PINCOCK Perspectives

Delivering Smarter Solutions

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Reconciliation of Reserves—Part 2

This newsletter is a continuation of Pincock Perspectives Issue 49 on the reconciliation of reserves. The initial article discussed the issues surrounding reconciliation of the resource model to mine production. This edition focuses on the closure of the process, with reconciliation of the mine to the mill, the mill to the smelter or refiner, and finally to sales. Once a reconciliation has been achieved between the resource model and the mine, the reconciliation process must continue through the other stages of production, as shown in the flowscheme diagram at the end of this article.

Mine to Mill Reconciliation

The mine to mill reconciliation poses its own set of considerations. There is generally a discrepancy between the mine estimate of production and the mill estimates. The mine normally will rely upon blast-hole samples and some form of interpolation (such as outline-and-average or kriging) to determine dig-lines for the operators. As with the exploration model, the blast-hole model is an estimate and is subject to standard estimation problems.

Typically, the mill values are perceived to be the most accurate, and are the basis for reconciliation in most cases (with the possible exception of in-situ or leaching operations). While there are instances where the mill is clearly off, a properly-run mill should be a more accurate estimate of production than the mine, for several reasons:

- The most common problem in taking samples is the size and distribution of particles. Mills generally can pull samples of material after grinding, offering a simpler sampling challenge.
- The product streams can be sampled more easily at regular intervals.
- The capabilities of modern mills, with on-stream analyzers, automatic sample cutters, and process control systems allow unprecedented control of the flow-streams.
- There are multiple checks possible within the mill, allowing for a superior mass balance, which is effectively an internal reconciliation.

Mills are not immune to sampling problems; problems can and do occur. Mills routinely operate on a 'balanced' estimate of the feed grade, which back-calculates the head grade as the sum of the tailings plus the products. The mill balancing methods can be quite sophisticated with the most recent methods making use of a multi-element sampling protocol at numerous points within the mill. Tonnes and grades are computed as a minimum-error fit using linear equations that simulate the flowscheme. The results from various sample points used in the balancing process should fall within certain ranges of error. Large estimation errors indicate either sampling or process problems and require a more exhaustive review of material balances within the mill.

Typical causes of major errors in mill balances include inadequate weightometer calibration, errors in moisture sampling, inadequate sampling, poor assaying protocols, collection of metal in sumps (particularly for gold), and

PAH NEWS PI

CALENDAR

- ***21st Annual Mineral Exploration Roundup***
  January 26–29, 2004
  Westin Bayshore Resort and Marina
  Vancouver, B.C., Canada
  email: roundup2004@chamberofmines.bc.ca
- ***106th National Western Mining Conference and Exhibition***
  February 3–6, 2004
  Hyatt Regency
  Denver, Colorado
  email: colomine@coloradomining.org
- ***2004 SME Annual Meeting & Exhibit***
  February 23–25, 2004
  Colorado Convention Center
  Denver, Colorado
  email: sme@smenet.org
- ***PDAC 04***
  International Convention, Trade Show & Investors Exchange
  March 7–10, 2004
  Metro Toronto Convention Centre, North Building
  Toronto, Canada
  email: pdac@pinngroup.com

■ ***OSM, NMA REACH SETTLEMENT WITH COAL INDUSTRY***

The Office of Surface Mining (OSM) and the National Mining Association have worked out a settlement regarding ownership and control rules in the coal industry. The two organizations have been waging a legal battle since 1988 and are now asking for public input on the resulting deal. Issues of concern include definitions of ownership and control, permit eligibility standards, and how to handle challenges by individuals or companies to how they are listed in OSM's applicant violator system database. OSM will take comments until February 27, with public hearings possible if requested. For more information, contact OSM's Earl Bandy at 859-260-8424 or ebandy@osmre.gov.

CHINA OPENS MINING TO FOREIGN INVESTORS

In an effort to encourage overseas investments and cooperation, China is expected to open its mining sector to foreign investors. China is one of the world's biggest producers of most metals but faces major shortfalls and has been buying stocks from around the world to help fuel its economic expansion. The government says it will try to make the industry more efficient, aiming not only to attract foreign funds, but also technology, management practices and expertise. They are also expected to improve environmental standards and crack down on illegal mines. China has a poor mining safety record with approximately 7,000 people killed in mine accidents each year.

