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Workshop on Mineral Processing
of Lead and Zinc Sulphide Ores
for Selected Countries

MINERAL PROCESSING TECHNIQUES PRESENT STATUS & PROSPECT OF LEAD-ZINC SULPHIDE ORE IN CHINA

(DRAFT)

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I. General situation of lead-zinc ores in China

China's orebeds can be divided into six types, skarn, metamorphic rock, carbonatite, extrusive-sedimentary rock, comprehensive rock and weathered residual rocks. The mines under production are mainly of carbonatite and comprehensive rock type, which account for over 70%. Mines of skarn and weathered residual rock type only accounts for less than 10%. On the basis of oxidation degree, ores in China's lead-zinc orebeds can be divided into three basic types, that is, sulfide ores, mixed ores and oxide ores. Zinc is the chief constituent in the resource. The grade ratio of lead to zinc is 1:2.45, while the total ratio in the world is 1:1 [8,10,3].

Lead-zinc resources are very abundant in China, distributing in southwest, northwest and central south part of the country. As viewed from the production of lead and zinc, their utilization degree is not high. Since China's production of lead and zinc only accounts for 3.3% and 3.9%, respectively, the potential of developing China's lead and zinc production is enormous. At present, there are nearly 100 lead-zinc mines in the country. Among them, 9 are key mines. Up till now, Guangdong Fankou Lead-Zinc Mine has still been the largest lead-zinc production mine in China. Undergroud mining is applied in all the nine key mines, only some small mines are of open-pit mining, the mining amount of which only accounts for 5% of the total mining amount of all lead-zinc mines.

Changba Lead-Zinc Mine Area and Xitieshan Lead-Zinc Mine Area are the main lead and zinc resources in the northwest area. The resource of lead and zinc in Changba belongs to the large-scale intermediate-low temperatûre hydrothermal filling-replacement orebed associated with minor-dispersed metals and noble metals like Ag, Cd, Tl, Ga, Ge, In, etc. The main valuable minerals in the sulfide ores are lead sulfide, zinc sulfide, pyrite, etc., and the main valuable minerals in the oxide ores are smithsonite, calamine, cerusite and so on. In Xitieshan Lead-Zinc Mine of Qinghai Province, according to the natural ore type, there exist mainly sulfide and oxide ores, while mixed ores are not developed. Most of the oxide ores are of sulfate minerals, assuming earthy and powdery, the oxidation rate of which is rather high, The sulfide ores assume compact-massive, disseminated and veinlet forms. The mineral composition consist of galena, sphalerite, pyrite, pyrrhotite, chalcopyrite, white pyrite, etc., and the gangue minerals are quartz, sericite, calcite, chlorite and gypsum.

Lead and zinc resources in the southwest part are rather concentrated, especially in Yunnan and Sichuan Provinces. Lanping Mine in Yunnan is a huge mine area rarely seen in the world, the reserve of which is only next to the lead-zinc mine area in the southeast part of Missouri State, USA (grade 4—6%), Marsal Mine Area in Australia (grade 14.1%) and Shalywen Lead-Zinc Mine Area in Canada (grade 11.9%), ranking the fourth place in the world. The average grade of lead plus zinc in Lanping Mine is 9.38%. Half of the metal amount comes from oxide ores. Besides Pb and Zn, it is also associated with various valuable elements like Ag, Cd, S, In, Tl, Ba, Sr, etc. According to the preliminary estimation, on the basis of the recovery value of every metal in the lead-zinc mine, the value per ton lead-zinc ore is equivalent to 2 to 6 times that of the common copper ores.

Huili Lead Mine Area in Sichuan Province contains 80% of sulfide ores. The upper part of the orebody is deeply oxidized. the lower the part, the lower the oxidation rate is. The main metal minerals in the sulfide ores are sphalerite, galenaand small amount of pyrite, chalcopyrite, cadmium blende, aphthonite, argentite, dark red silver ore, etc. The characteristics of the minerals' intergrowth lie in that part of the metal sulfides are compacted with each other in super fine particles. For instance, 1/3—1/2 of galena curstals of 5-25μm are interlaid in sphalerite; most of antimony-silver fahlore is interlaid in galena and sphalerite in the particle size of 2—26μm; chalcopyrite is mostly disseminated in sphalerite in the particle size of 5—10μm. All this makes the floatability of sulfides close to each other and causes difficulty in their separation. Fankou Mine is a typical lead-zinc resource in central south area. It is characterized not only by its large reserve but by its high grade. the average grade of Pb+Zn reaches 16% (Pb grade>5.0%, Zn grade>10.0%).

