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diagrams

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

EXPERIENCE IN DESIGNING CHINA LEAD-ZINC CONCENTRATORS AND CONCENTRATING EQUIPMENT

(DRAFT)

CHANGSHA DESIGN AND RESEARCH INSTITUTE OF
NON-FERROUS METALLURGY

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Experience in Designing China Lead-zinc

Concentrators and Concentrating

Equipment

Changsha Design and Research Institute of Non-ferrous

Metallurgy

Part One

Experience in Designing China Lead-zinc Concentrators

Introduction

China is rich in lead-zinc resources with its researves accounting for about 24 % of the world total. The lead metal reserve ranks the second in the world (just after U.S), accounting for 15 % of the world total, while the zinc metal the first and 30 % of the world total. Lead-zinc resources in China are distributed mainly in the south-west, the central-south and the north-west areas. Two thirds of the reserves are concentrated in such provinces as Yuennan, Neimeng, Guangdong, Hunan, Guangxi and Sichuang. At the present more than 100 mine properties have been developed, with the nation, the collective and individuals as their investors. The production capacity is 4500 t/d max.. The ores treated include easy - to - separate lead-zinc sulfides, somewhat difficult-to-separate mixed ores andrather difficult-to-separate oxide ores. The separation processes are generally preferential floatation, bulk floatation, partial bulk floatation, isofloatability floatation and ramified floatation. Flash floatation technology is also adopted. The optimum separation data are: Lead grade 72 %, recovery 90 % and zinc grade 55 %, recovery 92 %. All the lead-zinc concentrators are designed by Chinese design organizations which also provide technical services for concentrator construction, start-up and commissioning. Over the past years, we have gained much experience in this field, which will be presented in the following paragraphs.

1. Design Practice in China Lead-zinc Concentrators

1.1 Types of Deposits

The ores treated in more than 100 lead-zinc concentrators in China are mainly lead-zinc sulfides. Lead-zinc oxides are only processed at the lead-zinc mines of Chaihe, Siding and Nanping. The ores occur mainly in five types of commercial lead-zinc deposits.

1.1.1 Magmatic Hydrothermal Lead-zinc Deposit

This deposit is devided into skarns, vein and replacement types. The former, like the Henren Lead-zinc Mine, features a moderate lean ore with small to medium size, while the latter, like the Huang Sha Ping Lead-zinc Mine and the Shui Kou Shan Lead-zinc Mine, features a moderate high ore quality with medium to large size.

1.1.2 Volcanic Hydrothermal and Volcano Sedimentary Lead-zinc Deposit

This deposit is devided into four types : continental hydrothermal vein, hydrothermal replacement, porphyry, and marine sediment. The former three are lean ores and the latter is moderate rich with medium to large size.

1.1.3 Sedimentary transformed Lead-zinc Deposit

This deposit is devided into three types : sand stone, lime stone, and dolomite. The former two, like the Fankou Lead-zinc Mine, are moderate rich with medium to large size. The latter is lean with medium size.

1.1.4 Metamorphic Lead-zinc Deposit. Moderate lean ore with small size

1.1.5 Weathered Lead-zinc Deposit

Moderate rich with medium size, the Jiangshui Lead-zinc Mine and Hezhang Lead-zinc Mine are such deposits.

1.2 Studies on Ore Properties

The design organizations are responsibie for ore property studies from the view point of design work. They include the following aspects.

1.2.1 Participate in the examination of geologic reports, get to know the material composition, structure, texture, natural type, size, commercial grade and spatial distribution of ores. And additionally to know the content of valuable, harmful and associate elements in ores together with their variations.

1.2.2. Participate in the preparation of sampling design and selection of sampling method. Get to know ore occurences and mining conditions.

1.2.3 Participate in evaluating test programmes or in testing if necessary. Consider how to optimize the commercial implementation of the test results. Follow market situation to establish the product schemes.

1.3 Selection of Technical Process

1.3.1 Crushing and Screening Process (including ore washing)

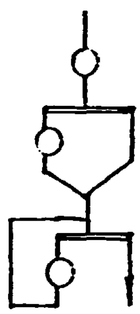
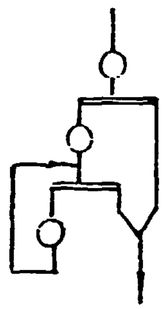
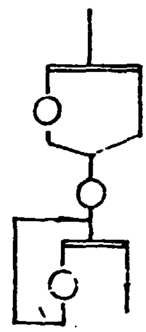
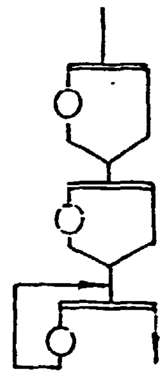
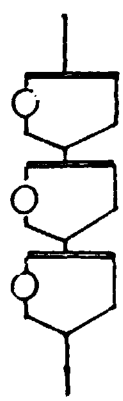
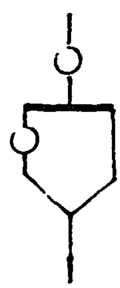
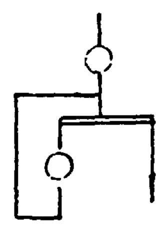
When determining the process the following must be taken into consideration: the max. run - of - mine ore lump size, the required final product particle size, size distribution of raw ores and crushed products from various stages, physical properties of raw ores, mud and water contents. These considerations will help determine the stages of crushing and screening as well as the necessity of ore washing.

It is easy for oxide ores or other ores with much mud and water content to block up crushing and screening equipments, ore bins, chutes and hoppers. This would reduce their capacities greatly and even interrupt the production process if serious. Raw ores should be washed if water content is greater than 5 % and mud (-0.074 mm) content greater than 7-8 %. In this case open-circuit crushing should be compared with the autogenous grinding both technically and economically.

As we all know, crushing features higher efficiency and lower power consumption than grinding. The design principles should be to use crushing in replace of grinding and more crushing, less grinding. This aims at lowering the crushed final product particle size as much as possible. Closed-circuit crushing with screening examination is characterized with the ability to control the crush product particle size and fully utilize the crusher capacity. It is widely adopted in the design. Three-stage closed-circuit crushing is generally adopted in the medium to large sized lead-zinc concentrators in China.

The typical crushing process is shown in Fig. 1.

Fig. 1

Mine	Fankou Lead-zinc Mine	Hangshaping Lead-zinc Mine	Xiaotieshan Concentrator	Yin Shan Lead-zinc Mine
Process	3-stage closed-circuit	3-stage closed-circuit	3-stage closed-circuit	3-stage closed-circuit
				
Mine	Taoling Lead-zinc Mine	Wutonghua Lead-zinc Mine	Feng Huang Lead-zinc Mine	
Process	3-stage open-circuit	2-stage open circuit	2-stage one closed circuit	
				

1.3.2 Grinding and Classifying Process

The selection of a grinding process mainly depends on the physical properties of ores, particle-size of feeds and the required separation fineness.

The typical grinding process of lead-zinc concentrators in China is shown in Fig. 2.

