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To Processing of Gold-Bearing Sulphidic and Arsenic Ores and Concentrates

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ABSTRACT: Are provided the short review on processing of gold-bearing sulphidic and arsenic ores and concentrates in article by oxidizing roasting by the subsequent cyanation or sorption cyanation. In the presents time conventional is considered the scheme including roasting and cyanation or melting of a candle end. This method allows to take gold at the level of 80-96%. Alternatively oxidizing roasting, we describe a method bacterial leaching of sulphidic and arsenic gold-bearing concentrates.

KEYWORDS: gold-bearing, arsenic ores, cyanation, roasting, candle end, oxidizing, chlorination, primary matte, melting cake, biooxidation.

I. INTRODUCTION

Gold and gold-silver ores of the Western Uzbekistan belong to persistent ores, first of all. For processing of such ores by various organizations it is offered:

- two-stadial oxidizing roasting and cyanation of candle ends (IRGIPRMD);
- roasting of a concentrate and melting of the burned candle end on the metallized matte (EMMRINFM);
- autoclave decomposition of sulfides and cyanation of cake (SibPSRINFM);
- roasting of a concentrate soda and hydrometallurgical processing of a candle end (KazIMS);
- dissolution of gold-bearing sulphidic and arsenic concentrates nitric acid and a gold leaching from cake solutions of thiourea or sorption cyanation (GC IMR);
- high-temperature chlorination (IRGIPRMD, ZabSRI);
- oxidizing melting of the granulated concentrate for dump slag and iron matte, retractive melting of primary matte, sulphuric acid decomposition of secondary matte, melting of a cake, sulphuric acid leaching on draft gold-silver alloy (GCSRPCIPMD);
- nitrogen-acid decomposition of sulphidic and arsenic concentrates with regeneration of nitric acid and cyanation of a cake (GC IMR);
- biooxidation as opening process the gold-content of sulphidic and arsenic concentrates, is widely applied in many countries of the world and other methods in recent years.

II. RELETED WORK

THE FACTORS DEFINING "PERSISTENCE" OF ORES.

The main factors defining technological complexity or "persistence" of gold-bearing raw materials are:

- existence in ores is thin - and dispersion the interspersed gold in sulfides from which it is practically not taken by direct cyanation;
- presence at initial raw materials of the tellurides of the gold which are slowly dissolved in cyanides;
- existence on a surface a golden, the films of primary or secondary character worsening contact gold with cyanic solution;
- presence at initial ores of components, the onside at cyanation a role of reducers (absorbent of oxygen) or "cyanide" (abductor of cyanide). Antimony minerals — antimonite, arsenic - realgar and an auripigment, iron - marcasite, pyrrhotine can be carried to number of reducers. The absorber of cyanide is copper in the form of oxides, sulfides, carbonates and sulfides;
- existence in ores of minerals which can cause premature sorption of gold and free cyanide from industrial cyanic solutions. The strongest natural sorbent of gold is carbonaceous substance.

On the nature of association of gold with mineral components which is the main factor, defining technological properties of ores on classification IRGIPRMD four geologo-technological types are allocated;



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In the presence of gold-bearing sulfides in finished are taken in a collective floatation concentrate (gold tellurides, gold-bearing sulfides, free gold) which is exposed to cyanation after roasting or other way of opening. Cyanation is the main method of processing of gold ores. It is applied also to extraction of gold from tails and concentrates of gravitational enrichment, candle ends, tails of flotation and flotoconcentrate, flotation industrial product. The fine gold concluded in minerals, the main in sulfides and quartz is practically not extracted by cyanation. Most often the complication of cyanic process happens because of presence of copper minerals, minerals of antimony and arsenic, the easily oxidized sulfides of iron, graphite. In last years, along with improvement and development ways of improvement of indicators of cyanation researching on development of the new hydrometallurgical ways based on application less toxically of solvents are carried out.

III. OBJECTS AND METHODS OF RESEARCH

SORPTION CYANATION with use of the activated coals (process "coal in a pulp") was considerable achievement in technology of processing of ores of gold and silver. This way is widely applied in a number of the countries with the developed gold extraction industry. The technology of a good way is fulfilled and in detail described in literature. Long-term experience more than 30 factories showed advantages of "coal in a pulp" technology before traditional: operations of condensation and filtering of pulps are excluded, duration of a leaching of precious metals is reduced, it is raised extraction gold (especially from ores and concentrates, the consist of sorption and active carboniferous substances), the quality of products, final for factories, is sharply increased.