II. Mineral processing techniques for lead-zinc sulfide ores

Lead-zinc ores mined in China are mostly of carbonatite type. The main metal minerals are galena, sphalerite, pyrite and chalcopyrite; the gangue minerals are calcite, quartz, muscovite, mica, chlorite, garnet, feldspar, etc.; the associated elements include Ag, Cd, In, Tl, Ge, etc. Most of the carbonatite type lead-zinc ores occur in the intermediate or intermediate-low temperature hydrothermal crevasse filling replacement orebeds. their structure are mostly in campact-massive, veinlet and disseminated forms followed by banded, network vein, starry, breccia forms, etc. Generally, the intergrowth between the valuable and gangue minerals is rather simple but the interlaying between valuable minerals is very complicated. the interlaying or dissemination particle size occurs heterogeneous or extremely heterogeneous.

The largest particle size of lead-zinc minerals can reach 1—20mm and the smallest 0.004—0.01mm.

Selection of mineral procssing flowsheets for Pb-Zn sulfide ores

1. Selection of Grinding Flowsheets

The selection of grinding flowsheets is determined by the intergrowth relationship and disseminated particle sizes between valuable minerals containing Pb, Zn, S and between these valuable minerals and gangues.

(1) One-stage grinding flowsheet

Generally, one-stage grinding flowsheet will be applied when the intergrowth relationship between the metal minerals and gangue minerals in Pb-Zn sulfide orebeds is not complicated; the disseminated particle size of the valuable minerals is comparatively homogeneous or these minerals assume heterogeneous interlaying in Coarse particles. Take Huangshaping Lead-Zinc Mine as example, the ore structure is complicated with compact-massive, disseminated, breccia, veinlet and banded forms, but mostly in the compact form. Besides, the interlaid particle sizes of galena, pyrite and sphalerite are rather coarse, generally ranging from 0.2—0.1mm. So one-stage grinding flowsheet is used there and the run-of-mine is ground to 60—65% of —200 mesh.

(2) Multi-stage grinding flowsheet

When the intergrowth relationship between valuable minerals and gangues in the Pb-Zn sulfide orebed is complicated and valuable minerals assúme heterogeneous interlaying and distribution, the multi-stage grinding flowsheet is recommended. In this way, not only the coarse interlayed and distributed valuable minerals can be sufficiently liberated into single constituents but it will not be overground also. In addition, multi-stage grinding can make fine or superfine particle interlaid and distributed valuable minerals sufficiently liberated into single constituents, which is beneficial to the recovery of valuable minerals. Usually the multi-stage grinding is applied in way of tailings regrinding and rough concentrates regrinding. As for Pb-Zn sulfide ores, the middlings regrinding flowsheet is seldom applied. So here we will only give some examples on tailings regrinding and rough concentrate regrinding.

Example 1: Ores from Shuikoushan Lead-Zinc Mine belong to the intermediate temperature hydrothermal replacement orebed. Most of them are of compact-massive form but a small part of them are of veinlet disseminated and breccia forms. The valuable minerals are interlaid and distributed heterogeneously. The coarse particle size of galena reaches 1.3mm but the fine one is only 0.007mm, usually 0.7—0.042mm. The finest particle size of sphalerite is 0.012—0.004mm, usually 0.84—0.072mm and for pyrite, the finest is 0.03—0.01mm, generally 1.4—1.0mm. In order to guarantee the valuable minerals to be sufficiently liberated and not overground, the run-of-mine is roughly ground to 50—60% of —200 mesh and then the tailings from scavenging is reground to 85% of —200 mesh.

