	76.33
Total	100.00	0.0277	100.00

**Table 7-5 the size distribution of scheelite rougher tailing for
C-Lens ore**

Size mm	Yield %	Grade WO ₃ %	Recovery WO ₃ %
+0.12	12.40	0.084	13.63
-0.12+0.10	8.90	0.072	8.38
-0.10+0.074	12.98	0.048	8.16
-0.074+0.043	12.80	0.053	8.88
-0.043	52.92	0.088	60.95
Total	100.00	0.0764	100.00

According to the above two Tables, more than 60% of scheelite is lost in the size of -0.043mm.

7.4 The size distribution of tailing from heated cleaning process

**Table 7-6 the size distribution of tailing from heated cleaning for
C-Lens ore**

Size mm	Yield %	Grade WO ₃ %	Recovery WO ₃ %
+0.074	11.17	0.44	8.89
-0.074+0.043	17.90	0.25	8.10
-0.043+0.030	31.16	0.41	23.11
-0.030+0.020	15.62	0.38	10.74
-0.020+0.010	13.91	0.58	14.63
-0.010	10.21	1.87	34.53
Total	100.00	0.553	100.00

According to Table 7-6, more than 83% of scheelite is lost in the size of -0.043mm while about 50% lost in the size of -0.020mm for C-Lens ore.

**Table 7-7 the size distribution of tailing from heated cleaning for
C-Lens ore**

Size mm	Yield %	Grade WO ₃ %	Recovery WO ₃ %
+0.074	1.69	0.69	1.90
-0.074+0.043	12.16	0.24	4.79
-0.043+0.030	33.51	0.35	19.24
-0.030+0.020	13.87	0.29	6.60
-0.020+0.010	18.29	0.49	14.71
-0.010	20.48	1.57	52.76
Total	100.00	0.61	100.00

According to Table 7-7, more than 93% of scheelite is lost in the size of -0.043mm while about 67% lost in the size of -0.020mm for B-Lens ore.

8. Conclusion

1) The scheelite ore (C-Lens ore and B-Lens ore) from Australia's King Island contains kinds of minerals with the main valuable mineral being scheelite which is evenly disseminated in the form of medium-fine grain in B-Lens ore while presents uneven dissemination in the form of medium-coarse grain in C-Lens ore. The secondary valuable minerals are pyrite, pyrrhotite, chalcopyrite and molybdenite, etc. with very low grade. The molybdenum of ore primarily is hosted in the scheelite, secondly exists in the form of molybdenite. The molybdenum contained in the scheelite accounts for 65% of the total molybdenum in the crude ore, while the molybdenum existing in the form of molybdenite only occupies 30%. So it is of little value to recover the molybdenum in the ore. The gangue minerals are dominated by andradite, with diopside, grossular, calcite, quartz, feldspar, fluorite, tremolite, etc. next in abundance.

2) The technological process of scheelite heated cleaning was compared with cleaning at ambient temperature by long time strong attrition of pulp of rougher concentrate for the provided C-Lens ore and B-Lens ore. For the C-Lens ore, when crude ore assaying about WO_3 1.344% is ground to 80%-0.10mm, the scheelite concentrate with grade WO_3 67.24% and recovery 91.16% can be obtained by adopting heated cleaning process; and for B-Lens ore, when the crude ore assaying about WO_3 0.50% is ground to 70%-0.074mm, the scheelite concentrate

with grade WO_3 66.58% and recovery 90.87% can be achieved by adopting heated cleaning process. The contract requirements are fully met even exceeded. The heated cleaning process is recommended as a basis for the feasibility study and plant design because of its higher index and stability in operation.

3) For the technological process adopted in this study, the scheelite collector ZL developed by GZRINM with strong collecting ability and good selectivity was used in the scheelite roughing stage, while an efficient combined regulator (sodium silicate and caustic soda) and addition of collector ZL is applied in the heated cleaning process, which strengthening the inhibition on gangue minerals bearing calcium and the activation on scheelite. The technological process is stable with simple reagent system and is easy to be realized in production.

4) Although the tailings water contains much water glass, if treated by appropriate amount lime (4.8kg / t • rom), the tailings water is clarified quickly, and then appropriate amount of sulfuric acid is added into, the tailings water could reach the Chinese standards for discharge. Preliminary tests show that this treated water could be recycled to tungsten flotation system with slight impact on tungsten flotation performance. In addition, the tests show that if all tailings slurry is thickened by thickener firstly, its overflow is untreated mud water (which can be directly recycled in flotation), and the underflow is the pulp with

density 60%. This kind of the pulp can be treated by a small amount of lime and sulfuric acid (the required amount of lime and sulfuric acid is only about 30% of the original), the treated overflow can be directly discharged or recycled to flow-sheet after clarification

5) The tailing of heated cleaning contains about 0.5-0.63% WO_3 , which can be considered to be comprehensively recovered further using appropriate gravity equipment.

6) The water quality in different places has a great impact on scheelite flotation when using fatty acids as collector, so the verification tests should be carry out to confirm whether the local water quality and the corresponding recycled water are suitable for the ore' processing or not.

7) The scale-up continuous test is advised to carry out in order to examine the adaptability of the technological process and reagent regime of scheelite flotation under the condition of pulp continuous-flow so that more complete information for plant design and trial production could be provided.

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