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Edited by

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Foreword

Practically, all human societies depend on the availability and use of mined products. Mining and mineral processing has played a vital part in the history and economy of the Balkans.

In the world, mineral processing was an art till the 1920s, when it started to become a science. The achievements of fundamental science enabled the explanation of phenomena in the processes of mineral processing, or they started from fundamental science to come to an appropriate solution in mineral processing. In many respects mineral processing becomes fundamental science.

Balkan countries have more or less rapidly accepted innovations in the field of mining and mineral processing.

Generations of professionals from Balkan trained on the tradition of mining schools, afterward universities, (Schemnitz established 1702, Jachimov 1716, Banska Štiavnica 1725, Jekatarinburg 1730, L' Ecole Polytechnique 1794 in Paris, Politehnika in Prague, and certainly the most famous Bergakademie Freiberg founded in 1765, and much later, universities in the United States and Soviet Union) contributed to today's level of development of mineral processing, and contributed to the quality of studies of mineral processing, both in the world, and so in the Balkans.

After the Second World War in the Balkans a large number of universities, faculty, institutes and laboratories of mining industry with special departments for mineral processing were opened. In many Balkan countries remarkable impact on development of mineral processing had Russian and American schools.

A great number of researchers and specialists in Balkan area were occupied for more decades by the research in mineral processing. The goal of this research was establishment of concentration process in industry, capacity enlargement, optimization of processes, increase the energy efficiency of processes and devices, introduction or construction of new machines. Based on those activities, Balkan mining has been evolving and continuously operates up to nowadays. As a result, in the Balkan countries appeared a significant number of successful researchers in the field of mineral processing. They founded the first Balkan mineral processing Committee (1973), and then the Balkan Academy of Mineral Technology.

Balkan Congress on Mineral Processing is beening held for 40 years. Participation in the work of the Committee of the Balkan mineral processing is a strong link between the development of the science and profession with global trends, and it provides the possibility of establishing direct contacts between researchers, designers, equipment manufacturers and investors from the region and around the world. It has already become tradition to hold every second year an international event, "Balkan Mineral Processing Congress," in which participate, not only Balkan experts, than experts from the whole world.

Maintenance XVI Balkan Congress on Mineral Processing in Belgrade from 16 to 21 June 2015 is held under the auspices of the Ministry of Mines and Energy of Serbia, with the financial assistance of the Ministry of Republic of Serbia. Incomparably greater financial support Congress had from sponsors who strongly support the mineral processing industry all over the world.

Prof. dr Nadežda Ćalić

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PILOT-PLANT FLOTATION TESTING OF COPPER, LEAD AND ZINC MINERALS FROM RICH POLYMETALLIC ORE

Dejan Č.Todorović[1], VladanD.Milošević[1], Zoran B. Bartulović[1], Branislav B. Ivošević[1], Jelena B. Čarapić[1], Vladimir D. Jovanović[1], Sonja Z. Milićević[1]

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Abstract: The investigation results presented in this paper were performed in order to examine the possibility of efficient processing of valuable minerals from the rich complex polymetallic ore with extremely high content of copper, lead and zinc (0.86% Cu, 4.46% Pb and 2.51% Zn). These tests were carried out in pilot-plant facility of the Laboratory for mineral processing in Institute for Technology of Nuclear and Other Mineral Raw Materials(ITNMS). The role of scientific research is to thoroughly investigate the flotation concentration of valuable components and to confirm the laboratory tests on which the technological scheme to produce a separate concentrates of copper, lead and zinc is defined, on pilot-plant scale. While performing those pilot-plant tests, it was found that it is possible to produce three commercial products from this ore, following a copper, lead and zinc rough concentrates single-stage cleaning.

Keywords: polymetallic ore, flotation, pilot-plant, copper, lead, zinc.

INTRODUCTION

In order to investigate the possibilities for effective preparation and concentration of copper, lead and zinc minerals from the rich polymetallic ore in the Laboratory for mineral processing of ITNMS Institute, technological experimentswere conducted in pilot plant facilityusing ore representative sample.

As a basis for defining the technical and technological flotation conditions onpilot-plant level, Institute researchers used the Report of technological results defined from laboratory tests carried out during the last few years.

This paper provides an overview of the activities conducted during the pilot-plant test and are presented with the achieved results.In addition, paper contains expert commentary ITNMS associates who are engaged in this problem, as well as conclusions with a proposal on further activities.

The ultimate goal of these tests is to obtain a copper, lead and zinc concentrates according to commercial conditions and requirements for further pyrometallurgical processing.