Example 2: Ores from Fankou Lead-Zinc Mine belong to the intermediate-low temperature hydrothermal cravasse filling-replacement orebed, mainly containing pyrite and Pb-Zn minerals. The interlaying relation of valuable minerals is very complicated. The interlaying and distribution particle sizes of sphalerite and pyrite are rather coarse, so they can be basically liberated into single constituents when ground to 80% of —200 mesh. As for galena, not only the interlaying and distribution particle size is extremely fine, but the interlaying characteristics are complicated also. Though small part of galena particles are in coarse size, 0.5—1.0mm, most of them are in hoterogeneous fine particle interlaying. The smallest particle size is 0.01—0.04mm or less and most fine-sized galena are compactly interlaid with fine-sized pyrite. All these factors force Fankou Mine to take the multi-stage grinding flowsheet. The flowsheet is as follows: The run-of-mine is first ground to 80% of —200 mesh, so that most of the sphalerite and pyrite can be liberated into single constituents and part of the minerals containing Zn and S will be combined with galena, entering Pb rough concentrate in the state of aggregate. The rough concentrate is then reground to over 90% of —400 mesh, so that galena, sphalerite and pyrite can all be liberated into single constituents, with this grinding flowsheet, satisfactory results have been obtained in Fankou Mine.

2. Selection of the flotation flowsheet

Generally, the contents of valuable minerals in Pb-Zn sulfide ores are rather low. These minerals are mostly in fine particle dissemination and are often associated with various valuable constituents such as valuable minerals containing Pb, Zn, Cu and S. The flotabilities of them are obviously different. These conditions decide that flotation should be applied for Pb-Zn sulfide ores. There exist many factors affecting the choice of flotation flowsheets. The most essential factors are: the dissemination characteristics of valuable minerals in the ore; different kinds of valuable constituents; values and contents of these constituents and other physical and chemical properties of the ore. Generally, the minerals' interlaying features will decide the stages of the beneficiation flowsheet and the structure of the flowsheet will be decided by the users' requirement for the concentrate quality. The conventional principle flowsheets for Pb-Zn sulfide ores are two-straight selective flotation and bulk flotation, from which other flowsheets with different names can be derived.

(1) Flowsheet of straight selective flotation

The flowsheet is as follows: After the grinding of the massive ore, some depressors and activators are added properly. Then according to the sequence of different flotabilities of various valuable minerals, flotation is taken place in these minerals in succession. this flowsheet is advantageous to the separation between valuable minerals and to the separation between valuable minerals and gangues. Generally, high-quality concentrate can be obtained in this way. For this reason, the straight selective flotation flowsheet is mainly used for rich ores of coarse particle dissemination which contain various metal minerals with high contents but contain less gangues. This flowsheet is also suitable for compact-massive sulfide ores containing a large amount of sulfide minerals, no matter what the production capacity is or how complicated the property of the run-of-mine is. However, this flowsheet is more suited to the concentrators with small production capacity.

(2) Bulk flotation flowsheet

The bulk flotation flowsheet is suitable for the beneficiation of lean ores and ores in which the valuable minerals are in the form of aggregate or in compact intergrowth. The ores must first be ground to the degree that the mineral aggregates can be separated from gangues, then flotation starts. The valuable minerals will come into the froth product called "bulk concentrate", which will be separated again to get individual concentrates.

The advantages of this flowsheet are: The run-of-mine can be roughly ground so that a lot of tailings can be discarded as early as possible; equipment and investment for grinding and flotation can be reduced; reagent consumption can be saved in the separating operation. If the product is lead-zinc bulk concentrate, higher recovery can be obtained by bulk flotation than by straight selective flotation.

The disadvantage of this flowsheet is: During bulk flotation, large amount of reagent will remain on the surface of minerals, which makes the separation between valuable minerals difficult, so it is difficult to get high-quality concentrates.

(3) Other flotation flowsheets

With the development of mineral processing techniques, since 1970's, new processes or flowsheets such as flotability-ranking flotation, coarse-fine separating flotation, branching in series flotation and stepwise flotation and repid flotation have come out one after another, which are the development of conventional straight flotation and bulk flotation.