CURRENT STATE OF TECHNOLOGY OF PROCESSING OF GOLD-BEARING CONCENTRATES.

Carbonaceous gold-arsenic concentrates belong to special type of persistent gold-bearing raw materials.

Technological persistence of these products of a conditional a thin impregnation of gold in sulfides (mainly in arsenopyrite) and existence of mainly amount of active carbon with highly sorption ability in relation to a gold-cyanic complex.

The main methods of processing of persistent concentrate are oxidizing roasting and its variety, bacterial leaching, a hydro-sulfatization in solution of nitric acid, autoclave leaching. All these methods allow to open persistent gold. Then for its transfer to a commodity product cyanation using.

OXIDIZING ROASTING. A main objective of oxide roasting of gold-bearing sulphidic concentrate is opening of persistent gold, which is not taken in the course of direct cyanation of a concentrate.

To category persistent, first of all, on the gold:

- being in close association with sulfides, sulfoarsenides (generally with pyrite and arsenopyrite);
- covered with films of oxides of iron and other compounds;
- thin-imbedded in quartz.

The quantity of other forms of persistent gold in the radial sulphidic concentrates, as a rule, insignificantly has also no significant effect on total balance of metal.

Processing the gold-sulphidic gravio-and floto-concentrated can sometimes be carried out by cyanation after a re-milling to fineness of 95% of-0,044 mm. In case of persistent the arsenic-content of concentrate opening of gold before cyanation is necessary.

PYROMETALLURGICAL METHODS. The most extension way of opening of sulphidic floto-concentrate is the oxidizing roasting consisting in heating in an oxidizing atmosphere up to the temperature of 400-500 °C. Oxidizing roasting is carried out so that to receive a candle end which physical and chemical properties provide most extraction of gold at the subsequent cyanation. When roasting pyrite is oxidized to hematite $\gamma\text{-Fe}_2\text{O}_3$, arsenopyrite - to the maggemit $\gamma\text{-Fe}_2\text{O}_3$. The fullest decomposition of sulfides happens at a temperature of 650-700 °C. Above 800 °C begin melting of particles and agglomeration of a candle end (due to local overheating, pyrrhotine alloyage - an intermediate product of oxidation of pyrite iron oxide-protioxide Fe_3O_4).

As when roasting arsenopyrite formation of arsenates of iron which negatively influence cyanation is possible, IRGIPRMD offered to carry out roasting to two stages: with removal in 1 stage of roasting of bulk of arsenic in the form of As_2O_3 (at the same time access of air is limited) and in the 2nd stage — sulfurs. For roasting furnaces of the boiling layer are used. It is necessary to carry a necessary of extraction of gold to shortcomings of roasting from poisonous the arsenic-content dust which granulate and subject to roasting together with an initial concentrate. For catching of sublimate with three-oxide of arsenic used a complex system of purification of gases, inclusive cyclones, electric precipitators, hose filters and other devices.



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In dust of cyclones and electric precipitators passes up to 16% of gold. Quite often when roasting components of workability ore give fusible mixes which cover with a dense bed parts of gold, doing them inaccessible to effect of cyanic solution. Especially indicators of cyanation of argentiferous concentrates worsen.

Processing of the sulphidic concentrates rich with arsenic, roasting is connected with pollution of the environment harmful oxides of sulfur and arsenic.

IRGIPRMD [1] for processing of carbonaceous gold-arsenic concentrates two-stadial oxidizing roasting in BL furnaces with the further hydrometallurgical processing of candle ends is recommended (cyanation).

The hydrometallurgical scheme includes interval alkaline processing of cake of the 1st cyanation for opening of the gold browned in the course of a total by oxides of iron and arsenic-content components. Despite the achieved success in direction of processing arsenic-pyritic the gold-bearing of concentrates according to the scheme "roasting-cyanidation", even when roasting in the boiling layer it is impossible to recognize indicators of extraction of gold on the advanced foreign companies as satisfactory and the gold content in dump tails at a number of factories makes 8-9 g/t, and in certain cases 14-17g/t.

