Designing for metal accounting

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Introduction

This paper is based on the Code of Practice and Guidelines for Metal Accounting which is being developed as a deliverable of the AMIRA International project P754 Improving Metal Accounting. The P754 project had its origins in a workshop, Challenges in Metal Accounting and Information Management, held in Cape Town in August 2001, and is sponsored by five major mining companies. The project currently involves seven post-graduate students at the universities of Cape Town, Queensland and Stellenbosch, who are conducting research projects into various aspects of metal accounting in metallurgical plants ranging from concentrators and smelters to hydrometal-lurgical refineries. The development of the code and guidelines has taken place in parallel with the research projects, which have also provided input into these documents. Contributions and guidance have also been received from the sponsors' operating companies and from members of the South African accounting profession.

As part of the development of the code of practice and guidelines, a set of metal accounting principles was formulated. These stipulate that metal accounting must be unbiased and precise, and therefore accurate, and based on a full 'check in–check out' measurement system. The system must generate sufficient data to allow for data verification and reconciliation, metal or commodity custody transfers, and measurement of accuracies and error detection, which should not show any ongoing bias. The expected precision levels for mass measurements, sampling and analyses must be identified for each input and output stream used for accounting purposes, and plant and in-process stock figures must be verified by physical stocktakes at prescribed intervals. The entire metal accounting system and its design must be subject to approval by a competent person (someone with sufficient relevant experience and expertise in metal accounting), and to regular independent audits.

The primary purpose of data generated by a metal accounting system is to provide information to operational management, rather than for financial reporting. However, outputs from the metal accounting system feed into the company's financial reports, so that the metal accounting system must be transparent, with clearly defined audit trails. In view of this, it is essential that the design of the metal accounting system should form a part of the design scope for any new metallurgical plant.

The major risks associated with metal accounting are related to uncertainties in the evaluation of the quantities of metal received and produced or lost in various solid (including slurries), liquid or gaseous effluent streams or by unknown causes, by a particular metallurgical operation. From the system design point of view these uncertainties can be attributed to incorrect weighing, sampling and assaying; inaccurate weighing and sampling equipment; incorrect recording of receipts and dispatches; accounting samples mishandled or misplaced; incorrect estimation of stockpiles; arbitrary methods used for calculating metal recoveries; the use of illegitimate or biased data; and incorrect calculations. In addition, uncertainties due to random errors will always occur. The use of inaccurate weighing and sampling equipment can be the result of incorrect specification, faulty design or incorrect installation, as well as poor maintenance and operation.

The design of a metal accounting system must, therefore, take these risks into consideration. The mass measurement and sampling points needed to obtain an unbiased metal balance at the required level of precision must be carefully identified.

Careful attention must be devoted to the selection of mass measurement and sampling equipment, as well as to the installation of that equipment, with due attention being given to its ease of routine operation, maintenance and calibration. An area, which is often neglected in design, is the design and provision of the equipment necessary to calibrate the mass and flow measurement devices by suitable prescribed methods. The design and specification must also give due consideration to safety and health factors.

In order to achieve this, the design of the metal accounting system must be a part of the initial plant design and specification, and must not be left as an afterthought, to

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be addressed once the design scope, and the capital cost estimate, for the plant have been finalized. This design and costing should take account of the total cost of ownership and the benefits of an improved mass balance and metal accounting. Inevitably, if the design and specification of the metal accounting system is addressed only during the final stage of the plant design and specification, any changes to the overall plant design and layout, to accommodate correct installation of the accounting equipment, can be costly and lead to compromises, which can affect the long-term operability of the system and the quality of the information generated.

An essential part of the process of specifying, designing, and costing a new metallurgical plant is a critical review of the design and cost estimate to eliminate any non-essential items and reduce the final capital cost. There is often an inclination at this stage of the design process to make capital cost savings by eliminating items of accounting equipment or altering their proposed mode of installation, as these are seen as peripheral to the performance of the final operating plant. Any such late changes should be strongly resisted, unless it can be clearly shown that they will have no impact on the performance of the specific item of equipment, or on the overall accounting system.