Fig. 2

Process	Mine	Grinding fineness (-200 mesh) %	Remarks
1-stage closed circuit grinding before separation	Huang Sha Ping Lead-zinc Mine	60 - 65	
	Xiao Tie Shan Lead-zinc Mine	70	
	Yin Shan Lead-zinc Mine	60 - 65	
	Si Ding Lead-zinc Mine	65 - 70	
2-stage closed-circuit grinding before separation	Fankou Lead-zinc Mine	82	
	Ba Zi Zhi Lead-zinc Mine	78	
	Tian Bao Shan Lead-zinc Mine	73 - 75	
Coarse Concentrate regrinding	Fankou Lead-zinc Mine	85-90 % -325 mesh	Coarse concentrate regrinding
	Qing Chen Zhi Lead-zinc Mine	90	Pb-Zn-S mixed concentrates regrinding
	Xi Ling Lead-zinc Mine	93	Coarse Zinc concentrate regrinding
	Ba Jia Zhi Lead-zinc Mine	95	Cu-pb coarse concentate regrinding
		90	Zn-S mixed concentrate regrinding

Closed-circuit grinding is mainly adopted in lead-zinc concentrators. The fineness of 1-stage grinding is 50-60 % -0.074 mm. Multi-stage closed circuit grinding is adopted when fine grinding is necessary. At the Fankou Lead-zinc Mine, 2-stage grinding and coarse lead concentrate regrinding are adopted before separation. At the Ba Jia Zhi Lead-zinc Mine, 2-stage grinding, pb-Cu coarse concentrates and Zn-S mixed concentrates regrinding are adopted before separation.

The degrading mineral resources and rising separation costs have become a troublsome problem to the mining people nowadays. A heavy-medium preconcentration has arouse ever greater interest. Many new types of such equipments have come into being.

1.3.3 Separation Process

Floatation is mainly adopted in Pb-Zn ore processing nowadays. This paper only presents the typical floatation of Pb-Zn ores. They are elaborated according to ore types, dissimination characteristics, intergrown relations and ore floatabilities.

1.3.3.1 Preferential Floatation

Preferential floatation is generally used for easy - to - separate lead-zinc ores featuring simple intergrowth among valuables and coarse dissimination. This process is characterized with simple process operation. It is used at the Tao Ling Lead-zinc Mine.

1.3.3.2 Bulk Floatation

Bulk floatation is used for lead-zinc ores featuring intimate intergrowth among valuables and relatively simple relation between valuables and gangues. This process is characterized with coarse grinding for tailings rejection, less equipment investment and production cost. At the Qing Cheng Zhi lead-zinc Mine, the bulk floatation in case of 50 % -1.074 mm grinding fineness is used for Pb-Zn-S ore to reject 80 % of the final tailings.

1.3.3.3 Partial-bulk Floatation

Partial bulk floatation is commonly used for Pb-Zn-Cu ores featuring intimate intergrowth and fine disseminations. Chalopyrite has its floatation close to that of galena. Bulk floatation is often used for Cu and Pb, as well as for Zn separation from the tailings. The process is used at the Tian Bao Shan and the Tin Shan Lead-zinc Mines.

1.3.3.4 Iso-floatability Process

The process as used at the Shui Kou Shan Lead-zinc Mine is a typical example. As part of sphalerite has its floatation close to that of galena and another part of difficult-to-float sphalerite has its floatability close to pyrite, a " pb-Zn iso-float " and " Zn-S iso-float " process is adopted. This process is characterized with enrichment of sphalerite with different floatabilities under suitable conditions. Its separation data are better than those of the single preferential floatation or bulk floatation.

1.3.3.5 Ramified Floatation

This process is used for separation of single or multi-metal ores with low grade and poor floatability. The typical process is shown in Fig. 3. It is characterized with the ramification of the pulp feeds into two or more than two branches.

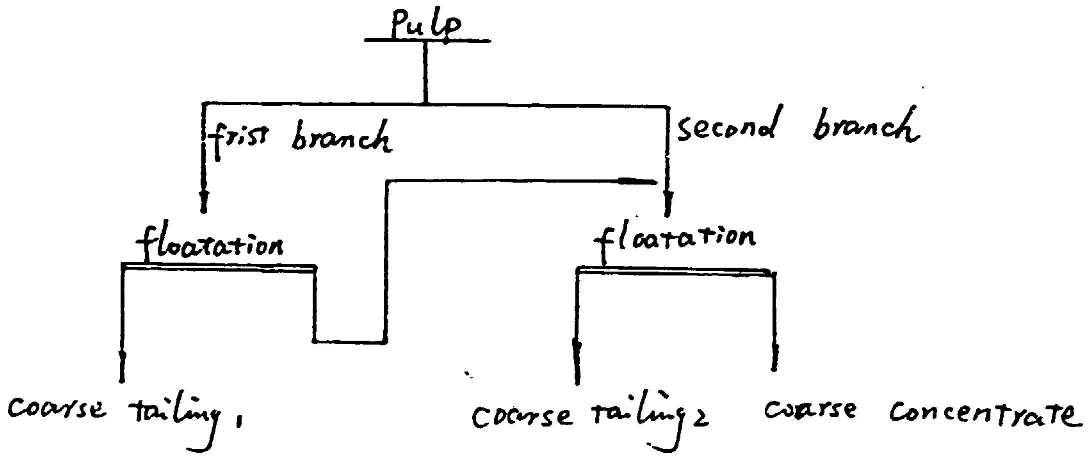


Fig 3 Typical precess of ramified floatation

The first branch of froth product from roughing joins the second branch for roughing. As this helps improve the grade of the second pulp branch and the ore floatability, separation data will be better. Additionally the reagent from the first branch can be fully ultilized, thus reducing the reagent consumption and saving its cost. At the Yinshan Lead-zinc Mine up-grading programme, the original preferential floatation from one circuit was modified with the ramified floatation. The grade of lead concentrate is thus increased by 0.7-2.8 % and recovery by 0.5-1.0 %. Recovery of zinc concentrate is increased by 1-1.5 %. The cost of the reagents is reduced.

1.3.3.6 Flash Floatation

Single-cell is provided in the grinding-classifying circuit for flash floatation of coarse particles from the unevenly-dissiminated ores. In doing so high specific-gravity target minerals are preferentially floated from the cyclone underflows. The flash floatation has the following characteristics.

a). Less overgrinding of the target minerals and more stable feeds.

b). Fine selectivity in coarse particle floatation. Direct production of part of specified coarse particle concentrates.

c). Coarser particle size concentrate, thus reducing moisture of concentrate filter cakes.

d). Less fluctuation of pulp circulation in floatation circuit, less space requirements for installation of floatation tanks.

1.3.4 Concentrate Dewatering Process

An optimum dewatering process depends on the material properties, the User requirements for concentrate moisture contents and the conditions of packing and transportation. Fine particle concentrates are mostly dewatered by a 2-stage process of thickening and vacuum filtering (or press filtration). A drying operation is added in the cold areas if necessary.

1.4 Equipment Selection

Equipment performance and its applications will be presented in Part 2 " Concentrating Equipments in China " and only some principles of equipment selection is outlined here. They are as follows :

1.4.1 Requirements for advanced equipment, which must be reliable,adaptable, easy operation and maintenance as well as low energy consumption.

1.4.2 Attention to the development tendency for large-sized equipment, which has the advantages of less quantity, smaller investment, and lower production cost. In addition, such equipment is convenient for management and automation.

1.4.3 Requirements for uniform loads of the upstream and downstream process equipments. And the capacity of the auxilliary equipment must be matched with that of the main.

1.4.4 The equipment specifications of the same operation must be identical as much as possible. This will facilitate operation, management and process automation.

1.4.5 Necessity for techno-economic comparisons in case of many options. Such comparisons include capital investment and production cost. The advantages and disadvantages of operation management must be analyzed accordingly.