The main products of roasting of concentrates in the furnace of "BL" are a candle end and dust: cyclonic, electric precipitators, crystallizer, hose filters. The gold bulk (73-75%) when roasting in "BL" concentrates in a candle end. Other 25-27% distribution between dust of cyclones, the electric precipitator, a crystallizer and the hose filter.

In the last two devices products with the high content of arsenic (30-60%) turn out. Components of the gold caught from a dust of a cyclone and the electric precipitator makes about 25% at a content of 50-75 g/t. Gold in the dust of a crystallizer and hose filters belongs to losses.

In the work performed by N.A. Kolesnikov [2] in EMMRINFM when studying persistent arsenic-carbonaceous gold-bearing ores of the "Bakyrchik" field the optimum mode of oxidative roasting in BL furnaces is set. At the same time a provided a possibility of conducting process of roasting both in a one, and in two stages. Taking into account return of dust of cyclone and electric precipitators extraction of gold in a candle end made 97,3%, arsenic in arsenical anhydride more - 60%. Oxidizing roasting possesses a significantly shortcoming.

From the economic and ecological points of view emission in the environment arsenical and the sulfur of gases is inadmissible. Now the scheme including roasting and a cyanidation or melting of a candle end is considered accepted. Extraction of gold on this technology can make 80-96% of concentrates.

One of options of processing is the sulphatizing roasting of a concentrate which is carried out at limited access of air, "clearing" of a candle end with water, its mixing with strong sulfuric acid, a sulfatization, leaching of a agglomeration, drying of the rest and its heating for combustion of the emitted sulfur. Though this option is also more difficult, than oxidative roasting of a concentrate "tightly", its big advantage is that he leads to considerable (by 4-4,5 times) to reduction of weight of a derivable product in comparison with a candle end exit.

On a sulfatization granules from concentrate mix with a strong chamois oxide have to come to BL furnaces (by analogy with a sulfatization dust, applying at the Chinkent lead plant).

E.K. Galimzhanov, V.V. Chesnokov and etc. [3] is established by that in interaction of pyrite, arsenopyrite with soda and carbon in the oxidizing atmosphere arsenic and sulfur almost completely (for 97-99%) remain in a candle end, turning into nonvolatile water-soluble connections - arsenate of sodium and sulfate of sodium: iron at the same time is oxidized for 90-95% to Fe_2O_3 , for 5-10% to FeO and Fe_3O_4 .

IV. RESULTS OF RESEARCH

When roasting the carbonaceous gold-arsenic concentrate with soda (100% of concentrate weight) at 700 °C within 1 hour almost full decomposition of the main gold-bearing minerals without allocation of toxic compounds of arsenic and sulfur in a gas phase is provided. At the subsequent water leaching of a candle end arsenic and sulfur proceed in solution in the form of arsenate and sulfate of sodium and are removed from process. Received cake, an exit of which makes 70-72% of concentrate weight, consist of 0,3-0,5% of arsenic, 0,2-0,4% are gray, 0,5-0,8% of carbon and 93-100 g/t of gold.

For destruction of films of oxides of iron, the passivation the gold opened in the course of roasting and decrease in sorption activity of a residual carbon cake water leaching of a candle end cast to hydrometallurgical preparation for a cyanidation, the cake consisting in processing of a pulp sulphurous gas of small concentration (1,5-2,5%). The received product practically does not contain the components interfering the cyanation executive on standard technology. Extraction of gold in cyanic solutions makes at the same time 95,5-96,5%.

Other method of processing of concentrates is chloridation. This process was offered by B.N. Lebedev for complex processing of pyritic candle ends, and then and for some industrial product of concentrating factories.



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Yu.G. Sazhin [4] researches established a possibility of processing of gold-arsenic concentrate by way of chloridation with complex extraction from them valuable components.

In the course of chloridation in optimum term volatilization of metals from the studied concentrates reached (%): 97,6-99,5 gold, 95,0-98,0 silver, 94-96,5 coppers, about the 100th lead, 82-90 zinc and from candle ends 85-95 sulfurs. Gold content in the remains of chloridation was 1,4-2 g/t.

Process of chloridation is very universal, it can be used for extraction of gold from concentrates practically of any structure. The important advantage of this process - a possibility of complex processing of concentrates with extraction from them not only gold and silver, but also the concomitant of precious metals. It is necessary to refer complexity of hardware registration of high-temperature roasting and an recovery of sublimates to shortcomings of a chlorine-sublimation. For this reason chloridation is not applied in a gold mining manufactory yet.

