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Mine Slag - Precious Metal Recovery
Inhouse recovery versus external refiner.
Created by Bobby Boekhoud/Just Refiners USA, Inc.

Refinery Slag Process Recovery Test Work

Composite samples of typical Mine Refinery Slags were tested in a laboratory for projected recoveries of Gold and Silver when processed onsite, assuming average types and grades.

The Test work on the slag was based upon typical milling and primary leaching operations and anticipated expected recoveries of the precious metals in slag with Heap Leach or CIL operations, to be even lower.

This slag test work was commissioned to review onsite processing and recovery versus offsite refining of this important and valuable mine by-product commodity.

Some mines process their slag 'inhouse' for convenience and some mines send their slag to external refiners to obtain maximum value and to reduce concerns about operational security and metallurgical accounting.

We carried out experiments in a laboratory environment, where milled slag was subjected to agitation and controlled cyanide residence time. After 12, 24 and 48hrs of leaching. The cyanide was evaluated for precious metal content as well as the glass/metal residue.

As shown on an attached test work appendix, overall weighted average recovery for Gold using cyanide was 43.79% while Silver was 33.51%. These results are slightly variable depending upon slag type, composition, grades, and glass versus metallic content but representative overall demonstrating a significant loss of value when processing the materials onsite.

We also observed from the lab test, the longer the leaching test progressed the slower the dissolution became.

To compliment these findings, there is a paper written by Fathi Habashi, titled Kinetics and Mechanisms of Gold and Silver Dissolution in Cyanide Solutions. Department of Metallurgy, Montana College of Mineral Science and Technology.

Factors effecting the rate of dissolution of gold are:

1) The rate of dissolution depends on the surface of the metal (gold) in contact with the liquid (cyanide) phase.
2) The rate of dissolution depends on the rate of stirring. (No agitation on the heap leach.)
3) The rate of dissolution is only slightly affected by the increase of temperature, the process requiring an activation energy of 2 to 5 Kcal/mole.

Similarly;

Factors effecting silver dissolution are as follows:

1) Silver dissolves in cyanide at half the rate of gold.
2) Dissolution rate increases with oxygen and agitation. (No agitation on the heap leach)

Taking into account the handling/shipping costs and the refining and treatment charges, a mine can assume a 40% increase in Gold revenue and 50% increase in Silver revenue when their slag materials are refined offsite. When taking this into account, yearly Refinery Slag tonnages, estimated additional revenues would be significant and worthwhile.

Environment

With reference to the above, a very important factor, with regards to shipping the slag off the mine site, is the environment legislation.

In accordance, with the Basel Convention or the Control of Transboundary Movements of Recoverable Wastes, Slag generated from precious metal melting operations is classified as a green list waste under Code GB040. (Please refer to Appendix 3 attached.)

The slags materials generated by the gold mines is subject to Green Control Procedures. The definition of the Green Control Procedure is as follows:

Regardless of whether or not wastes are included on this list, they may not be subject to the Green Control procedure if they are contaminated by other materials to an extent which (a) increases the risk associated with the waste sufficiently to render them appropriate for submission to the Amber Control procedure, when taking into account the criteria in Appendix 6, or (b) 'prevents the recovery of the wastes in an environmentally sound manner'.