1.5 Concentrator Site Selection and Equipment Layout

1.5.1 Site Selection

For site selection, the relative positions and interrelations among various process sections, auxilliary sections, auxilliary installations, routes for communications and transportation and pipe-line works must be determined. Transportation, water supply, power supply, tailings dump, engineering geology, earth and stone work amount and construction conditions, etc. must all be taken into consideration. Principles for site selection is as follows.

1.5.1.1 The principle of centralized or decentralized concentrator construction according to resource distribution, topography, mining, transportation, etc.

1.5.1.2 The principle of avoiding to build the concentrator on the deposit. The caving area or the blast-endangered area is not the desirable site.

1.5.1.3 The principle of making fully use of topography. The concentrators in China are mostly built on slopes. This option is characterized with compact building layout, smaller space occupation and less capital construction investment. It also features pulp transportation by gravity and lower costs.

1.5.1.4 The principle of paying great attention to the influence of harmful gases, waste water and waste residues from the concentrator upon the environment.

1.5.1.5 The site must be good in terms of engineering geology. It must be situated above the flood level.

1.5.1.6 Space should be reserved for future development and extention programmes.

1.5.2 Equipment Layout

1.5.2.1 Layout of Crushing Equipment

According to equipment grantity, process and topography, the equipment in the crushing section can be arranged in many ways. Their selections will necessitate techno-economic comparisons, which include the capital construction investment of concentrator buildings, once for all investment of maintenance cranes, and management fees. The aspects of production management, industrial hygiene, and others must also be considered.

Two-stage open-circuit crushing features less equipment required and easy layout. The integral building or separate ones can be arranged on the slopes.

The integral building is characterized with the equipments sharing the same hoisting facilities. Process operation and access are quite convenient. This option is suitable for use on the gentle slope.

The separate buildings are characterised with the elimination of long belt-conveyors in the buildings.

Three-stage open-circuit crushing has a similar layout to that of two-stage. The straight layout of three-stage open-circuit integral building parallel to the contour and its ladder-type layout following the slope are separately shown in the slides. The former has the advantage of convenient operation management and sharing hoisting facilities, while the latter features a compact equipment layout, less ground occupation and reasonable ultilization of the building space.

The layout of closed-circuit crushing is somewhat a little more complex. For the two-stage closed-circuit crushing, the screening operation can either be incorperated into the crusher section, or arranged separately.

Its characteristics are similar to those of open-circuit crushing.

Three-stage closed-circuit crushing is characterized with the separate arrangements of screening sections. One of the typical layouts of crushing facilities is the use of integral building with the characteristics of the same overhaul equipment shared by three crushers. It is suitable for layouts at the flat ground or on the gentle slope. Another typical layout is the ladder-type, with the characteristics of compactness, smaller ground area, and shorter distance from primary crushing to secondary crushing. It is suitable for the medium-sized crushing section to be built on the steep slope.

1.5.2.2 Layout of Grinding Equipment

Layout of grinding section is much simpler than crushing section. Two basic layouts are as follows :

a). Longitudinal Layout

The central line of the grinding mills and classifiers are perpendicular to that of the long-lined fine ore bins. This is a most common layout of grinding mills, that suits large-sized concentrators or concentrators with more grinding mills. It has the advantages of neat layout and easy operation.

b). Transverse Layout

The central line of the grinding mills and the classifiers runs parallel to that of the long-lined fine ore bins. It is suitable for the small-sized concentrators or the concentrators with less grinding mills. It has the advantages of shorter building spans. Transverse layout has been applied to two-stage grinding.

1.5.2.3 Layout of Floatation Equipment

The layout of floatation equipment should be based on the overall considerations of the layouts of grinding, classification and concentrate dewatering. And topography should also be considered. According to the performances of the floatation machines, the banks can be arranged horizontally or ladderwise. Convenient reagent dosing, sampling, operating and maintenance should be taken into full account.

1.5.2.4 Layout of Concentrate Dewatering Equipment

Two common layouts are as follows :

a). Thickeners and filters are arranged at the same building and linked with the grinding and floatation building for convenient operation. This layout suits the small-sized concentrators with less concentrate output. It can prevent frostbite in high-cold areas.

b) Thickeners are arranged in the open air and filters in a separate building near the thickeners. This layout is suitable for the medium to large-sized concentrators with large diameter thickeners.

The underflow of the thickeners can flow by gravity into the filters or be pumped into them according to topograghy.

1.6 Process Instrumentation and Control

Although China is abundant in labour forces with low labour price, the process automatation in the concentrators has been developing rapidly in recent years. The following is the main reasons.

1.6.1 An optimizied stable control of the process can improve the enterprise management and economic efficiency. For example, increasing production capacity, improving separation data, reducing energy and ultilities consumptions, and lower labour force requirements are all possible by this means.

1.6.2 Ever increasingly complex process at the large-sized mines.

1.6.3 China has made ever larger and better equipments.

1.6.4 Checking instruments and control components with high precision and quality all made in China, computers widely applied.

1.6.5 Technical people have more knowledge of the process. Labour force have been futher qualified.

The process automation in China today consists of two types. One is automatic testing and measuring, but with manual control. The other is single-loop computerized control of some key processes or automatic control of multi-variables. They are as follows.

1.6.5.1 PC-controlled interlocking of complex processes.

1.6.5.2 On-stream analyzers for metal grade measurements.

1.6.5.3 Particle-sized monitors (including densimeter and flowmeter) for automatic control of the grinding and classifying circuits. The aim is to obtain max. capacity or optimum particle-size. Control method is determined according to ore properties, technical parameters of floatation process, separation data and product schemes.

1.6.5.4 Proportional cascade, DDC control system for controlling feed rate, floatation tank level, aeration, level of sand pump sump, pump rotation, PH value of floatation, reagent dosing, special instruments, etc. The aim is for a balanced stable control of material flows in the concen-trators.

The concentrators at the Fankou Lead-zinc Mine and the Fan Huang Shan Copper Mine are among those with the above automation in China today.

1.7. Design Requirements of Main Auxillary Specialities

1.7.1 Civil Engineering

The main building materials are cement, sand, stone and reinforcing steel. They should be available as locally as possible. The concentrator buildings are mostly of brick and concrete structure. Large-sized equipments should be provided with reinforced concrete foundations. The investment of the building construction for medium to large concentrators usually accounts for 15-30 % of the overall investment. It is characterized with small capital investment, conventional requirements for construction technology and equipment.

1.7.2 Power Suply

Attention to the adoption of energy-saving technology and equipment. Consideration of the reactive power compensation. Medium to large concentrators are supplied through the local power network. The first-class power load is supplied through double-loop or self supply power plant. Distribution voltage is 380 v. Voltage of large motors for crushing and grinding operations is 3000 v or 6000 v. Based on concentrator sizes and processes, the installed capacity is about 50-80 kw/10000 t/y.

1.7.3 Water Supply

Attention to water saving, use of the recirculated water and waste water treatment. Medium to large concentrators usually have a water consumption of 4-5 m^3/t. The recirculated water is required to account for 70 % of the overall water consumption.

1.8 Technical Economics and Engineering Economics

1.8.1 Technical Economics

The evaluation of technical economics deals with the analysis of investment results which is the most important for investors.

