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# Use of Design and Analysis Techniques To Increase Metallurgical Zinc Recovery In A Mexican Mining Company

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***ABSTRACT***
*This work considers an optimization process of the characteristic values that can be controlled in a lead-silver-zinc flotation process. The historical parameters used in the process were reviewed and it was decided to carry out a formal analysis that considers: the review of the design criteria of the recovery process, the chemical and metallographic analysis of the raw material being processed, which are useful to determine the control parameters, and concludes with some recommendations to optimize the operation process through the use of a linear model that is statistically analysed. The results obtained are used to propose a methodology that suggests the optimal parameters in a zinc recovery process, when a sequential selective flotation process is employed.*

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## I. INTRODUCTION

The work was carried out in a Mexican mining company and generates a proposal for improvement in the operation, which allows exceeding the historical performance of the zinc recovery process. The mining company uses a lead-silver-zinc selective foam flotation process, after grinding the ore in a ball mill to produce aqueous pulp that is sent to hydro-classifying cyclones. After the concentrate is obtained using the Flotation system, it is thickened and filtered. This system uses selective reagents or agents, depressants and collectors.

In the area of extractive metallurgy, the optimization of the zinc recovery process turns out to be an opportunity to apply techniques generated in light of theoretical concepts and aspects related to the experience and sensitivity of experts [3] [4] [5]. The planning of a proposal that allows obtaining yields that exceed what has been obtained historically is directly related to the minimization of the time required to perform tests and verify the results; as well as the cost and use of the resources available. Empirical research allows a process of recovery of valuable metals to be initiated [5], but once it has begun, the importance of a profit-generating operation is neglected, and attention is lost to cost analysis.

The optimization of the metal recovery process has always been a source of controversy, because stabilizing the parameters that must be considered is a technical challenge. In this work, an analysis has been carried out of the main factors that intervene and that can be critical when it is desired to propose values that allow obtaining acceptable performance in mineral processing to recover zinc.

Selective sequential flotation is used to prevent one or more minerals from floating. Lime, sulphites or sodium cyanide are used, although reagents are currently being used that cause less damage to nature [6]. It is a process to achieve the separation of Sulphur solutions, as well as lead-zinc and copper-zinc. The separation occurs based on the difference in the physicochemical properties of the surface of each mineral [8].

The flotation process for the benefit of minerals is considered as part of an appropriate technique for the separation of minerals [2] [4]; its application is complex, since it is a physicochemical process used to separate solids that are finely divided and knowledge of physicochemical reactions on surfaces is required. In metallurgy, this is a topic of interest to those responsible for stabilizing concentration processes to recover zinc; using viable mechanisms to optimize the variables that arise in the process.

## II. MATERIAL AND METHODS

In this project, the relevant factors that affect the recovery of zinc were determined; To achieve this, a planning process was carried out that considers four important aspects:

2.1.1. Flotation process design criteria to optimize zinc recovery
2.1.2. Design parameters for metallurgical control
2.1.3. Raw material and operating conditions
2.1.4. Human factor competencies

It is considered that a careful analysis based on these aspects allows the use of a robust methodology to propose control parameters for the selective flotation process and increase the performance in zinc recovery.

### 2.1.1. Flotation process design criteria to optimize zinc recovery

The process considered in this work is known as "sequential selective flotation". In a first stage, a silver-lead concentrate is obtained and in a later stage a zinc concentrate. Initially, the most important parameters of the process are reviewed and selected: degree of mineral release (granulometry defined by the p80 factor), use of chemical reagents, flotation times in each of the circuits for lead and zinc, pH of the mineral pulp. Figure 1 shows the flow chart of the sequential flotation process for Pb and Zn.