EXPERIMENTAL PROCEDURE

Testing samples

Sample preparation

Ore sample for technological tests was prepared as follows:

- The ore sample was first crushed in the jaw crusher in open circuit to - 12 mm particle size.
- Primary crushed sample was further delivered on open circuit grain size reduction in the roll crusher with 4 mm gap between the rollers.
- The third level of the sample grain size reduction was carried out also in the roll crusher with 2 mm gap between the rollers, in a closed circuit. As a crushed product classification device was used continuous feeding vibration sieve with screen opening d = 2 mm.
- In this way, the sample coarseness was reduced to - 2 mm size.
- In this way comminuted sample after homogenization, represented the feed to milling process.

Physical and chemical characterization of samples

Sample specific gravity was determined by the pycnometer, and amounts:

γ=2.87 g/cm3

The ore natural pH value before milling and flotation process, measured inpulp with 68%of solids, amounts:

pH = 8.6

The sample moisture content amounts:

Wo=3.38 %

Table 1, Ore sample chemical composition.

Element	Ag, ppm	As, ppm	Bi, ppm	Ca, %	Cd, ppm	Cu, ppm	Fe, %	Hg, ppm	Pb, ppm	S, %	Sb, ppm
Content	>10	3382	0.51	1.10	185.90	8616	3.99	0.21	>10000	>5	497

Element	Se, ppm	Sn, ppm	Zn, ppm	Au, ppm	Au(R), ppm	Au(S), ppm	Ag, ppm	Pb, ppm	Zn, ppm	SiO_2, %	Al, %
Content	3.1	0.5	>10000	0.07	0.07	N.A.	33.2	48500	28800	51.5	4.84

Mineralogical and geological composition

Rich polymetallic ore microscopic examinationsare defined following ore minerals: galena, ch alcopyrite and sphalerite, and subordinated marcasite, pyrite, tetrahedrite and bournonite.Ganguemineralsare represented by quartz, diopside, chlorite, calcite, etc. (Figure1,2, 3, 4, 5, 6)

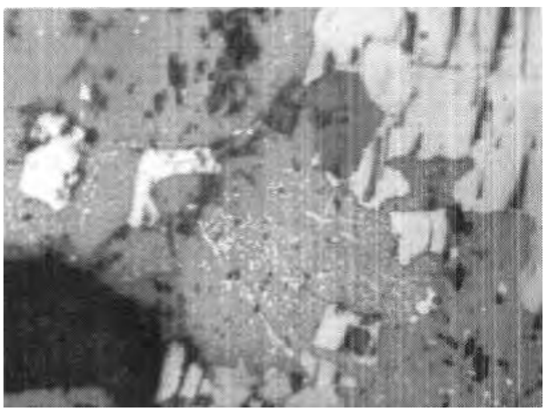

Figure 1, Marmatite with chalcopyrite inclusionsand suppressed galena remains.

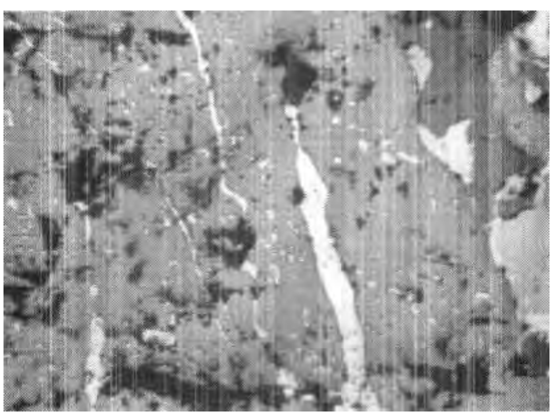

Figure 2, Marmatite with chalcopyrite inclusions and veins.

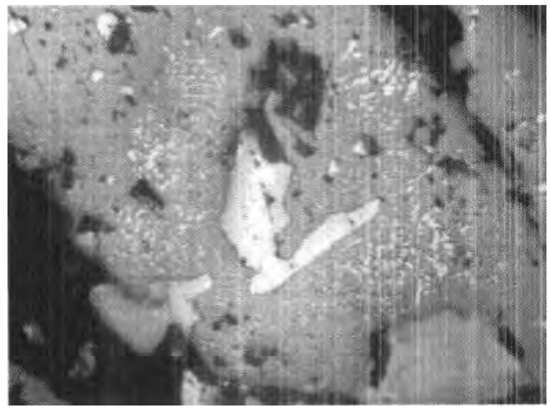

Figure 3, Marmatite with the galena affected chalcopyrite high density inclusions.