In flotability-ranking flotation, the valuable minerals are divided into two parts, the easy to float part and the difficult to float part, according to their flotable properties. The two parts will be put in bulk flotation, respectively, to get their own bulk concentrates. Both of the bulk concentrates will then be separated in order for obtaining individual concentrates containing valuable minerals. This flotation process takes advantage of the natural flotability of minerals and eliminates the complicated physicochemical change caused by the addition of large amount of regulators. Therefore, it has the following advantages: Without overdose of depressors, valuable minerals can float sufficiently, which is beneficial to increasing recovery; Without overdose of activators, it is beneficial to increasing the concentrate quality and saving reagent consumption in separation. Especially when there exist in the ore Zn minerals both easy to float and difficult to float, only by flotability-ranking flotation can good results be obtained. All other flotation processes are not efficient as this one. Now let's take Huangshaping Mine as example. The ore in this Mine is mainly composed of polymetallic sulfide minerals like galena, marmatite, pyrite with quite a few of emulsified-interlaying marmatite and chalcopyrite. The ore contains Pb 2—3.5%, Zn 4.5—6% and S 2—18% and the main gangues are quartz and calcite. There often exist some carbonaceous substances in the ore which is disadvantageuos to flotation. The interlaying and distribution of the valuable minerals are heterogeneuos. Interlaid by intermediate-sized and fine-sized particles, these minerals are mostly in the form of compact intergrowth. Since its putting into operation in 1967, the mill had applied in order the complete flotation of ground ores (bulk flotation) and partial bulk flotation. However, results were unsatisfactory; the reagent consumption was enormous; separation of Pb from Zn was difficult; operation was uneasy to control and the sulfur recovery by partial bulk flotation was very low.

Since the flotability-ranking flotation was applied in 1971, the results have been much better. The production practice of over twenty years indicates that

a. In the flotability-ranking flotation zone mainlly for Pb separation, generally, the floating amount of Zn is 20—40% and that of S is 50—60%. When this part of naturally flotable Zn and S are separated from Pb, they are easier to be depressed, creating a good condition for obtaining high-quality Pb concentrate. As a result, the Pb concentrate contains Pb 70.74%, Zn 2.93% and S 16.23%, which is the best result compared with those from other flotation fiowsheets.

b. In the flotability-ranking flotation zone for Pb separation, generally the Pb-operation recovery is 93—95% and the separating operation recovery of Pb is 95—97%. In the Zn, S flotability-ranking flotation zone, the operation recovery is 96.5 - 97.5% and the separating operation recovery of Zn is 95—97%. So the total recovery of Pb and Zn are stabilized at over 90% and 92%, respectively.

c. In the flotability-ranking flotation process, the reagent consumption is not high. The reagent cost in this process is only 60% and 40% that of partial bulk flotation and one-stage grinding complete flotation, respectively.

Comparison of results from different technological flowsheets in Huangshaping Mine (%) Table 1 [7]

Technological flowsheet	Product	Grade			Recovery			Relative reagent cost, %(Yuan/t)
		Pb	Zn	S	Pb	Zn	S	
Partial bulk flotation	run-of-mine	2.96	6.06	15.65	100.0	100.0	100.0	100
One-stage grinding and complete flotation		2.68	6.34	13.45	100.0	100.0	100.0	158
Flotability-ranking flotation		2.98	5.58	13.60	100.0	100.0	100.0	58
Partial bulk flotation	Pb concentrate	63.70	6.72	17.67	89.40	4.61	4.48	
One-stage grindingand complete flotation		61.41	6.64	18.10	88.78	4.07	5.20	
Flotability-ranking flotation		70.74	2.93	16.23	90.52	1.99	4.55	
Partial bulk flotation	Zn concentrate	0.62	41.16	30.95	2.81	91.57	27.80	
One-stage grinding and complete flotation		0.52	43.93	31.06	2.54	89.00	30.02	
Flotability-ranking flotation		0.63	44.50	31.53	2.47	92.50	26.94	
Partial bulk flotation	S concentrate	0.90	1.22	31.22	2.13	1.27	19.79	
One-stage grinding and complete flotation		0.46	1.04	37.15	3.42	3.28	54.81	
Flotability-ranking flotation		0.52	0.75	31.62	3.94	3.05	52.75	
Partial bulk flotation	tailings	0.22	0.20	9.93	5.66	2.55	47.98	
One-stage grinding and complete flotation		0.22	0.37	2.13	5.26	3.65	9.97	
Flotability-ranking flotation		0.15	0.22	3.45	3.07	2.40	15.76	

Another successful example for the flotability-ranking flotation process is 70# Mill in Huize Pb-Zn Mine. The technological flowsheet of flotability-ranking flotation-high alkality selective flotation is shown in Fig. 1, by which good results can be obtained (see Table 2)