RUSSIAN GOLD RESERVE SOARS

For the first time in almost a decade, Russia discovered more gold in 2003 than it produced. According to the Natural Resources Ministry, the rise in gold reserves exceeded that of gold extraction in 2003 and stood at 207 tonnes or 106 percent. Gold production in 2003 was about 176 tonnes, compared to 170 tonnes in 2002. Russia's rapidly developing gold industry and high gold prices have attracted big foreign names in the past months. Local miners, like top gold producer Norilsk Nickel, and foreign ones, such as Highland Gold Mining, have been acquiring gold deposits across Siberia in the past year. Several companies will participate in an auction in the second quarter of 2004 for the giant Sukhoi Log deposit in Siberia. Analysts say the highest bidder for the property is likely to become a long-term dominate force in the industry.

theft, among other potential issues. The number and potential remedies for mill balancing problems is a lengthy topic in its own right.

Stockpiles

As mentioned earlier, a truly deterministic reconciliation is rarely possible. Stockpiles are one of the most common impediments to a full reconciliation, since the processing of this material is normally delayed for months or years. Stockpiles are employed at a number of points in mining—low-grade stockpiles, crusher stockpiles, concentrate barns, temporary stockpiles and coarse-ore stockpiles all delay or affect the timing of metals moving through the mine.

Accounting for stockpiles is primarily a matter of backing-out the stockpiled material from the production stream for the period, when feasible, or selecting a sufficiently long time period to allow the stockpiling effects to average out. Some typical strategies would be:

- Crusher stockpiles are normally fairly small in size, and can be ignored in many cases, particularly for quarterly and longer period reconciliation. Where they become large, they must be tracked as an inventory, or emptied at the end of the accounting cycle (usually monthly).
- Similarly, coarse ore stockpiles can often be ignored, particularly if the active portion of the stockpile (normally the portion of the stockpile over the drawpoint) is quite small. Again, cleaning out the pad at the end of each period is the ideal solution.
- The concentrate barn may represent a substantial percentage of a month's production, particularly with large inventories of material for ocean freight. Tonnage on hand in the barn is usually tracked, and some operators try to maintain an inventory rotation policy. In most cases, an estimate must be made of the inventory, and efforts should be made to clean out the concentrate barn periodically, preferably at a period closing.
- The material in-transit, or awaiting smelting and refining, acts much as another inventory, but the sampling mechanisms at the load-out are normally quite good, and the buyers are quick to point out discrepancies. While a correction for the smelter is normally small, it should be noted and if significant (systematically over 1% or more) additional auditing steps may be needed.

A major source of trouble in reconciliation is long-term stockpiles. Many operations have applied optimizing schedulers to their production schedules and will stockpile large quantities of lower-grade material for later processing. Some PAH projects are accumulating stockpiles sufficient for several years of milling. Clearly, this presents problems for the reconciliation, because the material in the stockpiles remains less certain until processed.

There are two somewhat complementary methods for reconciling around large stockpiles. The most common practice is to simply assume that the value estimated by the mine is correct, and carry the inventories accordingly, depleting them as needed. The stockpiled material is deducted from the mill-feed stream as reported by the mine. Clearly there is potential for error in this practice, as stockpiles are normally found to have a lower tonnage than expected when they are finally processed.

A better method is to segregate the various stockpiles by grade ranges, and to reconcile not to the low-grade cutoff, but only to the material fed to the mill, in essence ignoring the stockpiles in the reconciliation. This system works best when relatively constant cutoff grades can be maintained over time, but variable cutoffs can be managed by careful record keeping.

PAH has noted a trend with operators that employ long-term stockpiling: Many operators are now building stockpiles and are maintaining careful track of the exact location of each truckload using a GPS system. With careful application, the operator can produce a reasonable prediction of the grade of the stockpiles at various locations.