The evalluation covers the following : overall analysis of techno-economic targets, comparison of main design proposal, survey and analysis of manning and production efficiency, capital investment, working capital, production cost, product price, investment pay-back ability, concentrator construction results, market situation, etc. Among them, comparison of main design proposals takes the most important place. The main design proposals are classified into two aspects : general proposal and specialized proposal. The general proposal covers the following : technical level, structure and production layout of the concentrator, layout of ultilities and auxilliaries, principal design proposals, (such as proposal for concentrator size, concentrator site, process flowsheet, product range, etc.) All these constitute the technical framework for concentrator construction and play a key role in its future economy. A specialized proposal is highy specialized. The precise and reliable comparison of the two proposals is a decisive factor in the whole techno-economic evaluation quality.

A techno-economic evaluation is carried out based on the current price and financial system and in view of input and output. Two methods are adopted. For the static method, time factor is not regarded. While for the dynamic method, the influence of the construction project in the economical life time has to be regarded. The two methods are generally combined in the design to ensure the reliability and risk-resistance of an econnomic evaluation.

1.8.2 Engineering Economics

Engineering economics covers budget preparation so as to control capital investment and evaluate the investment results. The budget cost serves as a main basis for the construction organization to make a tender. It consists of three forms : totalbudget, combined budget and budget for individual project. The first two are prepared by engineering economics professionals and the last one by designers of individual projects.

1.9 Environment Protection

In the design of lead-zinc mines in China, much attention has been paid to environment protection. According to relavant stipulations in China, pollution control at the new or modified mine enterprises must be carried out at the same time as their design and construction. And they must be put into operation at the same time too. Environmental protection covers the protection of environment from the harmful waste gas, waste water, waste residue. Waste gas refers to the dust-laden air from the ore crushing, screening and transport. Waste water refers to the untreated flushing water from the process, the overflow and tail water from the thickening pond, accident pond in the sand pump station, etc. Waste residue refers to the tailings from the concentrator. In the selection of the methods of controling the above " Three Wastes " priority should be given to those with reliable technology and low investment. The following outlines the environment protection situation in China's lead-zinc concentrators.

1.9.1 Dust Control

The dust laden air from crushing and screening sections is purified by dust-removal exhauster and spraying system.

1.9.2 Waste Water Control

The waste water from the concentrator may be recycled for reuse to reduce fresh water consumption, sewage treatment and production cost. Generally, the concentrate overflow and supernatant from tailings pond mainly contain reagent remains, so they can be recycled. According to the requlations by environment authorities, the recycled water from the new flotation plant should be up to 70 % of the total water consumption.

The treatment method for discharged waste water is dependant on the types and content of harmful constitueuts.

Natural precipitation and precipitation with reagents are often used for suspension-bearing waste water, while natural purification, adsorption and purification with lime, bleaching powder and chemical reagents are used for reagent-bearing waste water. Alkali-chlorination, $FeSO_4$-lime purification, adsorption and natural purification, are used for cyanide-bearing waste water. Natural purification for cyanide-bearing waste water.

Alkali-chlorination, $FeSO_4$-lime purification, adsorption and natural purification etc. are used for cyanide-bearing waste water. Natural purification of cyanide-bearing waste water in the tailings pond is often carried out because of low cyanide consumption from the process and small CN content in the tail water. According to the industrial monitoring results made at Hengrong Lead-zinc Mine and Shuikoushan Lead-zinc Mine, the cyanide discharged to the tailings pond is disolved at a rate of 15 % per day, the cyanide-bearing waste water is up to discharge standard after stagnation in the tailings pond for some time.

1.9.3 Treatment of Tailings

Besides traditional stock piling in the tailing pond, new ways have been found out for general utilization of tailings according to the construction conditions of some mine and the inherent nature of the tailings.

1.9.3.1 Tailings Used as Underground Fillings

The Fankou Lead-zinc Mine has successed in using full grain-size tailings as filling materials with annual reduction of management cost at RMB 260000 (1988 price).The management cost and capital investment for tailings pond is reduced by over RMB 7000000 with remarkable economic efficiency.

1.9.3.2 Tailings Used as Building Materials

The tailings in a mine are used to make bricks., resulting in zero discharge of the tailings. A saving of capital investment for tailings pond and tailings transport system is thus realized, and the brick as by-product. The income from brick-making is quite remarkable.

1.9.3.3 Cycloned Coarse Tailings Used as Dam-building Materials. This method can lower the first-stage dam height with a saving of capital investment.

2. Design Procedures and Methods for Lead-zinc Concentrators

2.1 Design Procedures

The basic procedures for the design of concentrators in China covers several stages, such as plant-construction survey, feasibility study, preliminary design (conceptual or basic design) and working drawings design (final design or detail design).

To the projects outside China, the design organizations in China will offer good services according to the design procedures and requirements at the international market.

2.2 Design Methods

With the development of computer software and hardware, the design level has improved. Computer-aided designs are carried out in many ways with an improved design quality and design speed as well as reduced labor intensity of the designers.

2.2.1 Optimized design computer program

For example, computer programs may be used for automatic calculations, proposal selections and automatic drawing for such specialities as geology, mining, general layout, heating and civil engineering.

2.2.2 Computerized calculations and statistics featuring fast speed and high acuracy, geologic reserve calculations, civil engineering structure calculations, material blance sheet calculations for grinding-floatation circuit, intallation project and working drawings budget are some oxamples.

2.2.3 Improved drawing quality and speed by means of CAD microcomputer system.

Part Two

Concentrating Equipment in China

The mineral concentration equipment manufacturer in China today are capable to provide to the market various kinds of equipment needed by mine. They are also capable to provide the equipment intallation and commissioning services, as well as consumables supply on a long-term basis.

1. Crushing and Screening Machines

The commonly-used crushing machines include jaw crusher, gyratory crusher, roller crusher and cone crusher. Conventional jaw crusher and jaw type fine crusher (developed in China and has been put into production in the late years) are used in two-stage crushing circuit for small to medium-sized mines. Jaw crusher, standard and short-head cone crushers, are often used in three-stage crushing circuit while the gyratory crusher is generally used as coarse grinding equipment for medium to large open-pit mines.

The largest size of the jaw crusher in use is 1500 × 2100 mm, and the largest gyratory crusher 1600/230 mm. Cone crusher is of three types : the standard, the short-head and the medium-sized, all with hydrauiic / spring settings. The largest size in use up to now is 2200 mm in diameter.

Recently, the following new crushers have been developed and put into commercial operation in China.

1.1 Hydraulic Gyrtory Crusher

This crusher is provided with hydraulic over-load protector which works under non-stop operating conditions, offering higher equipment efficiency. The largest size is 500 × 900 mm.

1.2 Double-swing Jaw Crusher

The crusher consists of two swinging jaws and deep crushing chamber, with the advantages of large capacity, lower specific energy consumption, longer liner life and higher crushing ratio. In addition, such a crusher simplifies process by substituting secondary crushing to primary crushing. The largest size manufactured is 400 × 200 mm.

1.3 Gyradic Crusher

The crusher is used for producing fine particle-size and good-shaped materials resulting in lower energy consumption for crushing and grinding section. The largest size manufactured at present is 2100 mm in diameter.

The screens commonly used in China are of several types such as vibrating screen, stationary screen, revolving screen, sieve bends, trommel fine screen and probability screen. Only vibrating screens are used in the lead-zinc concentrator. They have the following features :

1.3.1 Inertia Vibrating Screen

The screen consists of the single-deck, the double-deck, the seat and the suspended. It is only suited for handling fine to medium-sized materials. Uniform feed is required, otherwise screening efficiency may be affected negatively. Generally, the maximum grain size of the feed is 100 mm, the screen apertures ranging from 6 to 40 mm.