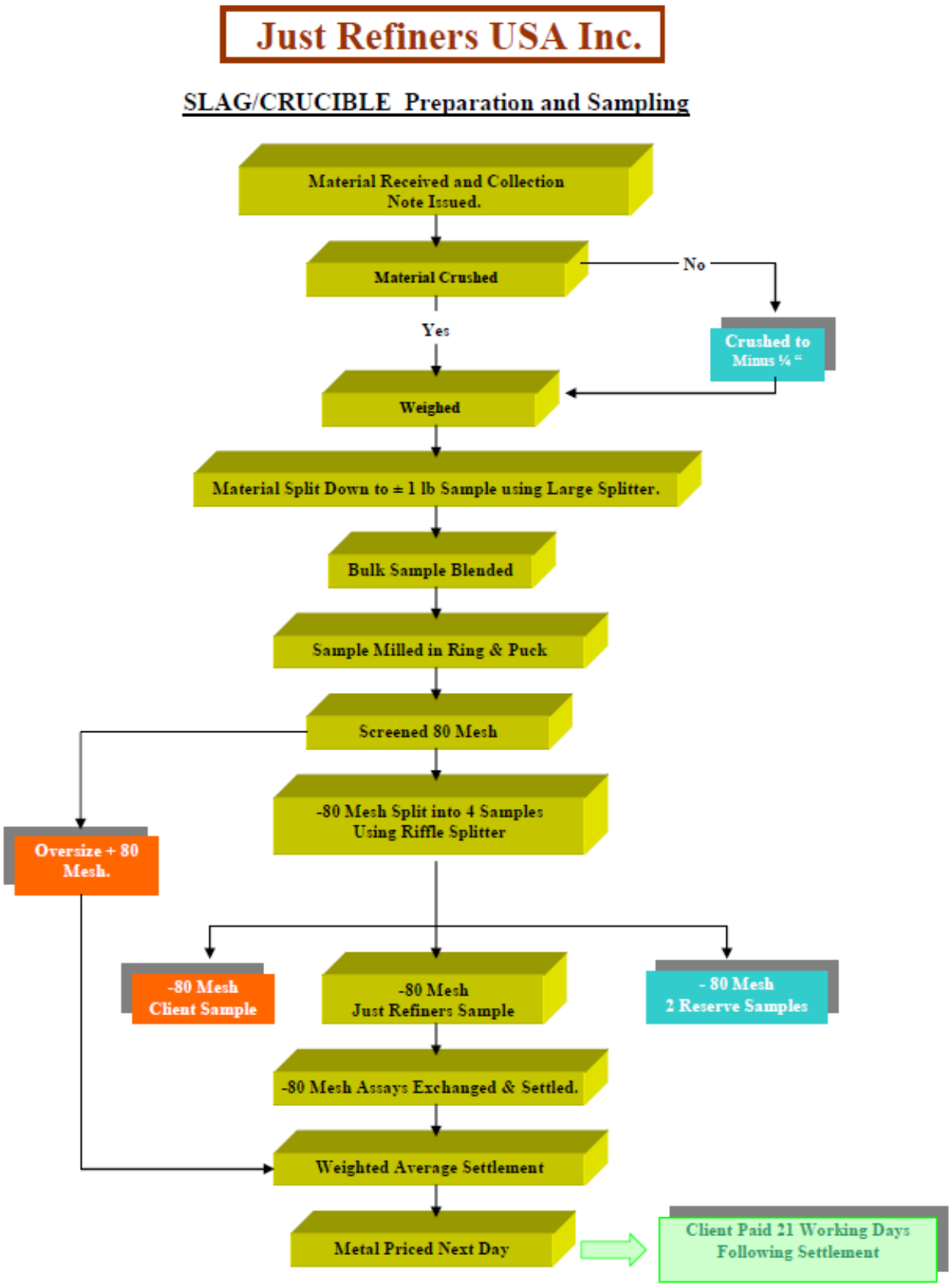
When one reads Appendix 6, it makes reference to Appendix 2 of the Control of Transboundary Movement of Recoverable wastes. (Both Appendix 2 & 6 have been attached for ease of reference.) Both Appendices have relevance to the classification of slag.

None of the Hazardous Characteristics in Appendix 2 of the Basel Convention and the Control of Transboundary Movements of Recoverable Waste: is found in the slag materials generated by the mines. The slag is classified a non-hazardous waste and is correctly categorized as a green list material which is not regulated.

The slag materials are received and processed at Just Refiners. Each material lot is prepared, sampled and evaluated for precious metal content. In addition, a scan is carried out by a the JRI laboratory to determine the presence of deleterious elements. With each shipment, Just Refiners determines the safest and most economical disposal route possible. All slag, crucible, and furnace lining materials are processed in house.

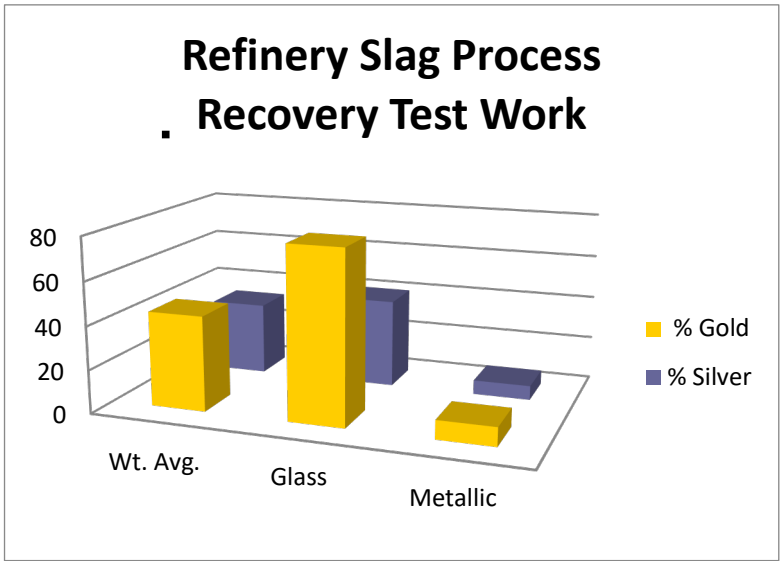
Since the opening of JRI in 1993, JRI has never experienced an environmental violation.