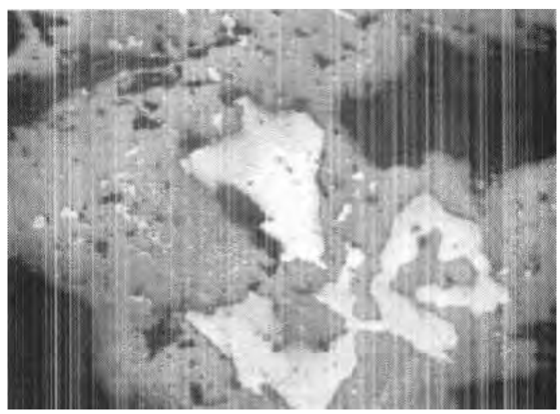

Figure 4, Marmatite with the galena affected chalcopyrite high density inclusions.

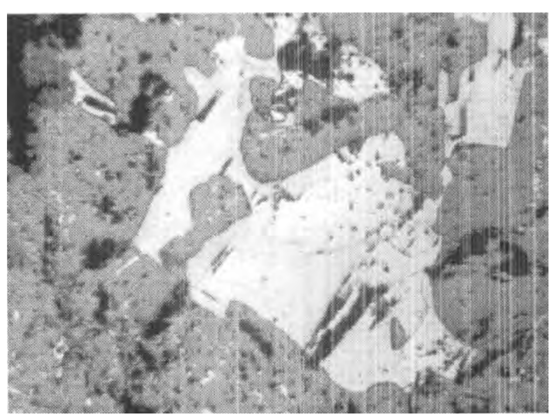

Figure 5, Marmatite with the chalcopyrite inclusions, suppressed galena remains, chalcopyrite, tetrahedrite and pyrite.

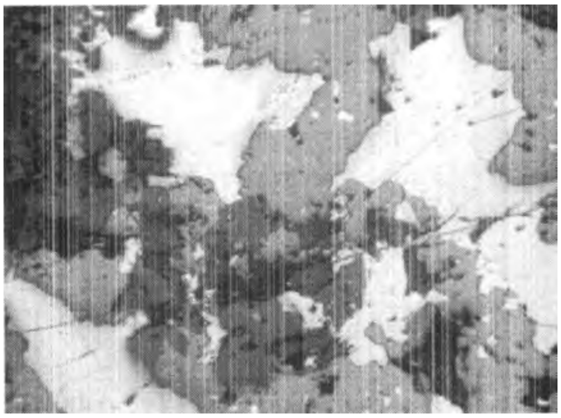

Figure 6, Marmatiteaffected galena, galena "Rags" in younger sulphides.

Galena forms a larger surfaces with fragments of sulfides and gangue minerals. Coarsenessof these fragments in galena is from 0.02 to 0.1 mm. Galena is also located in chalcopyrite in the form of inclusions grain size from 0.015 to 0.05 mm, and as well forms the surfaces to 0.15mm.

Sphalerite builds larger surfaces cracked and pushed with galena, tetrahedrite and chalcopyrite, wherein these minerals reach the coarseness of 0.025 mm to 0.1 mm. Sphalerite also occurs in the form of fragments in chalcopyrite and galena, and reaches the coarseness of 0.025 mm to 0.1 mm. Cracks in sphalerite are filled with a gangue minerals.

Likewise, chalcopyrite allocations in sphalerite are characteristic.Chalcopyrite grains, which occur in the form of intergranular film around the sphalerite grainsperimeter reach coarseness of 0.010 mm to 0.025 mm, while inside sphalerite grains chalcopyrite allocations can be very small, to under 0.005 mm.

Fine chalcopyrite allocations in galena and sphalerite can cause increased losses of chalcopyrite in lead concentrate and sphalerite in copper concentrate.

Technical and technological description of the flotation concentration pilot-plant process

Based on the laboratory tests results and technical and technological ITNMS equipment capabilities, equipment connectionand parameters synchronization is carried out for efficient probe implementation. Technical - technological processing and sampling parameters in the pilot-plant facility were established as follows:

- Flow capacity: Q=42kg/h,
- Grinding coarsenessin classifieroverflow: 69% -0.074mm,
- Pilot plant probe duration: ~10h/working day
- Sampling interval: t=15min,
- Concentration productswere sampled after probe.

According to previously established scheme made on laboratory scale, maintaining all relevant parameters at a constant value,pilot-plant test was carried out.