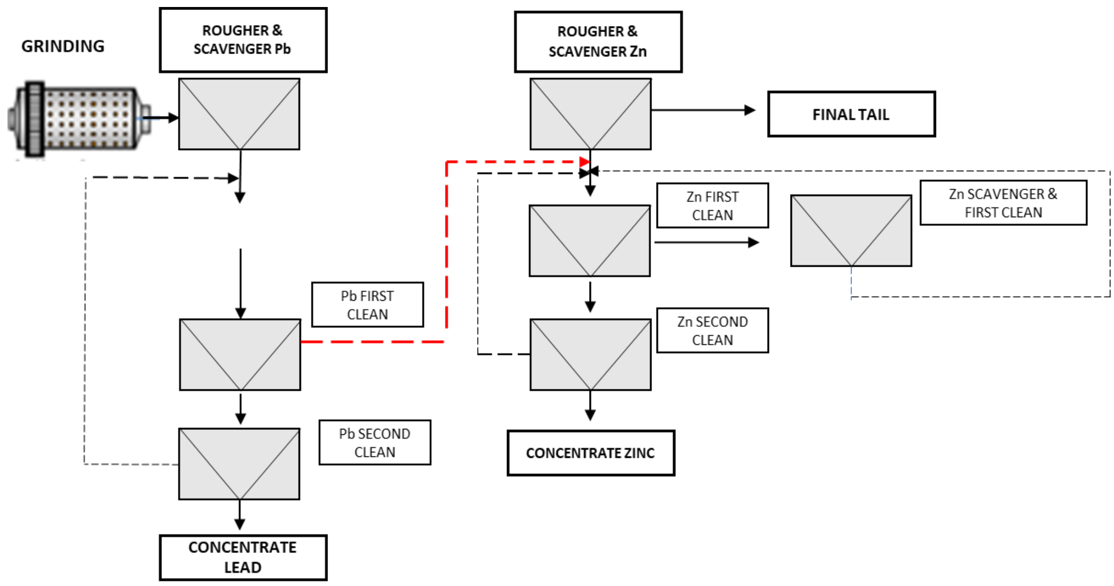



**Figure 1. Process flow chart**

Once the basic elements for the process design have been determined, the concentrate produced from the grinding and flotation operations is analysed through laboratory tests and the metallurgical results obtained are verified. In this case, the metallurgical recoveries were the following: 80% silver in the lead concentrate, 10% in the zinc concentrate, generating a loss of 10% reflected in the process waste; It was found that the recovery of lead was 80% and of zinc, also 80% in the respective concentrates, while the grade of the lead concentrate was around 50% with silver grades of more than 4500 g / ton. The degree of zinc concentration was a minimum of 48%.

### 2.1.2. Design parameters for metallurgical control

Instrumentation in the addition of chemical reagents is considered a relevant factor, because it has an important effect on recovery and consists of activating a control process that ensures the appropriate dosage of the required chemical reagents [9] [10]. The installation of automated equipment that doses quantities at a previously scheduled time is considered. Some reagents are added manually ensuring that the flow rate is not reduced to avoid instability in the dosage of reagent amounts and maintain constant control of the process.

To achieve efficient zinc recovery, the elements that have the greatest impact on recovery and that show a significant improvement in the stability of the metallurgical process were determined; the most relevant are:

**a) Physical release time of the mineral in the grinding process.**
This is possible when an efficient grinding process is carried out, together with the appropriate operation of the particle size classifying cyclone, assuming that 80% of the production (design value) has a value of 45 microns.

b) **Selection of reagents.**

This operation is perhaps the most complex because the flotation process requires controlling different physical-chemical variables. Each of the variables has a specific function and interact together. The control of the lead-zinc separation process depends on the chemical balance between the reagents, which, depending on their function, are called: depressants, activators, collectors, pH modifiers and frothers [11].

An essential function of zinc depressants is to prevent zinc from emerging in the lead-silver concentrate flotation circuit. This is necessary because it tends to concentrate with lead, due to the activation of zinc, caused by the presence of metal ions that are released from the mineral in the grinding process. Another factor that intervenes is associated with the fact that these ions are present in the water that is recovered, considering the flow of the thickener tanks or in the water recovered from the tailings dam. To depress zinc, reagents are added to the process, such as zinc sulphate and sodium metabisulfite.