Heap Leaching

The use of heap leaching poses a unique problem to the reconciliation process. In this method, the last point of reliable estimation is the blast-hole model, except in those cases where sample-cutters are used (these tend to be expensive and are variable in reliability). Once the material is placed on the heap, the operator must rely on grade determinations from each cell to determine the accuracy of the blast-hole estimate, and must make some assumptions regarding recoveries. In addition, there is a considerable time-lag from the start of leaching to the rinse stage, often up to 120 days or more.

Reconciliation of heap leach systems requires that the operator track the date of placement on the pad, and the number of days the area has been under leach. In some cases, particularly for multiple levels on a single use pad, the problem is complicated further by the potential that metal production may continue from a cell even after active leaching is halted.

There is no rigorous way of reconciling a heap-leach operation, other than the comparison of gold yield over time as compared to the predicted values. Head samples taken after three or four stage crushing still present difficult sampling issues, though such samples offer some insight.

Other Issues

Much of the focus of this article has been most applicable to surface metals mines, although the reconciliation problem applies to all mines at varying levels of importance. Underground mines normally operate with smaller stockpiles, but accurate measurement of stope dimensions can be difficult at best and dangerous at worst. While current software packages are much better at complex 3D volumes, obtaining the real-world information can be troublesome. Otherwise the reconciliation process is comparable to a surface operation.

Non-metallic Deposits

With the higher levels of accountability expected now by the securities regulators, coal and industrial minerals producers will likely face growing pressure to substantiate reserves at the same level as the metals producers. Coal companies often list huge reserves, but the well-run companies can show what is usually called a 'recovery analysis' that documents the predicted tonnage and quality and the actual recovery. Coal is normally more forgiving than metal mines, and the reconciliation often is checked annually, rather than monthly or quarterly.

Industrial minerals have historically been more relaxed in their approach to reconciliation, although with the industry consolidation of many commodities, the resulting large companies are increasingly subject to the same level of scrutiny applied to metals and coal. The ability to make predictions of reserves, and the ability to support those reserves with facts and figures, is a concern to stockholders of these companies as well.

Manual Model Reconciliation

While more tedious than computer-based methods, the process for reconciliation in manually-generated resources is fundamentally the same. If the operation is a paper-only operation, the engineer must rely upon a planimeter and map to calculate the predicted tonnes and grade from the maps. In some cases, the work has been done in AutoCAD® or a similar drafting package, which eliminates the planimeter, but still requires manual

■ ***NEW BOLIDEN WORLD-WIDE LEADER IN MINING, SMELTING***

Sweden's Boliden AB and Finland's Outokumpu Oyj have combined mining and smelting operations to produce New Boliden, which starts operations on January 1, 2004. In the merger, Boliden acquires Outokumpu's mining and smelting operations within zinc and copper and sells its fabrication and technology sales operations to Outokumpu. Boliden's consideration to Outokumpu for the acquired mining and smelting assets consist of: issuance of new shares in kind to Outokumpu, corresponding to 49 percent of all shares in New Boliden; cash payment of EUR 373 million; and issue of a subordinated debenture to Outokumpu. The final consideration will be adjusted depending on the closing accounts of the transaction, which will be finalized in March 2004 at the latest. According to Boliden's President and CEO, Jan Johansson, New Boliden will be able to create long-term profitability and substantial grown potential.

Minerals Corner—

Hilairite
$Na_2Zr(SiO_3)_3 – 3H_2O$, Hydrated Sodium Zirconium Silicate

Hilairite is a mineral with small but generally well formed crystals, which have an interesting brown color and a good luster. Its crystals are transparent to translucent and opaque and are usually small prismatic crystals with rhombohedral terminations. Twinning is also common and crystals are found doubly terminated. Hilairite is one of the many new minerals to come from Mont Saint-Hilaire in Quebec, Canada where it was discovered in 1974. The rocks at Mont Saint-Hilaire are unique because they are the result of an alkaline metal- rich intrusion called an agpaitic pegmatite. The pegmatite is rich in traditionally rarer elements such titanium, zirconium, cerium, and barium. Hilairite's rarity and beauty make it a great collection mineral if a specimen can be found.

tabulation of predicted resources, presumably in Excel© or equivalent spreadsheet package. PAH recommends that maps showing the pit advance and a summary spreadsheet be available to easily trace the work that was done for audit purposes.