Continuous monitoring and sampling, to a greater extent, laboratory tests process simulation on the pilot-plant level was carried out, for verification and confirmation of laboratory tests.

Material balance and pilot-plant probe technological indicators

The pilot-plant process products, copper, lead and zinc concentrates were, after 6 days period (10-12 hours per day)of probe, dried and weighed in order to calculate mass balances and to obtain thetechnological effects data. After completion the entire pilot-plant test on the sample mass m = 2650.00 kg of dry ore, concentation products representative samples, copper, lead and zinc minerals concentrates and tailings, were sent to chemical characterisation. Material balance and pilot-plantprobe technological indicators are shown in Table 1.

Table 1, Material balance and pilot-plant probe technological indicators.

Product	M, %	Cu, %	Pb, %	Zn, %	Ag, g/t	I Cu, %	I Pb, %	I Zn, %	I Ag, %
Feed	100.00	0.86	4.46	2.51	33.71	100.00	100.00	100.00	100.00
C/Cu	3.02	20.88	6.53	4.30	580.00	73.25	4.43	5.17	51.96
C/Pb	5.23	1.30	71.26	4.10	260.00	7.90	83.64	8.53	40.34
C/Zn	3.86	1.20	1.80	52.20	17.10	5.38	1.56	80.15	1.96
Tailings	87.89	0.13	0.53	0.18	2.20	13.47	10.37	6.15	5.74

Technological scheme of copper, lead and zinc minerals flotation concentration in the pilot-plant facility

Figure 7 shows the production copper, lead and zinc minerals concentrates technological scheme, with intermediate products and concentrates technological positions.