Once the depression of most of the zinc is achieved, the Aerofina 3418 collector reactor is activated, which is highly selective to separate iron, arsenic minerals and non-active minerals into zinc. This makes it possible to select floating lead minerals containing the mentioned elements. This collector reactor is very effective in the flotation process of lead-silver minerals; However, if it is added in excess it can cause the zinc that has already been partially depressed to also float and it will not be possible to recover it.

**c) Determination of the pH of the mineral pulp**

Another important chemical variable is known as the pH of the mineral pulp produced, which associates the potential of hydrogen ions. It is expected to have a variation from 1 to less than 7 in the case of acidic solutions and from 7 to 14, for alkaline solutions. The neutral value is 7 and, in the analysed case, the pH fluctuates between 7 and 8 in the lead flotation while in the zinc flotation it fluctuates from 9 to 10. It has been observed that as this value approaches 7.8 in lead flotation, zinc is more likely to tend to float along with lead; Therefore, to counteract this tendency, a certain amount of sodium metabisulfite is added when it is desired to reduce the pH to less than 7.5 because when it exceeds this value, the zinc tends to float.

**d) Floating times in the lead-silver circuit and in the zinc circuit.**

In order to know the behaviour of the process, flotation times were selected in ranges that are usually used in a standard test. A range to define flotation times is selected. it is common to perform flotation kinetic tests or open batch type tests in the laboratory, to determine the minimum times necessary to optimize metallurgical recoveries; Once the flotation time for each stage has been determined, the time necessary is scaled in minutes to determine the flotation times in the plant, multiplying by 2 or 3. In this case, open tests were carried out for both circuits (lead-silver and zinc).

Based on the analysis of the obtained results, it is observed that the flotation time has an effect on the performance of the zinc recovery process. Float times were analysed and test results were verified. Table 1 presents the results obtained from a previous design. The following flotation times were recorded at each stage of the process.

**Table 1. Flotation times for each stage of the process**

| LEAD-SILVER FLOTATION CIRCUIT | | | ZINC FLOTATION CIRCUIT | |
|---|---|---|---|---|
| **STAGE** | **LABORATORY** Minutes | **PLANT** Minutes | **LABORATORY** Minutes | **PLANT** Minutes |
| PRIMARY STAGE | 9 | 18 | 12 | 20 |
| EXHAUSTIVE STAGE | 9 | 14 | 9 | 8 |
| FIRST CLEAN | 6 | 10 | 6 | 10 |
| SECOND CLEAN | 4 | 12 | 4 | 12 |

The registered flotation times indicates that at each stage it is possible to have sufficient residence times to recover financially valuable minerals and that flotation time is not a factor that directly affects the performance of the recovery process.

### 2.1.3. Raw Material and Operation Conditions

A mineralogical characterization study was carried out to determine the initial conditions of the zinc recovery process. The study is aimed at identifying the different species of minerals, the association between them and what are the particle sizes in which the physical release and separation of valuable concentrates is achieved.

To achieve an efficient separation, it is necessary to ensure grinding of the mineral to a size such that the release of the different valuable minerals is carried out properly; That is, it is advisable to achieve a p80 indicator, which represents 80% of the mineral with a size below 45 microns and which can be successfully used in the recovery process.

## III. RESULTS

The results of the study show that silver occurs as a freibergite mineral which consists of a tetrahedrite/Ag type copper sulfosalt, this species also has zinc content. 5 species of lead, galena, 2 oxides (cerussite and anglesite) and two sulfosalts (jamesonite and bauranoite) were identified. The zinc mineral is sphalerite and is significantly abundant.

The presence of pyrite as iron sulphide in minimal quantities was observed and significant quantities of fluorite and barite were also identified. Other minerals located in the gangue obtained are quartz, calcite and dolomite. An XRD analysis was performed and provided a semiquantitative composition of the sample species.

Minerals were mainly found in the form of sulphides, oxides, carbonates, sulphates, silicates. It is very important that the mineral release process is highly reliable to achieve separation of valuable concentrates. It is known that an excessively ground product generates a proportion of ultrafine particles that makes the flotation process difficult, significantly affecting performance due to metal losses that accumulate in the residual matter of the process. Tables 2 and 3 show results of the analyses carried out on the target mineral, which are analysed to generate a proposal to carry out the design of experiments useful to define the values of the factors of interest.