1.3.2 Self-Centering Vibrating Screen

The screen has the advantages of simple construction, easy adjustment and operation, heavily-vibrated screen surface, little material clog-ups and high screening efficiency. Yet it is has the disadvantage of unsteady screening efficiency due to considerable influence of the ore feed fluctuations on the screen amplitude. At present, this screen is mostly used in the medium to large-sized concentrator in China for screening fine to medium materials, Screen aperture ranges from 6 to 50 mm.

1.3.3 Heavy-duty Vibrating Screen

The screen is robustly constructed and can withstand heavy impact load. It is used in the large concentrator for prescreening prior to secondary crushing. Generally the maximum feed size is 400 mm, Screen apertures range from 10 to 100 mm.

1.3.4 Single-spindle Vibrating Screen

The screen runs along a round orbit, with the advantages of simple construction, easy maintanance and high screening efficiency. It is suited for the screening of fine to medium-sized materials. The largest feed size is 100 mm and the screen aperture 6-50 mm.

1.3.5 Double-spindle Vibrating Screen

The screen operates on the principle of isopachous screening. It is suited for the dry/wet screening of fine fractions (<25mm). It is characterized with less aperture clog-ups high throughput, easy layout and small floor space.

2. Grinding Machines

Various rod mills, ball mills and autogeneous mills are being used in the lead-zinc mines in China. A rod mill features a linear contact of grinding medium with the ore, providing selective comminution with relatively uniform product size and less overground particles.

It has larger throughput than ball mill of the same size when used in coarse grinding (product size 1-3 mm). However it is less efficient than the ball mill of the same size when used in fine grinding (product size <0.5 mm).

Up to now, the largest size of the rod mill available from China is Φ 3600×5400 mm, the effective capacity 50 m^3 and the throughput over 200 t/h per machine.

Ball mills may be divided into grate-discharge and overflow. A grate-discharge mill is fitted with grates at the discharge head. Its pulp level is lower and helps reducing overgrinding of ore particles, thus discharging specified products. The grinding efficiency is about 15 % higher than the overflow mill of the same size. The upper limit of the product size is generally 0.2-0.3 mm. It is normally used for primary grinding.

The overflow ball mill is characterized by higher overflow level, longer dwell time of the pulp in the mill, finer product size (generally <0.2 mm) and small throughput per unit volume. It is generally used for the secondary grinding and regrinding of the middlings in the two-stage grinding circuit. At present, the manufacturers in China can supply various sizes of ball mills up to Φ 3600 × 6000, including grate-discharge and overflow. The available volume per machine is up to 55 m^3 and the throughput over 100 t/h.

The autogeneous mill is characterized by small drum, short dwell time of the particles in the mill and large throughput. It may operate wet or dry. The wet autogeneous mill has the advantages of lower energy consumption, less dust pollution and auxillary equipment than the dry one. It is suited for handling coarse ores with high content of mud and moisture, and the crushing stage may be eliminated. Vertical mill is a newly-developed fine grinding machine in the late years. It has the advantages of large capacity, high efficiency, simple construction, small floor space and less capital investment. Its power consumption is over 50 % lower than the conventional horizontal ball mill.

3. Separators

The rapid development of new separators in the late years in China has met the requirements for design and equipment selection for diffirent ores. At present, the following floatation machine serieses are available.

3.1 Self-sucking Mechnically Agitated Flotation Machine

3.1.1 XJ-flotation Machine (or A-flotation Machine)

This is a self-sucking mechanically agitated flotation machine with radiant impellers. It is for roughing, scavenging and cleaning in the small to medium-sized flotation plant, as well as for cleaning in the large plant when less acration is needed. The largest size available from the manufacturer is 5-8 m^3 in effective cell volume.

3.1.2 JJF & XJO-flotation Machines

These machines have similar constructions. JJF, a self-sucking mechanically agitated machine, consists of two serieses : the deep cell and shallow cell. Skimming is carried out at one side or two sides.

These machines feature lower power consumption, smaller wear between the impeller and stator, stronger agitation, larger air suction, more freedon from precipitation, steadier pulp level and easier automation than XJ-machine. They are fit for roughing and scavenging in the medium to large-sized flotation plant as a typical large flotation machine developed in the late years.

Now, JJF & XJO-flotation machines have been widely used for the separation of Fe, Cu, Pb, Zn, S minerals with good results. The largest effective cell volumes are 16.20 m^3 and 38 m^3 respectively.

3.1.3 SF-flotation Machine

The machine preserves the advantages of self-air-sucking and self-pulp-sucking of A-flotation machine, but with the tendency towards larger size. It has been seriated and widely used in the mines in China.

3.1.4 XJB- Rod-shaped Flotation Machine

The machine is self-sucking and mechanicaly-agitated, with shallow cell, capable to suck the pulp. It has the advantages of large aeration, strong agitation, good dispersion of air bubbles, fast flotation rate, and low power consumption. It is suited for handling coarse, free-milling ores in small to medium-sized concentrators. The largest size available from the manufacturer is 4 m^3.

3.2 Aerating Machanically-agitated Flotation Machine

3.2.1 CHF-&L XJC-flotation Machines

These machines are characterized by cone-shaped circulating drum system, where pulp circulates upwards in vertical direction, so as to fully suspend the particles in the cell bottom. They are fit for roughing and scavenging of coarse and heavy refractory complex ores. Aeration can be adjusted.

CHF-X and XJC-flotation Machines have been seriated and used in tens of mines with good results. The largest sizes available from the manufacturer are respectively 14.4 m^3 and 8 m^3 in effective cell volume.

3.2.2 BS-K type and KYF-type Flotation Machines

The machines share the advantages of aerating mechanically-agitated types, and have been widely used in industry as large deep-cell flotation machines. They are suited for the roughing and scavenging of the low-grade material with small specific gravity. They allow for possible aeration adjustment, good air dispersion and easy automation. The largest sizes avaible are 16 m^3 and 39 m^3 respectively.

3.2.3 Flash Flotation Machine

It is a single cell machine specially designed for " flash flotation ". The machine is fit for handling unevenly-disseminated ores. Coarse grinding produces part of liberated coarse final concentrates or coarse concentrates. Two types are available from China : SK-0.7 type and SK-2.1 type.

4. Dewatering Machines

Traditional thickeners and vacuum filters are generally used as dewatering machines. Up to now, perpheral traction thickeners and center-driving thickeners are still widely used. Their sizes available from the manufacturer are Φ 1.8-20 m and 15-53 m respectively.

Recently there has been a rapid advance in high-efficiency thickeners. Various types have been developed in the world. China has without exception witnessed great strides in this field. The throughtput of this machine may be increased several times or even over ten times larger than traditional thickeners. This is due to their unique feeding aided by flocculants.

Several types of high-efficiency thickeners have been mass-produced. They are the 3.6m-diameter, 5.8m-diameter, 9m-diameter, 12m-diameter machines. Among them, the 9m-diameter machine designed by Changsha Design & Research Institute of Non-ferrous Metallurgy has incorperated the advantages of other types. Its many years of operation at the Fankou Lead-zinc Mine has proved its excellent thickening performance. It has passed national evaluation and won first-rate national prize in China.

Vacuum filters are mostly used as filtering machines. The following established vacuum filters are available from the manufacturer.

4.1 Internal Drum Vacuum Filter

This filter is mostly used for handling the coarse materials with great density and fast settling rate. Five sizes are available, with their filtering areas ranging from 8 to 40 m^2.