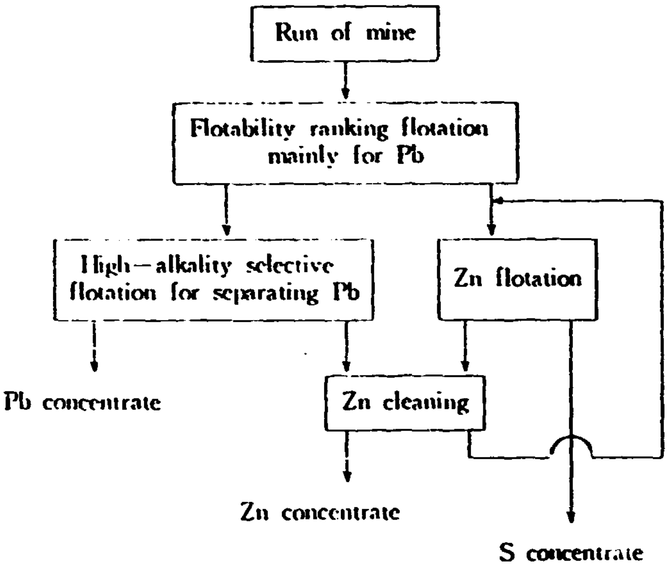

Fig. 1 Principle flowsheet of flotabitity ranking flotatin—high alkality selective flotation

Results from pilot tests by flotability ranking flotation-high alkality selective flotation Table 2. [1]

Name of product	Yield, %	Grade, %				Recovery, %			
		Pb	Zn	Fe	Ag, g/t	Pb	Zn	Fe	Ag
Pb concentrate	10.82	66.16	5.92	5.63	593.8	91.79	3.47	6.91	79.69
Zn concentrate	32.11	0.74	53.80	4.17	59.31	3.08	93.56	15.18	20.46
S concentrate	27.74	1.28	2.13	30.54	21.30	3.59	2.49	75.20	5.24
Tailings	35.33	0.34	0.26	0.69	4.00	1.54	0.48	2.71	1.61
Run-of-mine	100.00	7.80	18.47	8.83	88.38	100.	100.	100.	100.

In the branching in series flotation process, the raw pulp is first divided into two or more branches and the froth from the rough flotation of the former branch will combined with the latter branch for flotation together. After that, they will be connected in series properly and supplied with corresponding reagents. For instance, Shuikoushan Pb-Zn Mine has replaced the Zn-S bulk flotation system by the branching in series flotation process, that is, the pulp to be floated is divided into two branches and then put into flotation in one row of flotation machines. In this case, the middlings regrinding operation can be eliminated. The advantages of this process are [2]:

a. Recoveries of Pb and Zn have been increased by 2.25% and 1.13%, respectively.

b. Qualities of Pb and Zn concentrates can be improved.

c. The reagent consumption is reduced.

d. The flowsheet is simplified and operation stabilized.

The stepwise flotation process is developed on the basis of flotability ranking flotation. Unlike the traditional bulk flotation, this process will not let Pb and Zn float together but it will try its best to create proper flotation conditions for the two minerals. In the flotabilitly ranking flotation for Pb, Pb will be completely floated up in one run while in the stepwise flotation process, the part of Zn and S with identical flotability will float up simultaneously. The stepwise flotation process can create individual optimum flotation conditions for galena and sphalerite in different operations step by step. Whether at the first step or the second step, Pb and Zn will float up at the same time, In the first step of Pb-Zn stepwise bulk flotation, the method of flotability ranking flotation (no addition of regualtors) is kept, in which Pb flotation is incomplete, allowing galena of poor flotability to be floated at the second step or float up together with sphalerite that is activated by copper sulfate. This process is suitable for polymetallic sulfide ores for increasing recoveries of associated noble metals gold and silver or for obtaining bulk concentrates. With this process, the intermixing loss can be reduced and recovery be increased.