**Table 2. Results of the chemical analysis of the head sample fed to the mill**

| g/t Au | g/t Ag | % Pb | % Cu | %Zn | %Fe | | | | % As | %Sb | % PbOx | % ZnOx |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nd | 530 | 5.47 | 0.06 | 7.54 | 0.68 | | | | 0.10 | 0.48 | 0.78 | 0.11 |

**Table 3. Minerals identified by scanning electron microscopy**

<table>
<tr><td colspan="3">Silver ore<br><br>-Freibergite: Cu sulphosal Tetrahedrite/Ag: Cu12Sb4S13/Ag</td><td colspan="3">Pb minerals<br>-Galena, PbS<br>-Cerussite, PbCO3<br>-Anglesite, PbSO4<br>-Jamesonite, PbS.Sb2S3<br>-Bournonite, CuSbPbS3</td><td colspan="4">Zn ore<br>-Sphalerite, ZnS</td></tr>
<tr><td colspan="3">Iron ore<br>-Pyrite, FeS2</td><td colspan="3">Others<br>-Fluorite, CaF2<br>-Barite, BaSO4</td><td colspan="4">Non-sulphurous gangue (ns)<br>-Quartz, SiO2<br>-Dolomite, (Ca,Mg)CO</td></tr>
<tr><td>libre</td><td>Gln</td><td>Angl</td><td>Cerus</td><td>Bourn</td><td>James</td><td>Esf</td><td>Py</td><td>Gng</td><td>TOTAL</td></tr>
<tr><td>Galena</td><td>77</td><td>0.5</td><td>0.5</td><td>1</td><td>1</td><td>7</td><td>3</td><td>10</td><td>100</td></tr>
<tr><td>Anglesite</td><td>0</td><td>20</td><td>40</td><td>0</td><td>0</td><td>0</td><td>20</td><td>20</td><td>100</td></tr>
<tr><td>Cerussite</td><td>0</td><td>20</td><td>40</td><td>0</td><td>0</td><td>0</td><td>20</td><td>20</td><td>100</td></tr>
<tr><td>Bournonite</td><td>80</td><td>10</td><td>0</td><td>0</td><td>0</td><td>10</td><td>0</td><td>0</td><td>100</td></tr>
<tr><td>Jamesonite</td><td>80</td><td>20</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>100</td></tr>
<tr><td>Sphalerite</td><td>82</td><td>0.5</td><td>0</td><td>0</td><td>7</td><td>0</td><td>0.5</td><td>10</td><td>100</td></tr>
<tr><td>Pyrite</td><td>0</td><td>20</td><td>10</td><td>10</td><td>0</td><td>0</td><td>60</td><td>0</td><td>100</td></tr>
<tr><td>Bargain ns</td><td>89.7</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0</td><td>0</td><td>10</td><td>0</td><td>100</td></tr>
</table>

* The indicated percentages are considered as an approximation to the real releasing process and association

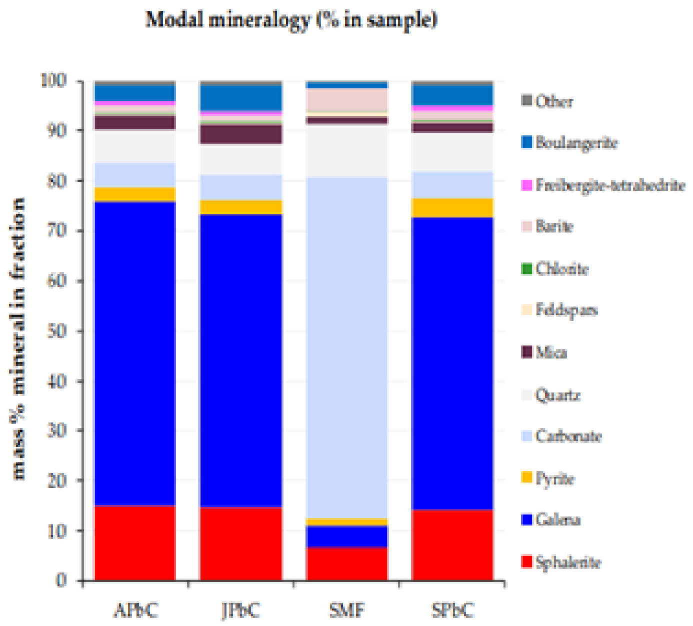



**Figure 2. Modal mineralogizes of the process products APbC - Ag Pb Conc, JPbC - Jul Pb Conc, SMF - Sep Mill Feed, SPbC - Sep Pb Conc**