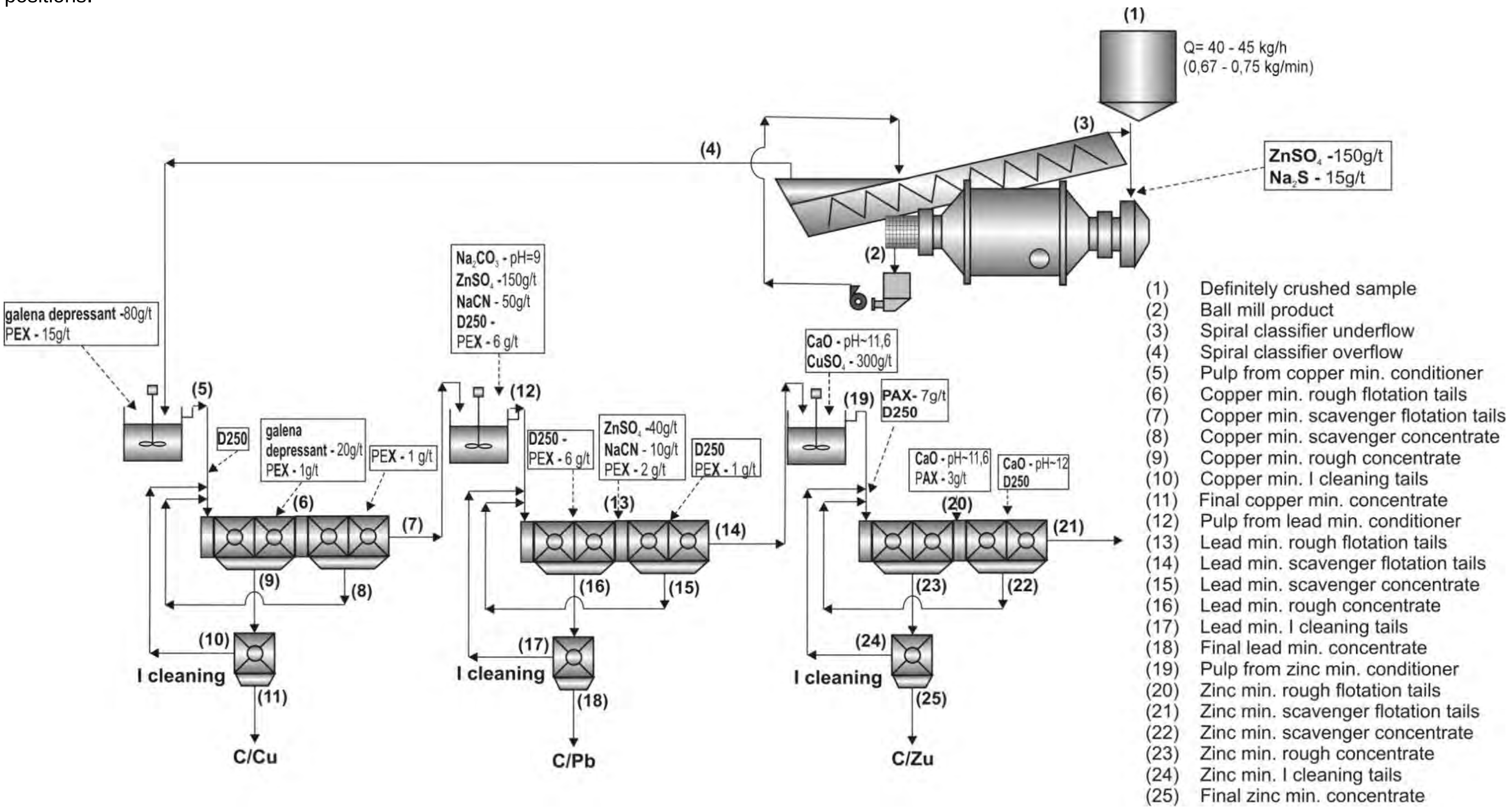

Figure 7,The technological scheme of production copper, lead and zinc mineral concentrates

Technical description of the Cu, Pb and Zn minerals pilot-plantflotation concentration process

Figure 8 shows the technical scheme of copper, lead and zinc minerals pilot-plant flotation process with the installed equipment positional arrangement.

