Are your measurement systems telling the truth?

Wrong, wronger, wrongest

Since the publication of the Amira P754 Code of Practice for Metallurgical Accounting, several mining companies have, or are in the process of, investing millions in automated metallurgical accounting systems. In anticipation of this need in the market, various software companies have developed such automated metallurgical accounting systems, thereby eliminating spreadsheets and minimising human error. Unfortunately, the same level of investment and rigour is not being applied to the measurement and sampling systems that provide the data to these systems.

By Dr Wynand van Dyk

Calculating contained metal

The flow of metal over a specific time-frame (*t*) can be calculated as follows:

Where:

$Metal_t$ = flow of metal over time period (*t*)

$Mass_t$ = Gross mass of solids and water over time period (*t*)

$\%solids_t$ = average % solids of the stream with $Mass_t$ over time period (*t*)

$Assay_t$ = average metal assay of the stream with $Mass_t$ over time period (*t*)

Therefore, in order to calculate the flow of metal past a specific measuring point over time period *t*, the following measurement sub-systems would be required:

- Measurement of the cumulative gross mass over time period *t*
- Sampling system to extract a sample from the main stream over the time period *t*
- Sample preparation system to determine the % solids in the sample
- Sample splitting system of the dried sample in order to prepare a sample for the chemical analysis
- Chemical analysis system

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Given the above requirements, it is not surprising that about 50% of the AMIRA P754 guideline document addresses accurate and precise measurement and sampling systems, with only about 20% dedicated to data management, metal balancing and reporting. Ironically, automated metallurgical accounting systems only address the latter requirements.

Errors

It is important to realise that "error free" measurement systems do not exist, due to the random variations in the process and the measurement system. Each measurement system will therefore introduce error (or variation) into the calculation of contained metal. As a result, metal accounts can never be exact and will always contain a degree of uncertainty and, consequently, all metallurgical accounts are wrong – some are just more wrong than others. The aim should therefore be to reduce the errors to an acceptable level, where the uncertainty in the stated metallurgical accounts are within an acceptable level of materiality.

The errors in measurement and sampling systems can be classified into three categories:

- *Random errors* are caused by the natural fluctuations in the measurement system such as temperature, humidity, vibration, instrument noise, human interaction and the tolerances of the measurement or sampling device. Random errors therefore affect the precision of the measurement system and the average of the error will in most cases approach zero over time. Random errors can be classified into two broad classes:
  - Repeatability, or the variation in measurements obtained when the **same operator** uses the same measurement system to measure the identical characteristic of the same part. These errors are therefore device driven.
  - Reproducibility, or the variation in measurements obtained when **different operators** use the same measurement system to measure the identical characteristic of the same part. These errors are therefore driven by the human interaction with the system.
- *Systematic errors* are caused by a measurement system yielding consistently higher or lower values than the true value, and are therefore related to the accuracy of the measurement. Systematic errors can be classified into three broad classes:
  - Bias is defined as the deviation of the observed value from the true value under ideal conditions. Regular calibration procedures can typically minimise and control bias within acceptable limits. However, bias can never be eliminated due to wear and tear of the sub-components of a measurement system, leading to stability errors.
  - Stability of a measurement system is defined as the magnitude of error as a function of time, i.e. whether the measurement system accuracy changes over time. Typically, stability errors are caused by environmental conditions, such as temperature, cleanliness and housekeeping. Regular maintenance of measurement systems, done to a high standard, can minimise stability errors.
  - Linearity is the difference in the accuracy of the measurement system over the expected operating range of the

system. Linearity errors are usually caused by the measurement system not being calibrated at the upper and lower end of the operating range, or by worn equipment.

- *Spurious errors* are usually caused by the interaction of humans with the measurement system, for example incorrect readings of the instruments, incorrect data capturing, swapping of samples and incorrect calculations.

Evaluating your measurement and sampling systems

Given the various types and sub-classes of errors, it is understandable that evaluating measurement and sampling systems can seem like a daunting task. No wonder that the majority of metallurgical operations function in the 'ignorance is bliss' mode when it comes to evaluating and improving measurement and sampling systems.

However, by understanding the possible errors that can be present in a measurement system, it is possible to plan and execute appropriate statistical experiments to quantify the errors and focus improvement initiatives. Fortunately, various statistical techniques have been developed by the continuous improvement and quality control fraternities, and have been incorporated in most statistical analysis software packages.

By integrating the efforts of continuous improvement initiatives (like Six Sigma) with metallurgical accounting, significant inroads can be made in reducing the errors associated with measurement systems. In addition, the AMIRA P754 guideline document contains several excellent examples with respect to sampling systems and the improvement thereof.

The key is to develop a clear and holistic strategy to quantify the errors associated with the measurement and sampling systems that provide the source data to the metallurgical accounting system. By working through the sub-systems in a systematic fashion, the major sources of error can be identified, and should then become the focus areas for any capital investment.

Garbage in, Gospel out?

Unfortunately it is just not possible for even the most sophisticated software based metallurgical accounting system, to turn Garbage-In into Gospel-Out. However, judging by the level of investment in these systems, and the concomitant lack of investment in measurement systems, it seems as if this is the current expectation from most operations venturing down this path.

Should your operation be amongst them, it might be worthwhile to consider that an automated metallurgical accounting, data capturing, reporting and sample tracking system will, at best, only eliminate the spurious errors associated with your metallurgical accounts.

I am by no means suggesting that operations should not invest in automated metallurgical accounting systems. On the contrary, these systems are required and will play a significant role in eliminating spurious errors. In addition, such systems cannot be matched when it comes to speed of reporting and standardising reporting calculations. However, without a clear and holistic strategy to evaluate and improve the fundamental measurement and sampling systems, automated metallurgical accounting systems will just arrive at an incorrect answer faster.

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