4.2 External Drum Vacuum Filter

The filter is suited for filtering fine materials requiring low-water content of the filter cake. Ten sizes are available, with their filtering areas ranging from 2 to 40 m^2.

4.3 Folded-belt Filter

The filter is best suited for fine and difficult-to-filter materials because pressure and scraper are eliminated in the discharge. Discharging is carried out without blower and scraper, eliminating the problem of moisture increase in the filter cake by the returned water from the blower. Three sizes are available, with their filtering areas ranging from 1.7 to 40 m^2.

4.4 Horizontal Vacuum Belt Filter

The filter has wide application with flexible operation and control. Washing, drying and discharging as well as the filter cloth development and correction can all be automatically controlled. Operation is precise and reliable. At present, four sizes are available, with their filtering areas ranging from 2.5 to 23 m^2.

4.5 Disc Vacuum Filter

The filter features larger filtering area (largest 120 m^2), smaller floor space and stronger adsorption than drum filter. It is suited for handing fine concentrates. Various Sizes are avaible from the manufacturer, with their filtering areas ranging from 9 to 120m^2.

Automatic filter press may be divided into belt, plate and frame, chamber and continuous. The new automatic plate and frame filter press developed by China has been widely used with the advantages of high filtering efficiency and easy replacement of filter cloth. Beijing Research Institute of Mining & Metallurgy has developed seven sizes of ZYL-Automatic Filter Press, with their filtering areas ranging from 5 to 25 m^2. Shuikoushan Mine Bureau has developed three sizes of SZY-automatic filter press, with their filtering areas ranging from 8 to 20 m^2. Wuxi General Machinery Works produces three sizes of BAJZ-Automatic Plate & Frame Filter Press, with their filtering areas ranging from 15 to 30 m^2.

Survey of Separation Processes of Multimetal Sulphides at Lead-zinc Concentrators, China

No	Concentrator (deposit)	Main metallic mineral	Grinding stage & fineness (-200 mesh)	Principle flotation flowsheet	Separating condition (g/T)	Process data (%)
1	Pb-Zn concentrator [illegible] (mesothermal filled)	galena sphalerite	one-stage grinding 60 %	Pb/Zn/S	Pb flotation: lime(PH8.5-9), $ZnSO_4$ 1000, ethylxanthate 20, butylamine aerofloat 12, butyl xanthate 10, Pine oil Zn flotation: lime (PH10-11) $CuSO_4$ 160, butyl xanthate 12, Pine oil	ore grade: Pb1.9, Zn2.4 lead con: grade 54.42 recovery 87.61 Zn con: grade 52.67 recovery 77.65
2	Singun (mesothermal filled replacement)	galena, sphalerite, some pyrite, arsenopyrite	one-stage grinding 55 %	Pb/Zn/S	Pb flotation: $ZnSO_4$ 1000, ethyl xanthate 20, Na aerofloat 5-10, diesel 6-24, cresol 120 Zn flotation: lime 600, $CuSO_4$ 300-250, butyl xanthate 25-35, 2# oil 60-120	Ore grade: Pb1.92, Zn 1.91 Pb con: grade 59.25 recovery 87.95 Zinc con: grade 44.44 recovery 76.85
3	Qingshuitang (mesothermal filled)	Sphalerite galena	one-stage 55 %	Pb/Zn/S	Pb flotation: lime (PH7.5), Na_2CO_3 500, $ZnSO_4$ 750, aerofloat 110, ethylxanthate 45, 2# oil 30 Zn flotation: $CuSO_4$ 750, butyl xanthate 170, ethyl xanthate 25, 2# oil 90	Ore grade: Pb1.13, Zn 3.42 Pb con: grade 58.77 recovery 90.55 Zn con: grade 57.06 recovery 87.30
4	[illegible]	galena Sphalerite Pyrite Pyrargyrite black canfieldite	one-stage grinding 65 %	Pb/Zn/S	Pb flotation: Na_2CO_3 1100 $ZnSO_4$ 1100, ethyl xanthate 30, 2# oil 25 Zn flotation: lime 900 $CuSO_4$ 500, butyl xanthate 50, 2# oil 40	Ore grade: Pb1.26, Zn1.95 Pb conc.: grade 67.55 recovery 93.79 Zn conc.: grade 43.33 recovery 79.35
5	Pb-Zn-S concentrator [illegible] (mostly skarn)	Sphalerite, greenockite, galena, pyrite	one-stage grinding 55 %-60 %	Pb, S/Zn/S Pb/S	Pb-S bulk flotation: $ZnSO_4$ 160, xanthate 12, 2# oil 20 Pb/S separation: activated C, lime (PH10), Xanthate 5 Zn flotation: $CuSO_4$ 250, lime (PH11), xanthate 100, 2# oil	Ore grade: Pb0.42, Zn 7.73 FeS 3.0-3.5 Pb conc.: grade 63.05 recovery 65.12 Zn conc.: grade 53.37 recovery 94.09 Pyrite conc.: grade 42.50

No	Concentrator (deposit)	Main metallic mineral	Grinding stage & fineness (-200 mesh)	Principle flotation flowsheet	Separating condition (g/T)	Process data (%)
6	Bailaxtala (mesothermal-filled replacement)	galena, sphalerite pyrite	one stage grinding 70 %	Pb-S/Zn/G Pb/S	Pb-S bulk flotation: $ZnSO_4$ 1500 ethyl xanthate 100, 2# oil 4.5 Pb-S separation: lime (PH10, cleaning 11), Zn flotation: lime(PH8-8.5), $CuSO_4$ 600, bytyl xanthate 100, 2# oil 50	Ore grade:Pb2.36, 5.68 Pb conc.: grade 56.60 recovery 83 Zn conc.: grade 55.07 recovery 64
7	Sixiang (mesothermal-filled replacement)	Sphalerite, galena pyrite	one-stage grinding 60-65 %	Pb/Zn/S/G	Pb flotation: $ZnSO_4$ 1150 aerofloat-68, bytyl-amine aerofloat 22 Zn flotation: Na_2CO_3, $CuSO_4$ 35, bytyl xanthate, 2# oil 22 S flotation: bytyl xanthate 70, 2# oil 60.	Ore grade: Pb 1.12, Zn 6-6.5, Fe 3.64 Pb conc.: grade 61.16 recovery 75.79 recovery 67.28 Pyrite conc.: grade 30.19(Fe) recovery 36.58(Fe)
8	Qingchengzhi (mesothermal-filled replacement)	galena, sphalerite pyrite, arsenopyrite	two-stage grinding one-stage 50 % mixed concentrate regrinding 90 %	Pb-Zn-S/G Pb/Zn-S Zn/S	Pb-Zn-S bulk flotation: Na aerofloat, $CuSO_4$, bytyl xanthate, 2# oil Pb separation: lime(PH9), Na_2SiO_3, $ZnSO_4$ 90, activated C (cleaning), bytyl xanthate, 2# oil Zn separation: lime(PH10-11) $CuSO_4$, activated C(cleaning) bytyl xanthate, 2# oil	Ore grade: Pb2.64, Zn 1.45, S7.38 Pb conc.: grade 67.52 recovery 91.41 Zn conc.: grade 54.50 recovery 88.25 Pyrite conc: grade 39.02 recovery 74.14
9	Shuikouchan (mesothermal filled replacement)	galena, sphalerite pyrite, pyrrhotite	two-stage grinding one-stage 50-55 % 90 % (purchased) Pb middlings regrinding 94-97 %	Pb/Zn-S/G Zn / S	Pb flotation: lime (PH7-8.5, cleaning 9-10.5), $ZnSO_4$, Na_2SO_3, Na_2S, aerofloat, xanthate, 2# oil. Zn-S bulk flotation:$CuSO_4$ xanthate, 2# oil Zn/S separation: lime (PH 11-11.5), $CuSO_4$	Ore grade Pb2.57, Zn4.50, S13.00 Pb conc.: grade 63.67 recovery 85.19 Zn conc.: grade 52.13 recovery 91.23 Pyrite conc:grade42.25 recovery 66.40
10	Huangshaping (hypo-mesothermal filled replacement)	galena, marmatite, pyrite, sphalerite, chalcopyrite	one-stage grinding 65 %	Pb-Zn/Zn-S/G Pb/Zn Zn/S	"Equiflotability" (mostly for Pb): aerofloat 30, xanthate 100, C10H18O oil 100, PH6-7. "Equiflotability"(mostly for Pb, Zn): lime (PH8.5-10.5), xanthate 15 Pb-Zn separation: lime (PH 11.5-12.0), $ZnSO_4$ 600, Zn-S bulk flotation: $CuSO_4$ 560-620, xanthate 150-220, C10H18O oil 110-170, Zn/S separation: lime(PH12) $CuSO_4$ 110 xanthate 15	Ore grade: Pb3.19, Zn 5.80, S13.64 Pb conc.: grade 71.22 recovery 81.31 Zn conc.: grade 44.11 recovery 93.29 Pyrite conc:grade 29.55 recovery 52.99