Examples of the flowsheet of stepwise flotation:

a. Stepwise flotation for Pb

This flowsheet is suited to the raw ore in which Pb is the main constituent with less S content and Pb is the main Ag-carrier mineral. At the first step, it is focused on fine lead flotation and no strong depressors are applied, resulting in the recovery of fine lead and silver. At the second step, coarse lead and silver will be recoveried so that rather high Pb-Ag recovery can be guaranteed. (See Fig. 2)

b. Pb-Zn stepwise bulk flotation

In this flowsheet, regulators will not be applied at the first step and sphalerite and pyrite should enter the forth product as less as possible. High pH is applied and copper sulfate is added for activation of sphalerite at the second step of bulk rough flotation so that pyrite can be depressed and the second step Pb-Zn bulk flotation focusing on Zn can be realized. By means of this process, minerals containing Pb, Zn and Ag can be recovered to maximum. (See Fig. 3)

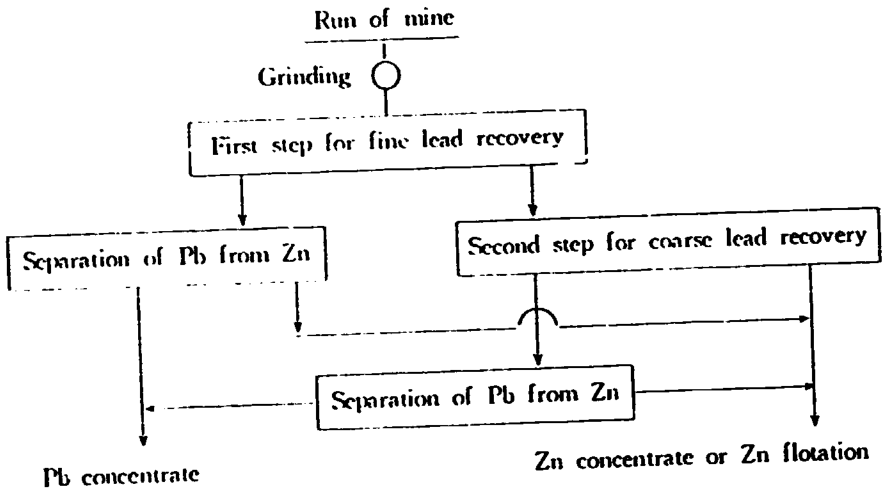

Fig. 2 Stepwise Pb flotation flowsheet

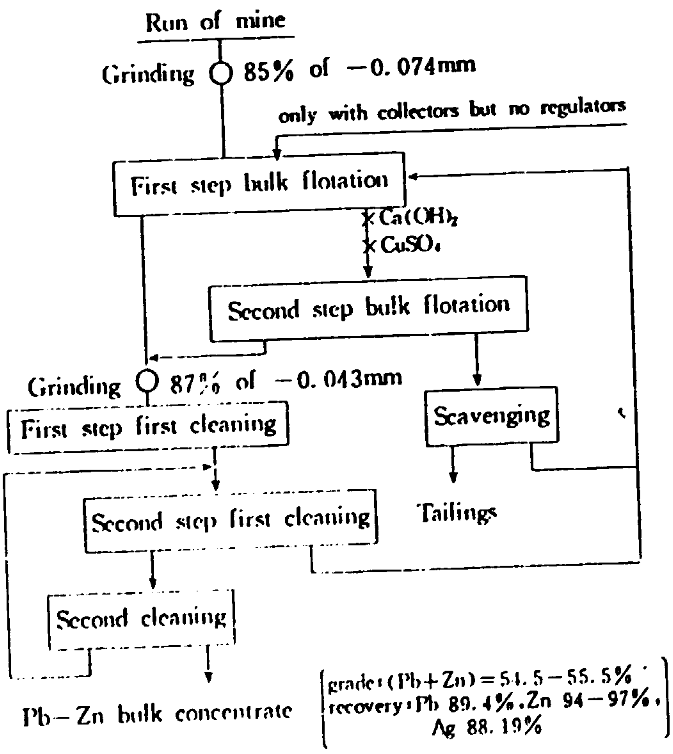

Fig. 3 Pb−Zn stepwise bulk flotation

Production practice of the stepwise flotation process:

a. Production practice in Huangshaping Pb-Zn Mine applying the two-stage (first treating fine particles then coarse particles) stepwise flotation proceess indicates that Ag recovery in Pb concentrate has been increased from 52.75% to 67%.

b. Since the application of Pb-Zn stepwise bulk flotation in Fankou Pb-Zn Mine, the grade of Pb-Zn bulk concentrate produced has reached 54.5—55.5%, the Pb recovery 89.4% and Zn recovery 94—97%. Moreover, the Ag recovery has amounted to 88.19%, nearly 88.7% of the theoretical value of Ag being distributed in Pb-Zn minerals. The sufficient recovery of Pb, Zn and Ag has thus been realized and the economic benefit is remarkable.