In M.N. Zyryanov's article, etc. [5] are given results of researches in laboratory and the half-industrial scales of processing of persistent floatation concentrates of various fields by chloride electric melting.

At the same time the possibility of rather full extraction of gold (94-97%) and the accompanying metals of silver, copper and lead (90-95%) in chloride sublimates of small volume (an exit of 5-7% of a concentrate mass) which can be effectively processed on commodity metals by the known method is shown.

One of ways of extraction of gold is melting.

R.A. Isakova, etc. [6] conducted processing researches the arsenic-bearing of gold concentrate with application of a vacuum. At vacuum processing of such concentrates (more than 10 deposits) irrespective of the initial content of 97-99% of arsenic in one stage it is transferred to the sublimates representing mix metal and the sulfide of forms.

The arsenic-bearing of materials appeared the most convenient device for a vacuum working the vertical vibroconveyor warmed from within. Semi-industrial tests on release of arsenic from the bacterial and the nejdantin floto-and gravio-concentrate, carried out on vibro-vacuum installation of Haydarkan mercury plant, show that at a temperature of 670-700 °C, pressure of 3,999-6,665 KPA arsenic for 97-98% passed into sublimates.

The sulphidic concentrate in the inert environment melting was also filled in blocks. Candle ends subjected to cyclonic melting in mix with a copper concentrate.

Lack of a way is the complexity of a execution of roasting in a vacuum and the small productivity of installation.

A significant amount received now at the gold-extracting enterprises the sulfur of concentrates is sent to the pyrometallurgical plants where gold is extracted in passing with non-ferrous metals of the main production. As a rule, in such a way process the gold-bearing sulphidic concentrates containing copper, lead or antimony along with gold.

In principle do not differ in way of pyrometallurgical processing of collective gold-bearing concentrates from well-known and in detail the ways of extraction of precious metals described in literature when melting copper, lead and antimonial concentrates

BACTERIAL LEACHING. Researches difficult the concentrates processed the arsenic-bearing persistent by Rudi showed to micro biological leaching that by optimization of such conditions of leaching as pH, the pulp temperature, fineness of an initial concentrate, concentration of a oxygen and carbon dioxide, nutrients, etc., it is possible to increase the speed of a leaching of sulfides considerably. The vat method of bacterial leaching has a number of features, which distinguish it from underground and compact. Leaching is carried out in tubs or the tank with air hashing therefore the speed of bacterial oxidation in them has to be much higher, than at underground and compact leaching. Leaching is carried out in dense pulps and applied to concentrates in which the content of sulfides is much higher, than in ore or waste breed.

Due to the features of vat process its efficiency is defined by a number of specific factors. In leaching solutions ions the different of elements collect in big number. For example, the content of arsenic reaches 8g/l, gland - 15 g/l and more. Such high concentrations of ions of especially trivalent arsenic, inhibit activity of bacteria, reduce its activity. Obtaining the production culture of microorganism steady against presence of these element and active in oxidation of sulfides, is possible by adaptation to all complex of the physical and chemical and chemical factors defining conditions of leaching of a concrete product. Only use of the adapted culture allows to increase leaching speed considerably.

Speed of leaching depends on many factors: concentration of reagents, temperatures, speed of hashing, surface of a firm phase and others. As a rule, it continuously changes during process.

Unlike chemical and pyrometallurgical methods at bacterial leaching necessary to bring arsenic out of process to stop a depression of activity of bacteria. During leaching the temperature of 40 °C needs to support within 20-40 °C, pH =1, 2, 5 (with sulfuric acid). Working bacterial solution prepare in special capacities - ferments. The equipment from rustproof steel is necessary for implementation of schemes of bacterial leaching. Process duration - 75-120 h. Process accelerates if to carry out it in the conditions of continuous cultivation of bacteria.



Purification of solutions after leaching from arsenic is made by lime. After a consolidation of solutions sulfuric acid they can be use in a turn.

Schemes of processing of concentrates include directly bacterial leaching, purification of bacterial solutions after leaching with their use in a turn and cyanation of the remains of leaching. Leaching conditions the next: L:S =1:5, fineness of concentrates of a 90-95% class – 0,074 mm, temperature is 28-35 °C, pH pulps 2,2-1,7.