Conclusions

Reconciliation does not simply examine the exploration model against mining results. In practice, each step of the operation must be examined sequentially from model to mine, mine to mill, mill to smelter or refiner or to final sales. Depending on the commodity and mining method, a complete reconciliation should adequately account for losses, dilution and production to no more than about 7% to 12% per year depending on commodity. Errors over this range should be analyzed to determine, and hopefully rectify, sources of inaccuracy. The best operators will insist upon even tighter reconciliation.

The process of reconciliation in mining is a reflection of the industry itself. In a few cases, the process is simple and intuitive. For the other cases, reconciliation must be tailored to the operation, taking into account the unique characteristics of the commodity, the geology, processing methods, and market requirements. The process is not perfect and only under ideal circumstances can a complete reconciliation be made.

Successful reconciliation can be illusory. In many cases, errors at one point of the process are offset by errors at other points in the operation, resulting in an excellent reconciliation. This can be either desirable, if the project has particularly difficult sampling issues, or can hide compensating biases in the system that may surface at some later date.

Reconciliation is also not a guarantee of future performance, since reconciliation is a historical process. There are any number of problems that can effect future reconciliation… exploration drilling is often less dense in the latter stages of mining, mining methods may change, mineralization suites often differ over time.

The pitfalls of reconciliation notwithstanding, it remains a powerful tool for determining if a production problem exists at an operation, and often provides diagnostics for resolution of those problems. Reconciliation remains one of the most compelling demonstrations of resource model accuracy, and is a hallmark of prudent operating practice. In today's climate of increased scrutiny, a good reconciliation will go far towards demonstrating operational health to activist boards, cautious regulators and investors, and even the occasional nosy independent engineering consultant.

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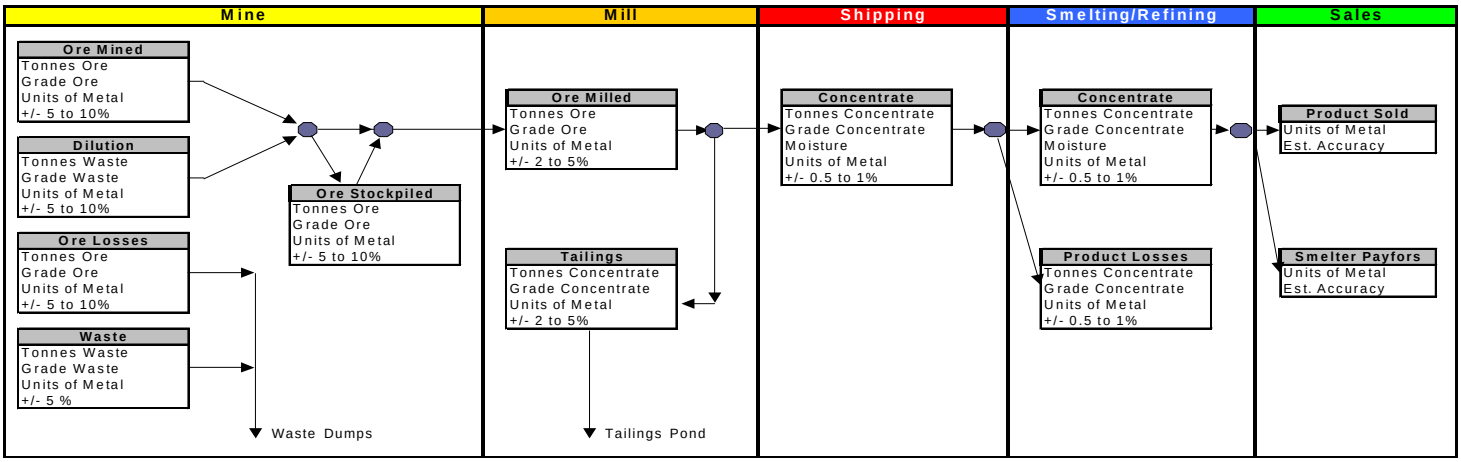
General Flowscheme for Reconciliation Mining to Sales



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