In Figure 2, the SMF column shows the distribution of the different minerals fed to the flotation process in the month of September, it is approximately 70% carbonates, 4% boulargerite and 6% sphalerite. When reviewing in the concentrate column in September, approximately 55% galena is observed, approximately 14% sphalerite and when adding quartz and carbonates, a total of 12% is obtained.

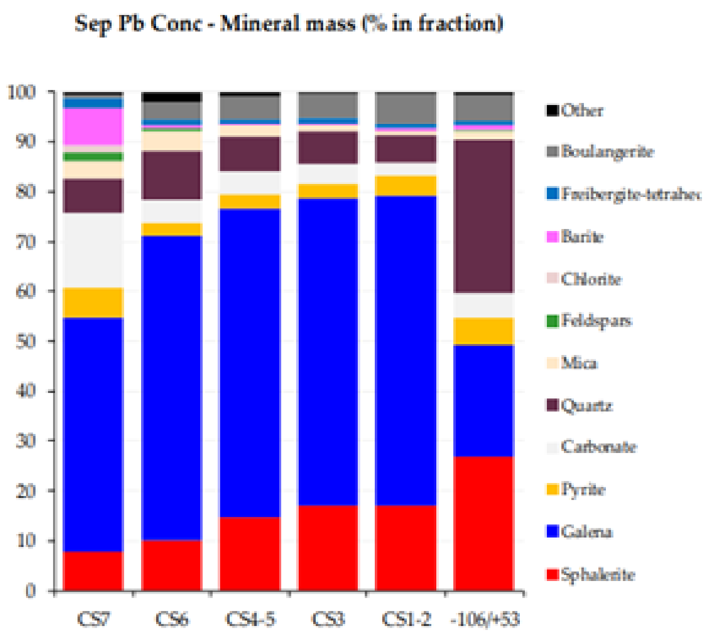



**Figure 3. Size x Size of the Pb Mineralogy produced in September**

Figure 3 shows the mineralogical distribution, size x size in microns from -106 to 53 microns, passing through CS1-2 (approximately 40-50 microns), CS3 35 microns, CS4-5 (approximately 20-35 microns), CS6 (approximately .18 microns) and CS7 (less than 10 microns); It is observed that the highest proportion of sphalerite in the Pb concentrate is found in the size -106/+53 microns.

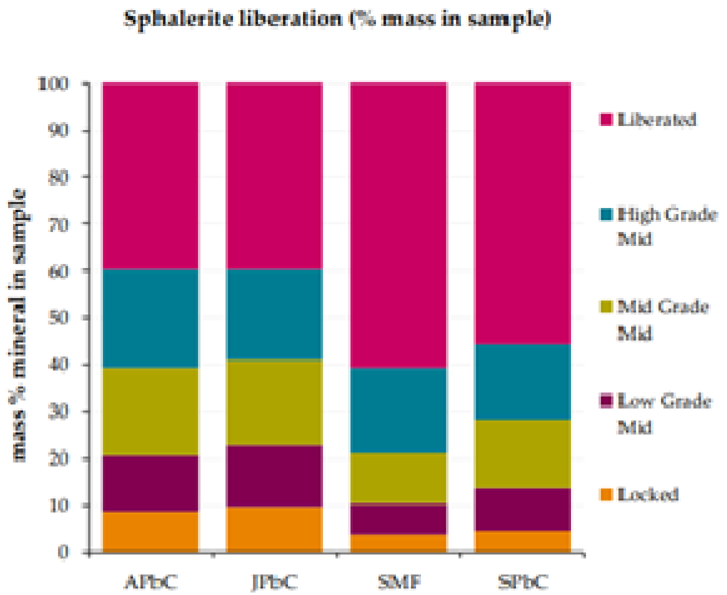



**Figure 4: Comparative release of sphalerite from process products. APbC - Ag Pb Conc, JPbC - Jul Pb Conc. SMF Mill Feed, - Sep Pb Conc**

