Flowsheet development for selective Cu-Pb-Zn recovery at Rosh Pinah concentrator

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ABSTRACT

Rosh Pinah Zinc Corporation (Pty) Ltd (RPZC) is operating an underground mine and lead–zinc concentrator in southern Namibia, the major valuable minerals being chalcopyrite, galena and sphalerite. Consistent ore characteristics over many years have demanded only minor process changes; this is set to change with ore being sourced from two new ore zones, namely the WF3 Zone 2 characterized by low Cu grades (0.09% Cu, 2.5% Pb, 6–7% Zn), and WF3 Zone 1 which is characterized by high Cu and low Pb grades (0.48% Cu, 0.31% Pb, 10–12% Zn). A laboratory flotation test campaign was therefore undertaken to (1) establish whether the Zone 2 (low-Cu) ore could be processed through the current plant and identify any flowsheet changes that would need to be made, and (2) demonstrate the conditions required to produce a separate concentrate from the Zone 1 (high-Cu) ore.

The results of the low-Cu ore indicated that it could be processed via the current RPZC flowsheet and operating conditions, but that Pb rougher and Zn rougher concentrate re-grinds would be required. This would enable the Pb circuit to produce a grade of 65% Pb at 81% recovery, and the Zn circuit, a grade of 57% Zn at 97% recovery. Mineralogical analysis of the final Pb and Zn products confirmed the need for the re-grinds.

For the high-Cu ore, the challenge was to produce three distinct Cu, Pb, and Zn concentrates. Whilst the initial approach of exploiting relative flotation kinetics using the current RPZC operating conditions did not achieve the desired Cu-Pb selectivity, a feasible flowsheet was developed based on a modified Black Mountain (Cu-Pb-Zn concentrator) processing route for the Cu circuit, and the existing RPZC route for subsequent Pb and Zn recovery. However, dilution of the Cu product by carbon and gangue minerals, and the Pb product showing high Zn and Fe levels, required further depressant and concentrate re-grind optimization.

This paper details the development philosophy and operational benefits of the proposed flowsheets, including improved efficiency resulting from the cleaners operating at reduced circulating loads. Further work is recommended on the WF3 Zone 1, high Cu feed to optimize the operating conditions and define the process design criteria more closely.

1. Introduction

The Rosh Pinah deposit is one of the largest and most important lead and zinc deposits in the world, having been discovered in 1963. It is located about 15 km north of the Orange River and 50 km east of the Atlantic coast in Rosh Pinah in the IlKaras Region of southern Namibia (Seke, 2005). Lead-zinc deposits are amongst the most abundant ores in the world, comprising a fairly large variety which can be classified as follows (Bulatovic, 2007):

- Coarse-grained lead–zinc ores with low to medium iron sulphide content.
- Massive sulphide ores with relatively coarse-grained pyrite, galena and sphalerite, and normally volcanic-associated sulphides.
- Finely disseminated massive sulphide ores with or without carbonaceous gangue.
- Refractory lead–zinc ores characterized by their fine dissemination where liberation of the individual minerals occurs at P80 < 10 μm.
- Oxidized and altered lead–zinc ores characterized by the presence of acid gangue, the natural pH being acidic.
- Lead–zinc–silver ores characterized by their high content of silver minerals; they are processed predominantly for the recovery of these minerals.

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Rosh Pinah does not conform well to any of the above-mentioned descriptions; rather, the orebody is presented as a series of discrete lenses which occur along different strikes. The ore body is approximately 1800 m in length, 700 m wide and 600 m high at its extremes (Fourie et al., 2007). The major Pb- and Zn-bearing minerals are galena and sphalerite respectively; these being diluted mainly by dolomite, quartz and pyrite as gangue (Seke and Pistorius, 2005). The mine has reserves amounting to 14 million tonnes at 2% Pb and 8% Zn (Seke, 2005). Rosh Pinah Zinc Corporation (Pty) Ltd (RPZC) has been operating an underground mine and lead-zinc concentrator since 1969, the concentrator producing two concentrates, both being ~55% in grade with recoveries exceeding 80%.

Since commissioning, the concentrator has been required to make only minor process changes to cope with slight fluctuations in ore characteristics. This is set to change in the near future with ore being sourced from two new ore zones, namely the WF3 Zone 2 characterized by low Cu grades (0.09% Cu, 2.5% Pb, 6.0–7.0% Zn), and the WF3 Zone 1 which is characterized by high Cu and low Pb grades (0.48% Cu, 0.31% Pb, 10–12% Zn). RPZC needs to ascertain whether Zone 2 (‘low Cu’ ore) can be processed to generate on-spec products using the current operating conditions. For the ‘high Cu’ ore (Zone 1), the option of producing a saleable copper product, in conjunction with the usual lead and zinc products, needs to be investigated.