No.	Concentrator (deposit)	Main metallic mineral	Grinding stage & fineness (-200 mesh)	Principle flotation flowsheet	Separating condition (g/T)	Process data (%)
11	Xinochan (mesothermal filled)	galena, sphalerite pyrite, 4 alkgite	one-stage grinding 65 %	C/Pb/Zn-S/S Zn/S	C-removal flotation: Na_2SO_3 450, Na_2CO_3 275, $ZnSO_4$ 236, 2# oil Pb flotation: $C_4H_9OH_2$ solution 36, Na_2SO_3 450, $ZnSO_4$ 450, 2# oil Zn, S bulk flotation: $CuSO_4$ 270, butyl xanthate 300, 2# oil Zn/S separation: lime (PH13)	Ore grade: Pb 1.61, Zn 3.44, S 16.59 Pb conc.: grade 54.39 recovery 76.02 Zn conc.: grade 45.66 recovery 57.94 Pyrite conc.: grade 36.53 recovery 65.16
12	Xiling (mesohypothermal filled replacement)	galena, sphalerite pyrrhotite, pyrite	two-stage grinding one-stage: 70-80 % Zn conc. regrinding 90 %	Pb-Zn-S/S/S	Pb flotation: $ZnSO_4$ 1000, Na_2SO_3 300, NaCN 10, butyl-ammon aerofloat 25, 2# oil 25 Zn flotation: lime 1000, $CuSO_4$ 405, butyl xanthate 120, 2# oil S flotation: H_2SO_4 6950, butyl xanthate 120, 2# oil 30	Ore grade Pb 2.95, Zn 4.46, S 22.29 Pb conc.: grade 77.60 recovery 85.10 Zn conc.: grade 47.36 recovery 79.07 Pyrite conc.: grade 22 recovery 65.79
13	Fankou (mesothermal filled replacement)	galena, sphalerite pyrite	three-stage grinding (continuous three-stage grinding 95-96 % Pb coarse conc. regrinding 85-90 % (-32.5 mesh))	Pb-Zn/S-S	Pb flotation: lime (PH11-12), $ZnSO_4$ 220, butyl xanthate 40, con. 70 oil 5-12 Zn flotation: lime (PH11-5), $CuSO_4$ 600, butyl xanthate 500, con. 70 oil 30 S flotation: H_2SO_4 2000-1500 (PH6), butyl xanthate 200, con. 70 oil 100	Ore grade: Pb 5.11, Zn 12.11, S 20.82 Pb conc.: grade 51.67 recovery 79.10 Zn conc.: grade 51.36 recovery 91.44 Pyrite conc.: grade 32.59 recovery 15.63
14	Lecheng (pyrite)	galena, sphalerite pyrite	one-stage grinding 75-80 %	Pb-Zn/S-S	Pb flotation: lime (PH11-12) $ZnSO_4$ 400, butyl xanthate 300-350, 2# oil 60 Zn flotation: lime (PH12), $CuSO_4$ 350-350, butyl xanthate 180-250, 2# oil 20	Ore grade: Pb 1.90, Zn 6.83, S 26.0 Pb conc.: grade 67.86 recovery 81.59 Zn conc.: grade 45.25 recovery 93.87
15	Pb-Zn-Cu concentrator Yingshan (mesothermal filled replacement)	galena, sphalerite pyrite chalcopyrite native silver	(Pb-Zn-S system) one-stage grinding 60-65 % (Pb-Zn-Cu system) one-stage grinding 65-70 %	Pb-Zn-S/S Zn/S	Pb flotation: lime (PH7-7.5) (cleaning) 6, $ZnSO_4$ 300, Na SO_3 5, xanthate 35-50, 2# oil 45-60 Zn, S bulk flotation: $CuSO_4$ 300, xanthate 60, 2# oil 90 Zn/S separation: lime (PH11) (cleaning 12), xanthate 7, 2# oil 16	Ore grade: Pb 1.36, Zn 1.36, S 10.50 Pb conc.: grade 66.15 recovery 85.39 Zn conc.: grade 51.51 recovery 82.86 Pyrite conc.: grade 40 recovery 45
				Cu-Pb/Zn-S Pb/Cu	Cu, Pb bulk flotation: lime (Ph 7, 5), Na_2SO_3 300, $ZnSO_4$ 400, xanthate 40, 2# oil 60 Pb/Cu separation: activated C, lime (PH10-12), NaCN 100, 2# oil (a little) Zn flotation: lime (PH8), $CuSO_4$ 300, xanthate 40, 2# oil 50	Ore grade: Pb 1.96, Zn 1.50, Cu 0.42 Pb conc.: grade 70.25 recovery 77.01 Zn conc.: grade 45.47 recovery 56.32 Cu conc.: grade 8.66 recovery 60.90