It is also critical that the plant management, operating and analytical personnel should be involved in the initial design and specification of the accounting system, so that they can understand and accept the system's operating principles and procedures and take ownership of them and, at the same time, ensure that they will be able to generate unbiased accounting data with known levels of precision.

The system itself must cater primarily for the needs of the accounting process, but the output from the system should be user friendly for ease of incorporation into other company management systems. Part of the system specification must include data collection, handling and reporting requirements, as well as reporting intervals, dates and timing, and the reporting rules and procedures for all data outputs. It must also specify the levels of authority required for approval and sign-off of the data.

The sampling specification must include a complete schedule of all samples required for metal accounting, including their frequency, preparation procedures, the analyses required and the analytical procedures to be used. The specification of the mass measurement requirements must include the mass measurement points, the type of measuring device required, the required precision of each measurement and provision for calibration.

The overall system specification must define the battery limits for the accounting process and stocktake procedures, to ensure that adequate provision is made for these in the plant specification and layout, and should also define training requirements for operating personnel.

Primary accounting allows for a material balance across the entire plant and is the objective of any metal accounting system. Provided the accounting period is relatively large, compared with the process residence time, a reliable mass balance can be carried out. Secondary accounting includes mass balances over specific circuits within a plant and provides information, which can be used to isolate the source of mass balancing problems and identify areas of process lock-up, time lags and measurement problems. The design of the metal accounting system should make adequate provision for secondary accounting measurements to reinforce the primary accounting data.

Mass and flow measurement must be repeatable to within defined error criteria, reproducible using different methods or equipment, and unbiased. The mass or flow measurement system must be selected to suit the specific application in question, and specified, designed, manufactured and installed to the appropriate guidelines that allow for safe calibration, operation and maintenance. They must be correctly operated and maintained, calibrated regularly, and certified by the appropriate authorities, or test facilities, as required. In particular, both mass measurement and sampling points must have easy access for inspection, cleaning, maintenance and routine operation. A facility should also be provided for diverting material into bins on load cells or into trucks for calibrating belt weightometers or into weigh or volumetric tanks for mass flow in conduits.

In the case of stockpiles, facilities should be provided to ensure that both the material fed to the stockpile, and the material withdrawn from it can be weighed and sampled. Twin stockpiles should also be provided to allow for each pile to be drawn down to zero regularly, to provide ongoing checks on the material in the stockpile. (The most effective measurement is obtained when the stockpile is empty.) In some instances, photogrammetry and surveying of stockpiles can be used to obtain an estimate of the volume of the contents, although the mass is subject to errors in bulk density estimation, while the best measurement of stocks in tanks or bins are, again, obtained when the tanks or bins are empty.

Static scales are the most accurate and precise method of mass measurement available and should be the first choice for all applications, wherever possible. These include road and rail weighbridges, platform scales, and gantry, hopper and bin scales. In-motion weighing is used in some instances, but the measurement is affected by truck speed. For this reason, in-motion weighers are certifiable for rail trucks but not for road trucks. Certification of both static and in-motion weighers could be a legal requirement for primary accounting applications, in terms of South Africa's National Metrology Act.

Second choice for metal accounting applications are electromechanical belt weighers, but their accuracy is dependent on their installation, which should be sufficient to allow a measurement accuracy of ±0.5% to be maintained at all times. Belt effects, such as tension, stiffness, and misalignment of the belt or its idlers, cause problems, as can the flexibility of the weigh carriage, operating with spillage on the weigh section, and errors in belt speed measurement.

Calibration errors and poor calibration techniques, incorrect belt loading, variability in the belt loading, changes in the material being conveyed and external factors such as wind, dust, excessive vibration and mechanical shocks can all negatively affect the performance of belt weighers and the installation must be designed so as to minimize the possible effects of these factors. Once installed and commissioned, housekeeping and maintenance must ensure that performance remains within specification. Again, the design of the system must facilitate housekeeping and maintenance.