JRI SLAG/CRUCIBLE PREPRATION AND SAMPLING FLOWCHART



Refinery Slag Recovery Test Work using milling and cyanide leaching method. Typical gold and silver recovery at mine site.

Metal Recovery	Overall Wt. Avg.	Glass	Metallic
% Gold	43.79	78.98	8.68
% Silver	33.51	40.78	6.58



Slag generated by the mines consists of predominantly two portion:

- Glass
- Metallic Oversize.

Laboratory Test Work:

Glass – Several lots of slag were milled down to minus 80 mesh. The milled slag was analyzed for gold and silver. A sample of the milled slag portions were weighed and emptied into roll bottles. A known quantity of 1% cyanide solution is added to each roll bottle. The sample bottles were placed on a rolling mixer for controlled agitation. To determine the rate of gold and silver dissolution in cyanide, the roll bottle was stopped and emptied at 12, 24 and 48 hours. (Multiple duplicate samples were run in parallel to determine values at 12, 24 and 48 hours.) Analyzing samples at 12, 24 48 hours determined the rate of cyanide dissolution. An average of the fire assay analysis indicated a gold recovery of 78.98% and silver recovery of 40.78% from the glass portion.

Metallic Oversize removed from the slag – Several individual lots of metallic oversizes were generated from milling the slag down to minus 80 mesh. The metallic portion (+80 mesh) was weighed and added to roll bottles. A known quantity of 1% cyanide solution was added to the metallic oversize. The roll bottle was placed on a rolling mixer. At 12 hours the roll bottles were emptied into a lab filter funnel. The cyanide solution was analyzed for gold and silver content. The metallic oversize was dried and weighed. This step was repeated at 24 and 48 hrs. Details were recorded to determine the dissolution rate of the metallic portion. Only 8.68% of the gold and 6.58% of the silver is recovered from the metallic portion at 48 hours.

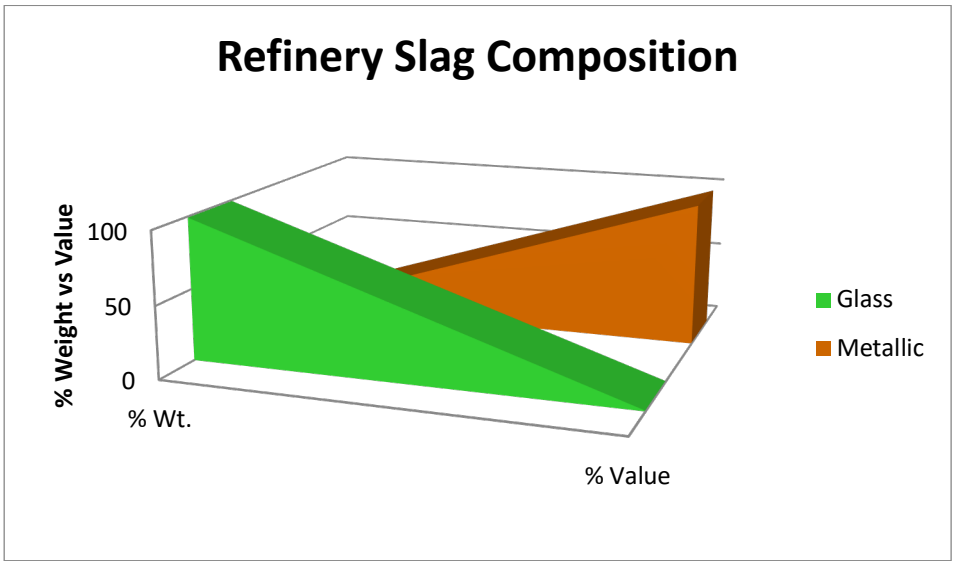
Conclusion.

If the mine decides to mill up the slag and return it to their CIP, it is likely less than 50% of the value of the slag will be recovered.

When one adds the recovery of the gold and silver from the glass and the metal portions using cyanide dissolution, the recovery mean of the two portions is an average of 43.79% gold and 33.51% silver.

Refinery Slag Recovery Test Work using crushing sampling and smelting method. Recovery of gold and silver at an external refiner.

Metal Contained	% Wt.	% Value
Glass	99.26	0.54
Metallic	0.74	99.46



When the mine chooses to send their slag to a reliable and competitive refiner, the mine is guaranteed to receive 100% value of the metal content, less the agreed refining/treatment charges.