This paper details the response of the variable low Cu ore to the current operating plant conditions, as well as the flowsheet development on the high Cu ore aimed at generation of distinct Cu, Pb and Zn products. Consideration is also given to the implementation of the new flowsheet on site.

2. Experimental procedures

About 700 kg of drill core sample comprising both the low and high Cu ores were delivered to Mintek for testwork. These drill cores were deemed representative of the different zones by RPZC geologists. The samples were treated separately by stage crushing to ~1.7 mm in jaw and cone crushers.

The crushed products of each sample were manually blended using cone and quartering method to extract 100 kg subsample, this was in turn split into 10 kg batches using a riffle splitter. The 10 kg sub-sample was split into 1 kg batches using a rotary splitter in preparation for flotation testwork. The grinding curve for each ore was constructed by milling three 1 kg samples for different time intervals using stainless steel rods in a laboratory mill at 50% solids by mass. This was followed by fractional analysis of the mill product at 80% −125 µm, i.e. the current plant grind, in 7 size fractions ranging from 150 to 38 µm, each fraction being analyzed for base and major elements by ICP, and Total S by LECO combustion.

Mineralogical analysis was conducted on the high Cu ore sample at the same grind of 80% −125 µm, involving X-ray diffraction (XRD), automated scanning electron microscopy (QEMSCAN) and electron microprobe analysis (EMPA). XRD analysis was conducted to determine the bulk crystalline mineral composition in the sample, the result being used to set up mineral identification parameters on the QEMSCAN. Representative portions of the samples were screened into five size fractions and mounted into polished sections for analysis by QEMSCAN as sizing of the sample provides better accuracy. The mineral particles were mapped to derive information on the modal mineral proportions and deportment of selected elements (Cu, Zn and Pb), including the mode of occurrence, liberation characteristics, grain sizes and associations of Cu, Zn and Pb bearing minerals. Analysis of the individual size fractions was used to establish a built-up dataset for the total sample.

Flotation testwork was carried out in Denver float machines at an impeller speed of 1200 rpm, aerated with compressed air, using experimental conditions that will be described in subsequent sections. The tests were conducted in singletons, with their quality ascertained by mass and metal balances, i.e. the variance between the measured and calculated mass and head grades.

3. Results and discussion

3.1. Sample characterisation

The low Cu (WF3 Zone 2) and high Cu (WF 3 Zone 1) ore samples head grades are shown in Table 1, the ‘high Cu’ ore being characterized by higher Cu and lower Pb grades than the ‘low Cu’ ore. Rough economic value calculations showed that value in the low Cu ore was contained largely in sphalerite (67% Zn) and galena (29% Pb) whereas for the high Cu ore, it was biased towards sphalerite (85%) and chalcopyrite (13%), with galena contributing only 4%. This implies that Zn and Cu products should be produced from the high Cu ore. The ores have a similar hardness, as suggested by the milling curves (data not shown), the low and high Cu ores requiring grinding for 15 and 13 min respectively to achieve a grinding product of 80% −125 µm. The WF3 ore is however harder than ores that have been processed historically.

Size by assay results of the ores are compared for value elements Cu, Pb and Zn in Figs. 1–3, showing a bimodal distribution of valuables for both ores. The low Cu ore contained the highest proportion of the valuable minerals in the ~38 µm fraction; in general, the results showed no preferential elemental deportment according to size. There was no significant upgrading of value minerals to any particular size fraction and the mineral distribution across various size fractions followed mass.

3.2. Flotation of low Cu ore under current conditions

Rosh Pinah ore has chalcopyrite, galena and sphalerite as value minerals in a gangue matrix comprising of pyrite, dolomite and quartz (Seke and Pistorius, 2005). The flotation conditions that have been developed and used since 1969 with minor modifications over the years were used and are shown in Fig. 4.

A 50:50 zinc sulphate: sodium cyanide mixture is used for depression of sphalerite and pyrite. Earlier reports indicate that the efficacy of this depressant system depends on the ratio of the reagents, hence the ratio is usually adjusted according to ore mineralogy (Gerson et al., 1999). The method of reagent addition has also been reported to affect the depressant system efficacy, i.e. either each reagent is made up and added on its own or the reagents are mixed in one conditioner to be

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Head grade assays of Rosh Pinah low and high Cu ores.</th>
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<tbody>
<tr>
<td>Sample Name</td>
<td>Cu (%)</td>
</tr>
<tr>
<td>Low Cu ore (WF3 Zone 2)</td>
<td>0.1</td>
</tr>
<tr>
<td>High Cu ore (WF3 Zone 1)</td>
<td>0.5</td>
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</tbody>
</table>

Fig. 1. Cu distribution across the size fractions of milled low and high Cu ores.
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