Key requirements for the successful installation of belt weighers are installation in a horizontal and relatively short conveyor (<70 m). Ideally, there should be no curved sections in the belt on which the weigher is installed and there must not be any curved sections between the belt loading point and the scale. The belt must be in contact with all idlers on the scale itself, and with three approach and three trailing idlers at all times. The conveyor belt must be endless, with any joints spliced, and must be sized to ensure 80% volumetric loading capacity, while the scale itself must be between 6 and 15 m from the belt loading point. Finally, the layout of the installation must allow for calibration of the weightometer with chains or weights, and check weighing by bulk material test, using a weigh bin or weighbridge. These requirements are specified in various national and international standards.

All these weighers will measure the wet weight of the material if it contains moisture, as is usually the case, and the correct determination of the moisture content of the material weighed, is as important as the mass measurement.

Where the flow rates of solution or slurry streams have to be measured for metal accounting purposes, electromagnetic flow meters are most commonly used. Their accuracy is affected by changes in the material being measured, such as particle size, mineralogy, velocity and magnetic constituents. The density measurement associated with the use of these flow meters introduces a further source of measurement error. Typical accuracies of these instruments vary between ±0.2 to ±1.0% on solutions and ±0.5% on water. Accuracies on slurries are not as good, but these remain the most suitable instruments for measuring slurries, provided the fluid component of the slurry is conductive. A variety of other flow meters are available, but their use is usually limited to specific applications. Initial calibration and certification of flow meters should be performed according to ISO 4185, or its local equivalent. Regular volumetric or weight calibration, utilizing the actual material being measured, is essential and the design of the system should include a diversion system with calibrated weighing tanks for checking purposes.

Most flow meters measure the volume flow and thus a measurement of the relative density of the stream being handled must also be carried out. This measurement is often a major source of error and again the ability to calibrate on the actual material is required.

There are various guidelines available from suppliers and in national and international standards, which should be followed in the selection, specification and installation of flow meters in order to be able to achieve the required accuracy.

Sampling is covered in a separate paper in this workshop. However, reference sampling should be performed on conveyors by stop-belt sampling and on slurries by cross-stream sampling. For cross-stream sampling the sample cutter must be non-restrictive and self-cleaning. The geometry of the cutter opening must allow for equal cutting times at each point in the stream. If the cutter travels in a linear path, the cutter edges must be parallel, and if the cutter travels in an arc or circle, the cutter edges must be radial. Installation of the sampler must not allow any foreign material to enter the cutter (especially in the parked position), which must intersect the stream being sampled in a plane normal to the mean trajectory of the stream, and must travel through the stream at a uniform speed. The cutter aperture gap must be not less than three times the nominal top size of the material being sampled, with a minimum size of 10 mm, and the maximum cutter speed should be 0.6 m/s.

Analytical procedures for metal accounting purposes must be accredited to the ISO 17025 standard. Samples should be analysed in a duplicate twin-stream system, with different analysts for each stream. There must be adequate quality assurance and quality control procedures for the entire analytical process for metal accounting.

Data handling and management is an essential part of the system design. Computerized databases are preferred and the use of spreadsheets must be avoided as far as possible, to eliminate any possibility of unauthorized changes to the accounting data. The system must incorporate clear audit trails, with a clear documentation system, and must provide for data reconciliation, using appropriate tools and software, and must specify clearly the data approval framework.

In summary, the metal accounting system must be designed and specified as part of the overall plant design specification. It must include the design of the data acquisition and handling system and the entire design should be approved and signed-off by a competent person, before it is approved for installation. Operating, management, and laboratory personnel must be fully trained in all aspects of the system and must be involved in the design and specification of the system, and all shortcuts or cost savings at the design stage must be avoided, as these can be very costly in the long-term.

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