The SMF column in Figure 4 shows the feeding process during the month of September and it is observed that approximately 60% of the sphalerite that has been released, approximately 15% is associated to a high degree (more than 85%), then 12% of moderately associated sphalerite (more than 50%), also approximately 4%. Sphalerite in low association (less than 20%).

The SPbC column shows that of the 100% of zinc mineral present in the lead concentrate, approximately 55% is already released, although its proportion should be lower when there is an efficient lead-zinc separation due to the action of the zinc depressant reagent.

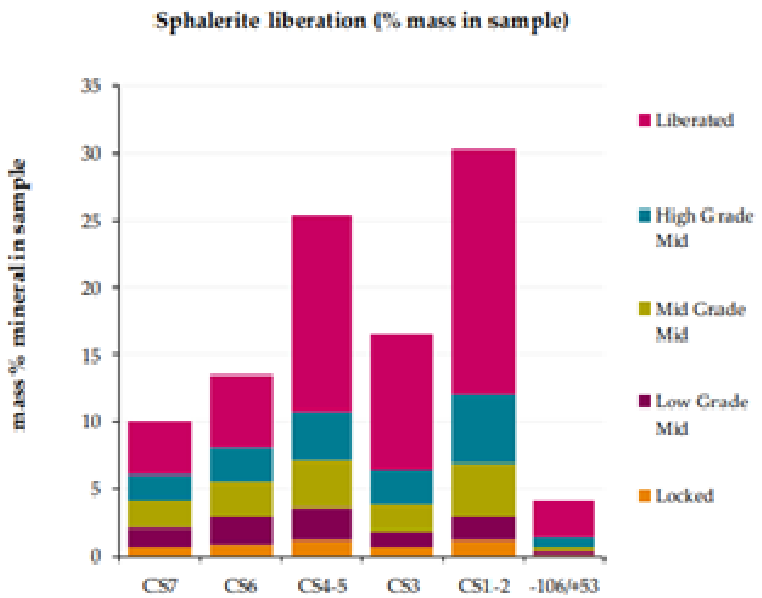



**Figure 5.-Size x size. Release of sphalerite in process products. APbC - Aug Pb Conc, JPbC - Jul. SMF Mill Feed, - Sep Pb Conc shown as % mass in sample**

The results shown in Figure 5 confirm that, when analyzing the different particle sizes of the Pb concentrate produced in September 2021, excess sphalerite particles floated together with the Pb, apparently randomly, since proportions of sphalerite are observed in each of the sizes of the concentrate obtained.

In summary, it is observed that the grinding process releases an acceptable percentage of sphalerite (60%) which is fed to the flotation process, in addition to 12% medium release and 4% low association. It should be mentioned that these proportions are those that present a low flotation capacity in the Pb-Zn separation process, and consequently, the most viable option is a percentage of 15%, since it presents a high degree of association with Pb. Likewise, in relation to the appropriate size for release, it is at a slightly low but acceptable limit.

**4. Human factor competencies**

The staff must be trained in the operation and control of the process; The operation of the production line, process metallurgy, process supervision and the person responsible for the concentrator plant must be considered. The staff is responsible for synchronizing each of the stages of the process, using previously defined metallurgical control criteria, ensuring the quality of the mineral concentrate and the success in the recovery of valuable metals, continuously monitoring the flow and final queues.

During the operation, it is of vital importance that timely decisions are made to correct deviations in the metallurgical control parameters, detecting in time failures in the quality of the concentrates and drops in metallic recoveries; To achieve this, personnel must frequently verify conditions using samples obtained in the flotation and/or grinding area.