No.	Concentrator (deposit)	Main metallic mineral	Grinding stage & fineness (-200 mesh)	Principle flotation flowsheet	Separating condition (g/T)	Process data (%)
16	Testing (mesothermal filled)	galena, sphalerite chalcopyrite (a few) pyrite (marcasite)	one-stage grinding 50 %	Cu-Pb/Zn/CaF2/S Cu/Pb	Cu-Pb bulk flotation: Na_2CO_3 (PH8-8.5), $ZnSO_4$ 550-650, $Na_2S_2O_4$ 450-500, NaCN 5, Na_2S 10-20, butyl-amine aerofloat 30-40, 2# oil 20. Cu/Pb separation: activated C 100-130, $Na_2Cr_2O_7$ 65-75, PH7-8. Zn flotation: $CuSO_4$ 150-200, xanthate 30-35, pine oil 60 Fluorspar flotation: Na_2SiO_3 50-100 Oleic acid 50-150, PH9	Ore grade: Pb0.79, Zn1.30, Cu0.087 CaF_2 11.74 Pb conc.: grade 72.45, recovery 85.95 Zn conc.: grade 55.65, recovery 88.95 Cu conc.: grade 23.17, recovery 65.60 CaF_2: grade 97.17, recovery 68.58
17	Huangshaping (skarn)	sphalerite, galena chalcopyrite molybdenite pyrrhotite pyrite	one-stage grinding 55 % - 65 %	Cu-Pb-Zn/S Cu-Pb-Zn Pb/Zn	Cu-Pb bulk flotation: xanthate 15-20, 2# oil 45-50, PH7 Cu/Pb separation: activated C 15, $ZnSO_4$ 165, Na_2SO_3 60, $K_2Cr_2O_7$ 6-10 Zn removal from Pb conc.: xanthate 3-5, 2# oil 1-3, NaOH (a little). Zn flotation: NaOH, $CuSO_4$ 25, xanthate 15-17, 2# oil 50	Ore grade: Pb0.30, Zn1.21, Cu0.25 Pb conc.: grade 65.60, recovery 65.61 Zn conc.: grade 50.52, recovery 90.76 Cu conc.: grade 25.64, recovery 65.75
18	Tiefeng (skarn)	galena, sphalerite chalcopyrite pyrite some secondary copper oxides	continuous two-stage grinding 70-75 % (Pb/Cu separation middlings back to two-stage grinding)	Cu-Pb/Zn/S Pb/Cu	Cu-Pb bulk flotation: $ZnSO_4$ 300, NaCN, aerofloat 35, xanthate 24, 2# oil 40 Pb/Cu separation: NaCN, 2# oil 3, PH7, lime (cleaning PH11). Zn flotation: lime (PH10.5, cleaning 11-12), $CuSO_4$ 250, xanthate 6, 2# oil 40.	Ore grade: Pb1.17, Zn1.56, Cu0.71 Pb conc.: grade 65.45, recovery 85.7 Zn conc.: grade 46.15, recovery 87.0 Cu conc.: grade 17.51, recovery 47.5
19	Hetian (skarn)	galena, cerussite sphalerite chalcopyrite pyrite, pyrrhotite bornite	one-stage grinding 70 %	Cu-Pb/Zn/S Cu/Pb	Cu-Pb bulk flotation: $ZnSO_4$ 300-400, butyl amine aerofloat 70-60, 2# oil 100. Cu/Pb separation: Na_2SiO_3 100, CMC 10, butyl amine aerofloat 5. Zn flotation: Na_2CO_3, $CuSO_4$ 120, diesel 55.	Ore grade: Pb1.82, Zn0.36, Cu0.111 Pb conc.: grade 61.42, recovery 87.29 Zn conc.: grade 46.60, recovery 88.64 Cu conc.: grade 21.37, recovery 45.63
20	Pb-Zn-Cu-S concentrator 20 Zhaigongling (mesothermal-filled replacement)	galena, sphalerite pyrite, chalcopyrite pyrite, native gold electrum	one-stage grinding 65 %	Cu-Pb-Zn/S Cu/Pb	Cu-Pb bulk flotation: butyl amine aerofloat 30-40. Cu/Pb separation: $K_2Cr_2O_7$ 30-40 Zn flotation: NaCN 15-20, $CuSO_4$ 70-80, butyl amine aerofloat 20-30. S flotation: $CuSO_4$ 80-100, butyl amine xanthate 40-60, 2# oil 40.	Ore grade: Pb1.22, Zn1.34, Cu0.16, S5.[illegible] Pb conc.: grade 54.00, recovery 75.27 Zn conc.: grade 43.22, recovery 64.48 Cu conc.: grade 17.61, recovery 42.26 Pyrite conc: grade 39.56, recovery 55.25

No	Concentrator (deposit)	Main metallic mineral	Grinding stage & fineness (-200 mesh)	Principle flotation flowsheet	Separating condition (g/T)	Process data (%)
21	Xiangjie ([illegible])	galena, sphalerite pyrite chalcopyrite	two-stage grinding Primary: 60 % Cu-Pb bulk flotation middlings regrinding 70 %	Cu-Pb-Zn-Sp/G Cu/Pb Zn/Sp	Cu-Pb bulk flotation: $ZnSO_4$ 1[illegible], NaCN [illegible], butyl xanthate 60, 2# oil 85 Cu/Pb separation: activated C 117, H_2SO_4 60, $K_2Cr_2O_7$ 300, $FeSO_4$ 55, butyl xanthate 4, PH 5.5 Zn-Sp bulk flotation: lime (PH7.0), $CuSO_4$ 280, butyl xanthate 16, 2# oil 77 Zn/Sp separation: lime (PH11), 2# oil 31.	Ore grade: Pb 1.16, Zn 1.23, Cu 0.12, S 5.10 Pb conc: grade 53.08, recovery 86.50 Zn conc: grade 45.66, recovery 81.06 Cu content: grade 27.39, recovery 45.46 Pyrite conc: grade 50.20, recovery 62.30
22	Bajiazi (hydrothermal filled replacement)	galena, sphalerite pyrite chalcopyrite black [illegible]	two-stage grinding continuous two-stage grinding 76 % Cu-Pb bulk flotation coarse concentrate regrinding 91 %	Cu-Pb/ Zn-Sp/G Cu/Pb Zn/Sp	Cu-Pb bulk flotation I (separate cell): lime (PH7.5), Na_2SO_3, $ZnSO_4$ 350, 31# aerofloat 35 Cu-Pb bulk flotation II: $ZnSO_4$ 45, NaCN, butyle amine aerofloat 35 Cu/Pb separation: activated C 120, H_2SO_3 (as SO_2) 400, $Na_2Cr_2O_7$ 0.0012, temperature 50 t, PH 5.5 Zn-Sp bulk flotation: $CuSO_4$ 200, butyl xanthate 100, 2# oil 50. Zn/Sp separation: lime (PH 12-13), $CuSO_4$ 10, butyl xanthate 20, activated C 50.	Ore grade: Pb 0.57, Zn 2.06, Cu 0.11, S 7.52 Pb conc: grade 56.18, recovery 82.20 Zn conc: grade 46.21, recovery 64.81 Cu conc: grade 20.73, recovery 37.61 Pyrite: grade 37.02, recovery 65.47
23	[illegible] (Pyrite)	pyrite sphalerite chalcopyrite native gold some tetrahedrite [illegible] bornite copper [illegible]	three-stage grinding 72 % mixed concentrate regrinding 94 % deslimerized mixed concentrate regrinding 99 %	Cu-Pb-Zn Sp/G Cu-Pb-Zn/Sp Cu/Pb-Zn	bulk flotation: free CaO 5.6-22.4 g/m³, butyl xanthate 150-230, 2# oil 20-30 S removal: free CaO 850 ±50 g/m³, butyl xanthate 130-170. Cu/Pb-Zn separation: Na_2S 800, H_2SO_3 (as SO_2) 900-1200, butyl xanthate 10-30, PH 6.	Ore grade: Pb 4.09, Zn 5.34, Cu 0.75, S 32.16 Pb-Zn conc: grade Pb 17.35, Zn 22.62 recovery Pb 74.41, Zn 75.01 Cu conc: grade 7.56, recovery 47.51 Pyrite conc: grade 31.61, recovery 27.69

Note: Pb, Zn, Cu, Sp, G refers to lead sulfide, zinc sulfide, copper sulfide, iron sulfide and gangue respectively. "/" left top corner and right bottom corner refers to floatable minerals and unfloatable minerals respectively. Pb/Zn/G refers to Pb, Zn preferential flotation flowsheet.