3. Selection of the reagent regime

There are many mineral prcessing reagents in China provided for the flotation of Pb-Zn sulfide ores. We have some chemical plants specially producing reagents for mineral processing. Various reagents are produced and developed there, such as collectors often used in the flotation of Pb-Zn sulfide ores-butyl xanthate, ethyl xanthate, sodium diethyl dithiocarbamate, ammonium butyl dithiophosphate, etc., and regulators like lime, sulfuric acid, zinc sulfate, copper sulfate, sodium sulfide, sodium hyposulfite, etc. The selection of the flotation reagent regime mainly depends on the properties of the ore treated, the principle flowsheet applied and the products to be produced. Naturally factors, like environment protection , economic cost and so on should also be taken into consideration. Finally, it should be determined by tests.

In early 1970's, the P.R.C. paid attention to the influence of cyanides on humanbodies and environment protection and developed various methods to replace cyanides in flotation. Especially after the "National Cyanide-free Mineral Processing Conference" held in 1976, most concentrators eliminated cyanides dichromates, which is a great advance in polymetallic mineral processing. At present, only few concentrators are still using a small amount of cyanides.

Separation of Pb from Zn: For the Pb-Zn ore which does not contain secondary copper but only contain small amount of pyrite in coarse particle interlaying, good separation results can be got by the application of sodium carbonate-zinc sulfate-sodium sulfide (Panjiachong Concentrator), the application of zinc sulfate-sodium sulfide (Siding Concentrator in Guangxi Province) and by the application of sodium hyposulfite-sodium carbonate-zinc sulfate (Taolin Concentrator). When the ore containing some easy-to-float pyrite is treated, the flotability of pyrite is close to that of galena, which will critically interfere the separation of Pb from Zn and S. If the traditional Pb-processing method is applied, pyrite will float up together with galena. When the pH value is increased, not only pyrite but galena is also depressed. Meantime, sphalerite will float up too with the increase of pH value. Therefore, in the processing of these ores, we have to break free from conventional reagents. For example, in Fankou Mine, large amount of lime (pH > 11.5) is applied to depress pyite; zinc sulfate is appiled to depress sphalerite and xanthate with long hydrocarbon chains is applied to collect galena. This reagent regime has the drawbacks of high reagent consumption, but at that time Fankou Mine did get good results and economic benefit, making the grade of Pb concentrate increase from 43.23% to 53.12% and the Pb recovery from 75.43% to 78.49% in the selective flotation flowsheet. [11, 12] Since the application of techniques like combination of collectors, new type of depressors and rapid flotation, beneficiation results have got a new increase.

Separation of Zn from S:

Generally, in Zn-S separation, copper sulfate is used for activating sphalerite and lime for depressing pyrite, but some individual concentrators are still using the method of heating the ore pulp (to 500 C) so as to increase the Zn-S separation efficiency and reduce lime consumption.

Separation of Cu from Pb:

For Pb-Zn sulfide ores containing Cu, usually the Cu-Pb bulk flotation is applied first, followed by separation techniques. The classical method for Cu-Pb separation is the cyanide process, in which Cu is depressed and Pb is floated or the dichromate process, in which Pb is depressed and Cu is floated. Previously, nearly 85% of cyanides in the polymetallic ore depressing plant was consumed for the Cu-Pb separating operation. However, as both cyanides and dichromates are toxic, harmful to people's health and environment protection, now they are rarely applied in the mineral processing plants in China. At present, the commonly used processes for depressing Pb and floating Cu are as follows:

a. Heating the pulp with the addition of sulfureous acid:

Under the condition of pH = 6 and the pulp temperature 45 - 50 C, sulfurous acid is added (density of SO_2 0.3%) into the pulp. The collector adsorbed on the surface of galena begins to desorb, so the Pb-depression is realized. In addition, sulfurous acid is advantageous to the cleaning of the surface of copper minerals. leaking to the increase of Cu flotabilitly.