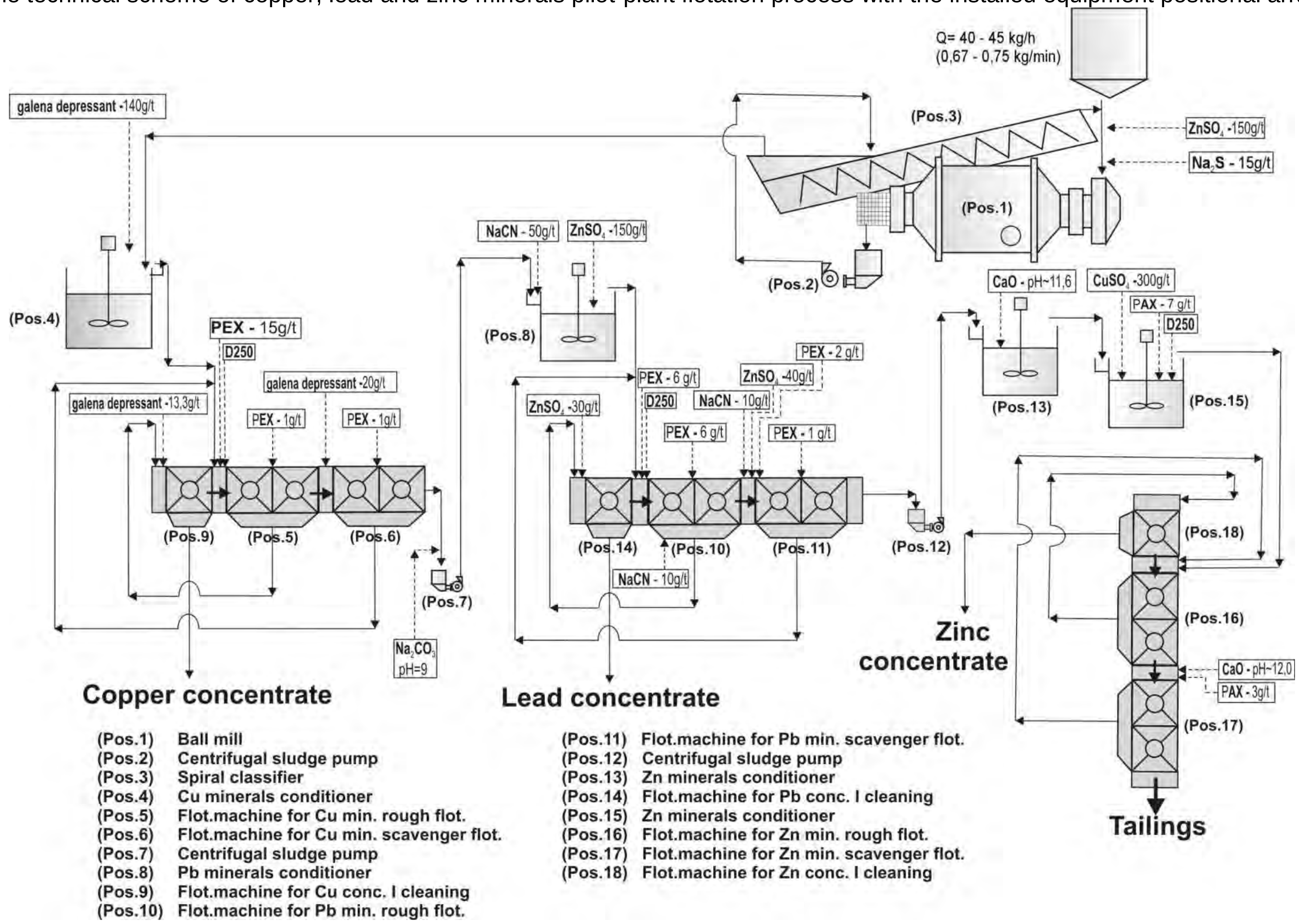

Figure 8,Technical scheme of obtaining copper, lead and zinc mineral concentrates with the equipment positions

Discussion

The main task of useful components flotation concentration pilot-plantprocess from the testedore sample was to confirm the laboratory tests results under which technological schemewas defined.It should be noted that the pilot-plant test was performed without greaterdelays, problems and concentration parameters oscillations, that were monitored. High degree of selectivity was achievedby applying used flotation reagents in the pilot-plant process, which allows obtaining separate copper, lead and zinc concentrates.

Regarding obtained concentrates quality, it can be stated:

Copper concentrate – Considering previous investigations, it was decided in advance to performonly one rough concentrate cleaning strage. Satisfying copper content in copper minerals concentrate was obtained after one rough concentratecleaning stage. Namely, 20.88% of copper in this product allows its further application in the pyrometallurgical processes.

Also preferred fact is that this copper concentrate contains 6.53% of lead and 4.30% of zinc and wich are in the acceptable range for pyrometallurgical standard.Eventualaddicional cleaning of this concentrate,could decrease lead and zinc contentin this concentrate and improve itsquality regarding the related components content.

Lead concentrate – As the lead content in this ore is very high, it was decided to perform only one cleaning treatment ofleadrough concentrate according to the laboratory tests conditions. In this way,71.26% of lead content was obtained in the lead final concentrate. Extremely high quality of this product was achieved after a single cleaning treatment.In this way lead minerals flotation is simplified, and also reinforce the given raw material processing techno-economic effects. The 1.30% of copper content is below the upper limit of tolerance and does not present any problem regarding price on market, especially if we take into account that this is a concentrate that can be further enriched.

Zinc concentrate - Content of zinc in this ore is quite high and very challengingin terms of processing and concentration.During the concentration of zinc minerals in pilot-plant process,it was also decided to run just one rough zinc concentrate cleaning treatment.Significantly higher content (52.20% of zinc) was obtainedthan minimum requirement for the pyrometallurgical processing.From this point of view it can be concluded that the zincminerals concentration during the pilot-plant probe completely succeeded.

Regarding the accompanying elements content, points out that 1.20% of copper content is entirely in the range of tolerance for the market and1.80% of lead content is below the upper limit prescribed value for the further zinc concentratepyrometallurgical processing.

As already mentioned in comments oncopper and lead concentrates, zinc concentrate may be also subjected to additional cleaning flotation process in order to increase the zinc content and a decrease accompanying components content, if necessary.

Based on these facts, it can be concluded that the pilot plant test fully succeeded from the point of confirming the laboratory tests results and conducting a continuous process during the ore sample processing.All mentioned suggests the that it is possibleto apply the given technological process on an industrial scale, relatively easy way of running processes and control of relevant flotation parameters.

CONCLUSION

After performedpilot-plant test on a rich polymetallic ore sample and the obtained results analysis, it can be concluded as follows:

- The tested ore sample physico-chemical characteristics represents a typical example of a very rich polymetallic ore with high potential and possibility for simple flotation valorization of copper, lead and zinc metals.
- Technical-technological scheme,defined bylaboratory tests, is quite simple and applicable in terms of reagent regime,running process possibility and controling relevant parameters, especially taking into consideration that it is a very rich polymetallic ore.
- Pilot plant flotation test results clearly indicates the possibility of obtaining three high quality separate product copper, lead and zinc concentrates, alreadyafter rough concentrates first stage cleaning.
- The impurities contents in the copper, lead and zinc concentrates is within the tolerance limits and therefore does not reduce the economic value of the concentrates.
- Copper, lead and zinc minerals flotation technical and technological parameters enable further purification process of

once cleaned copper, lead and zinc concentrates in order to obtain higher quality and commercially interesting products.

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