Regeneration of the fulfilled bacterial solution is carried out by neutralization by their limy agaric mineral to pH =2,8-3,2. Concentration of cages usually makes 106-109 ml.

Arsenopyrite oxidation level after 60-120 h leaching reaches 80-90%. Gold extraction by cyanation of the remains of a bacterial leaching reaches 85-91%.

Gold-arsenic carbonaceous concentrates differ by special persistence. Gold in them is connected with arsenopyrite, the carbon slates which are present at a concentrate possess a high sorption activity in relation to gold cyanic complex. The scheme of processing of these concentrates provide preliminary removal of a part of carbonaceous slates flotation, bacterial leaching of tails of flotation and cyanation of the remains of a leaching. When leaching during 70 h the arsenic content in a concentrate decreases from 6,6% to 1,0-1,2% at the oxidation level of sulphidic arsenic of 93-95%. After sorption cyanation of the remains of leaching extraction of gold made 92% of operation whereas cyanation of initial concentrate without leaching allows to extract only 5-10% of gold. The carbon concentrate received by flotation contains up to 20 g/t of gold and up to 1% of arsenic and can be processed, for example, by melting at a under-charge to other concentrates of non-ferrous metals.

The received results of laboratory research are confirmed with tests of technology of bacterial leaching on the integrated installation for carrying out vat process in the continuous mode with regeneration and use of reverse bacterial solutions. The expediency of conducting process of bacterial leaching in one stage and a possibility of leaching of concentrate without preliminary allocation from them the carbon of substances, in case of presence of the last is shown. Execution preliminary technical and economic calculations showed high efficiency and an economic of application bacterial a leaching for opening of thin-imbedded gold from the sulfide of minerals before their cyanation. Applying of bacterial methods when processing the arsenic-bearing of concentrates excludes the pollution atmospheres the toxic gases containing sulfur and arsenic.

HYDROMETALLURGICAL METHODS. In GS IMR researching the gidrosulfatization method with use as oxidizer of the nitric acid which is the most effective reagent for opening of thin-imbedded gold in sulfide. Sulfides of iron, non-ferrous metals and sulfoarsenides of arsenic oxidizing to sulfates and pass into solution (behind an of insoluble sulfate of lead). Arsenic is present at solution in the form of an orthoarsenical acid.

In addition, at solution there are a residual nitric acid and sulfuric acid formed as a result of reactions of oxidation of sulfides. The insoluble rest – cake gidrosulfatization - consists - in main of silicates and other insoluble component of an initial concentrate. In cake consenter gold, silver, lead, antimony. At the same time release of the harmful substances polluting the environment excluded. The nitroz gases which are emitted in the course of reaction of sulfides with nitric acid are easily regenerated in nitric acid which recovery in the process head. Along with it the possibility of complex use researching a concentrate is created. It is in passing possible to take a sulfuric oxide, iron sulfate, non-ferrous metals and to emit arsenic in the form of almost insoluble compound of arsenate of iron.

Processing of a concentrate is carried out in the reactor at a constant barbotage of oxygen (air) through a pulp at L:S =1:7. Concentration of nitric acid in an initial pulp has to consist of 400-500 g/l, duration a leaching - 2 h, pulp temperature - 75-80 °C. For acceleration of process at the beginning the pulp needs to be warmed up, further as a result of exothermic reaction enough heat is distinguished and heating it is optional. An exit of a cake depending on a composition of a concentrate varies within 15-35% of an initial concentrate.

Respectively the content of gold and silver in cake in comparison with an initial concentrate increasing by 3-7 times. The acid consumption taking into account regeneration of the gases departing the nitroz gases and of an oxides are made 900-1100 by kg/t. For full sedimentation of silver before filtration of a sour pulp it is necessary to load chloride sodium in the quantity corresponding to silver content in a concentrate.

V. CONCLUSION

From cake of a gidrosulfatization it is possible to apply to extraction of precious metals cyanidation, thiocarbamide leaching, or melting in common with a lead concentrate or with copper matte. Extraction of precious metals in cake gidrosulfatization usually makes 98,0-99,5%, in cyanic solution - 95-96%, when melting 98-98,5%.

There are other methods of opening the gold-bearing of sulphidic and arsenic concentrates.



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