b. Process of adding sulfurous acid and sodium sulfide :

The process is also effective for the ore containing large amount of slime and secondary copper sulfide.

c. Process of adding sodium pyrophosphate and carboxyl methyl cellulose:

This process can take the place of the dichromate process. Anyway, in the separation method of depressing copper and floating lead, a small amount of cyanides are still used. (it can be in combination with zinc sulfate)

4. Comprehensive recovery of other metals

In terms of statistics, 45% of silver production in the world come from the products of Pb-Zn mineral processing. One third silver produced in China are from Pb-Zn ores. Therefore, it is an important approach to increase the comprehensive recovery of noble metals for rising up mineral precessing economic benefits of polymetallic sulfide ores. In the past, the level of Ag recovery in China is unsatisfactory, remaining at the level between 40—75% in all Pb-Zn mineral processing plants. For the recent decade, the development of China's electronic industry has quickened the attention paid to silver recovery. Research work on it has been done and the silver recovery in many Pb-Zn concentrators has been obviously increased. For instance, the raw ore in Bajiazhi Pb-Zn Concentrator contains 150—200g/t of Ag. After they applied the cyanide-free flotation process and took other measures, Ag recovery has attained to 69.26% from 30%. Ag recovery in Hyangshaping Mine has increased from 52.75% to 67% and that in Fankou Mine has reached 88.19%, close to the theoretical recovery of Ag distrbuted in the Pb-Zn ore, 88.7%. Gold has a rather close relationship with copper, so there is not so much gold recovered from Pb-Zn ores. As for the minorly-dispersed metals like Ge,Ga,In,Cd,Tl,etc., they are also important objects for comprehensive recovery, but their recoveries are directly related to the recovery of Pb-Zn.

III. Research work and prospects

Theoretical research work on mineral processing of Pb-Zn sulfide ores has been carried out long in China. Professor Wang Dianzuo, a committee menber of the Academic Department of the Chinese Academy of Sciences and a foreign academician of American Academy of Engineering Science, has made a new approach to the flotation mechanism of sulfide ores by means of the foundation and methods in modern electrchemistry, quantum chemistry and semiconductor theory. He has explained three long-argued theoretical problems, the roles that oxygen plays in flotation, the collectors' mechanism and the natural flotabilities of minerals. On the basis of a large amount of testing data and theoretical derivations, he and his collaborators have developed the theory and technology on collector-free flotation, which is an important direction for the mineral processing of fine refractory ores. In the treatment of complicated, lean and fine-sized ores, as the mineral particles are extremely fine, their specific surface is enlarged and the reagent consumption is increased, which affects the flotation course and environment protection; while for collector-free flotation, separation is conducted by controlling the electric potential of the pulp. By taking adbantage of minerals' own hydrophobicity, collectors can be eliminated or used in small amount, so the pollution to the environment can be reduced. According to Professor Wang's collector-free theory, whether collectors exist or not, the purpose of separating sulfides by flotation can be reached by properly controlling the pulp electric potential (the oxidation-reduction atmposphere) and pH value so as to control the condition of forming S element or other hydrophobic substances on the surface of sulfide ores. This theory is highly valued by many colleagues in the mineral processing circle. Besides, he has also created the " Molecule design of mineral processing reagents" theory. [13]

Another important direction of the research work is on the technological research for the mineral processing of Pb-Zn oxide ores, because there are large amount of Pb-Zn oxide resources in China. For the recent tens of years, not only in the research on the mineral processing technology, but on reagents for Pb-Zn oxides, significant progress has been made and progress has also been shown in the production practice. [4,5]

The prospect of lead zinc industry in China is encouraging. As China's lead-zinc resource is abundant, its production potential is enounnous. Apart from meeting the domestic need, the lead zinc concentrate can be considerably exported if the price is acceptable. As for the construction of lead-zinc mines, not only the use of Pb-Zn sulfide resources should be expanded out the resource of the giant lead oride mine-Lanping Mine should also be put into use. China has got some achievements and foundation in respect of environmental protection in mines, study and development of nontoxic, economic and highly-efficient flotation resgents and the study and production of large type flotation machines. Now we are unceasingly doing all the work which can be rapidly strengthened with the market development.

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