In order to realize experimental tests, it was verified that they were carried out by experienced personnel, the dosage of depressants was carried out, the values determined from the results obtained in the metallographic tests were used as a reference. Experimental tests were carried out considering the analyzed parameters.

## IV. DISCUSSION AND CONCLUSION

V. Discussion

Some adjustments to metallurgical control parameters were realized based on the obtained results. To obtain a significant performance in the zinc recovery process of at least 80%, the analysis process is based on the answer to the following questions.

a) What are the factors that affect the reduction in the performance of the zinc recovery process?

b) What are the most important parameters that have to do with your recovery?

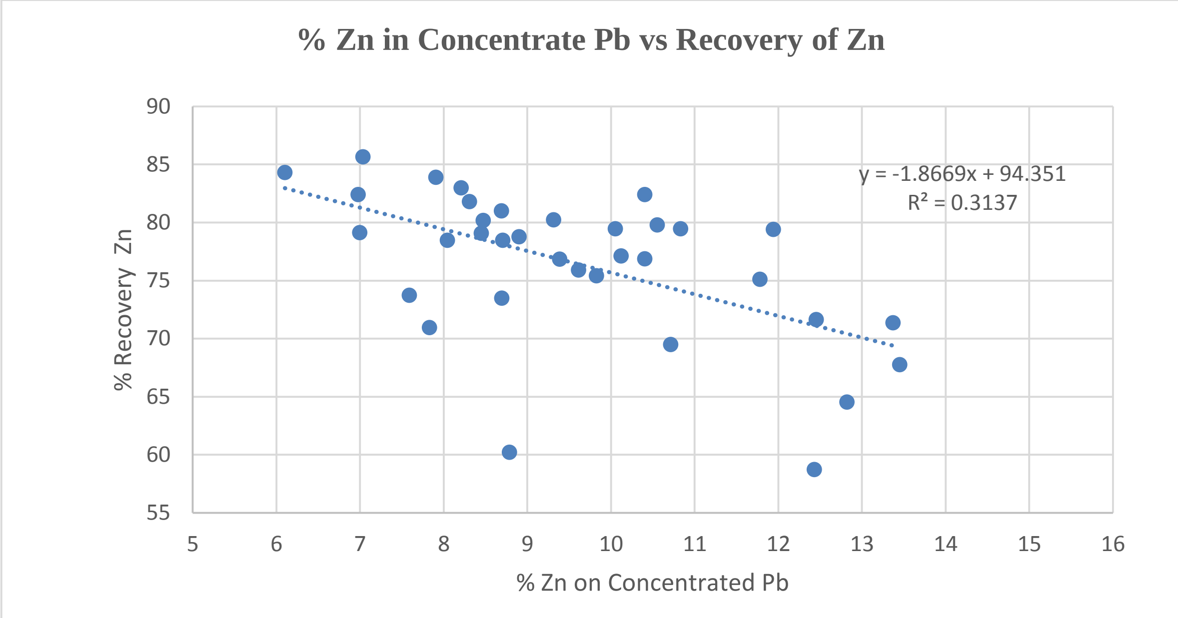
To compare the results of the actions carried out, the results obtained in the production area during the months of June, July and August 2021 are shown; Table 5 shows a summary of the results obtained

**Table 4. Shows values associated with the zinc recovery process from the concentrate mineral.**

**PRODUCTION STATISTICS. PERIOD: JUNE - AUGUST 2021**

| | HEADS | | | CONCENTRATE Pb-Ag | | | CONCENTRATE Zn | | | RECOVERIES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ag | Pb | Zn | Ag | Pb | Zn | Ag | Pb | Zn | Ag | Pb | Zn |
| | gr/t | % | % | gr/t | % | % | gr/t | % | % | % | % | % |
| Junio | 520 | 5.0 | 6.1 | 5327 | 52.1 | 8.5 | 446 | 2.3 | 51.1 | 88.7 | 81.2 | 77.8 |
| Julio | 607 | 5.3 | 5.5 | 6712 | 53.2 | 9.1 | 472 | 3.9 | 44.6 | 90.2 | 76.7 | 78.3 |
| Agosto | 456 | 4.4 | 5.1 | 5336 | 50.8 | 9.6 | 446 | 2.7 | 49.2 | 88.6 | 79.0 | 76.4 |

**It is observed that historically recovery does not reach 80%; that is, because a high percentage of zinc remained adhered to the lead-silver concentrate. In this case, if you want to increase the performance in the recovery process, it is advisable to have a zinc concentrate between 5 and 7%, but not 8.5 to 9%, to prevent a percentage of zinc from being transported among the waste. process or in the so-called floating queues.**




**Graph 1. Percentage of Zn recovered versus % of concentrate of zinc**

Graph 1 shows the relationship of the percentage of zinc in lead concentrate with the percentage of zinc recovered, which is very useful to establish the conditions of the concentrate that is desired to be processed. It is observed that, if it is desired to obtain at least 80% zinc recovery, its content in the lead-silver concentrate must be in a range of 6 to 8.5%.

**Table 5. Production in the period September – November**

| PRODUCTION STATISTICS. PERIOD: SEPTEMBER -NOVEMBER | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HEADS | | | CONCENTRATE Pb-Ag | | | Zn | | | RECOVERIES | | |
| | Ag | Pb | Zn | Ag | Pb | Zn | Ag | Pb | Zn | Ag | Pb | Zn |
| | gr/t | % | % | gr/t | % | % | gr/t | % | % | % | % | % |
| Sep | 491 | 4.8 | 5.3 | 5338 | 50.1 | 7.3 | 447 | 2.4 | 51.4 | 90.6 | 80.3 | 79.8 |
| Oct | 468 | 5.1 | 6.2 | 4605 | 48.6 | 7.3 | 401 | 3.1 | 51.8 | 90.4 | 79.1 | 81.5 |
| Nov | 346 | 3.6 | 4.1 | 4727 | 48.1 | 8.4 | 483 | 3.3 | 50.7 | 87.4 | 73.4 | 80.5 |

Considering the methodology described above, the process parameters were adjusted as follows: p80 granulometry at 45 microns, depressant reagents were added in the grinding process, zinc sulfate in a range of 850 to 2000 grams per ton, and metasulfite. in a range of 50 to 70 grams per ton. As shown in Table 5, once the adjustments were made to the reagents, as well as to the pH of the mineral pulp, it was possible to increase the recovery of zinc to just over 80% of design, also slightly improving the recoveries of silver.

It was probed that the effect on the zinc recovery process is positive when the personnel applies design and analysis techniques in order to propose the best options to improve the conditions for the process itself.

The project motivates the responsible staff and operators of a zinc recovery process by selective flotation, to dedicate time to planning that allows the generation of a viable proposal and optimizes the conditions to achieve optimal performance. It demonstrates that timely process planning directly influences operating costs derived from time savings and equipment care.

The selective sequential flotation process is a process in which the cost of the depressant mechanisms must be analyzed, as well as the appropriate dosage of the depressant reagents will allow greater efficiency in the separation of zinc. The cost is a variable that must be considered and a proposal for the combination of other factors is of interest to increase the profitability of the recovery process. It is important to consider that flotation time could have an effect on the performance of the zinc recovery process.

Based on the findings, it is possible to mention that there are other operating factors of the grinding process that affect zinc recovery performance; These can be: the consumption of the electrical energy required to activate the mill, which is associated with the cost of the recovery process [12]; It has been shown that excess energy consumption is related to failures or inefficiencies in the operation of the mill which have a harmful effect on the mechanical conditions of the grinding process [13]. Mechanical wear and fatigue, failures in the thickening and drying operation before delivery of the produced pulp, reduction in the permeability of concentrate pulps, and an inefficient drying and sedimentation process are aspects that affect optimization of the parameters of the zinc recovery process. It is important to maintain continuous monitoring of mineral variations as well as the control parameters defined during the flotation tests in the design stage because changes may occur in the mineral and in the process that require adjusting the amounts of reagent to have an effective separation. of lead and zinc minerals, thus optimizing the production of each of the concentrates

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