PLANT AUDITING

A Powerful Tool for Improving Metallurgical Plant Performance

BY DEEPAK MALHOTRA

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To my wonderful wife Jyotisna and daughters Ruchi and Anisha who have been patient while I was away auditing plants worldwide.
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If this sounds familiar, we are talking about the mineral industry. Mining companies are in the business of making an acceptable profit on their investments. The mining community recognizes that it is necessary to continuously strive for lower unit production costs and increase productivity and revenue in light of declining ore grade to compete in the global market. The burden of achieving this objective falls on the plant manager. He or she must strive to produce a salable product in an environmentally acceptable manner while continuously improving profit margin.

Companies must simultaneously enhance revenue and reduce operating costs to remain a low-cost producer in the long run. This involves continuous evaluation of technologies and reagents, periodic audits to locate
revenue losses, and gathering and analyzing statistical plant data to facilitate a clear understanding of the impact of process variables on efficiency.

Mineral companies are caught in a catch-22 situation. They need resources (i.e., trained personnel, time, and money) to accomplish their objectives in a cost-effective and timely manner. Most mill staffs were cut to a minimum level to maintain production during the recent period when metal prices were low. Resources such as time, personnel, and money are scarce, and mill managers and metallurgists struggle to use these limited resources productively.

Both evolutionary and revolutionary changes have enhanced metallurgical performance in the past. Will they continue to do so in the future? How much more improvement can a process engineer achieve from an efficiently operating plant? One visionary metallurgist defined an ideal plant to be one that achieves 100% recovery at 100% grade and zero cost. Is it possible? Definitely not. However, it is a worthwhile goal (or challenge) for a metallurgical engineer to pursue.

A metallurgical engineer needs several tools to make his or her job more efficient. He or she not only needs management support but must also have training in problem identification, data analyses, and problem-solving techniques. It is mandatory that the engineer understands basic economic concepts of capital and operating costs, depreciation and depletion, and cash-flow analyses. Other activities that he or she must be familiar with include team building, team participation, and resource management. The term resource implies people, money, and time in the present context.

Since mining companies have gone global, understanding of cultural issues will help the engineer to be better prepared to work worldwide. Understanding technology transfer issues are equally important in helping the process engineer do an efficient job in performing meaningful audits.

This book is based on experience gained during the last 30 years auditing plant operations worldwide. The formal methodology was developed over a period of time and has been implemented successfully in improving plant operations. The book provides managers and engineers associated with all fields of mining (geology, metallurgy, environmental, etc.) and senior executives with an overview of systematic methodology used in plant auditing. It addresses the types of audits as well as when, where, and how to audit the plants. The book covers the systematic approach for
global and specific audits. The same methodology can be used in any field to improve operations.

“Hit and miss” methodology for plant optimization has been practiced by metallurgists for decades. **PART 1** of this book presents methodologies for plant auditing as a formalized procedure that encompasses all the aforementioned tools to help the metallurgist in achieving his or her goals. **PART 2** illustrates through case studies how plant auditing can be successfully used to make significant improvement in plant operations through the evolutionary route. Most of these examples are real-life problems encountered by the author.

**ACKNOWLEDGMENTS**

The concept of developing a systematic approach to plant audits started more than 30 years ago when I was troubleshooting at the various plants owned by Amax Inc. Over the years, I realized that one could learn from everyone you meet and I am fortunate to have had so many mentors. They have helped me to develop the ideas and formalize them into systematic concepts. Thanks are extended to Bill Horst, Keith Wick, Jim Johnson, Jose Roco, Len Harris, and so many other individuals too numerous to mention here.

And finally I thank my wife Jyotisna, who has stood by me for 39 years, helping and supporting me in all my endeavors. She has assisted in revising the manuscript several times over the last decade.
This section of the book provides a formal definition of audit and audit categories. It discusses why, where, and how the audit should be performed. The plant auditing methodology consisting of a formalized nine-step approach is discussed in detail to provide the reader with a good understanding of the requirements for a successful audit. In addition, a brief overview of economic principles and management of resources, which are key to success of audits, is also presented.
CHAPTER 1

THE PLANT AUDIT

THE ECONOMIC PROFITABILITY of any mineral company is dependent on maximizing mineral recoveries while minimizing operating costs. The effectiveness of any strategy to meet this objective is dependent on first obtaining quantitative information at steady-state plant operation and then efficiently using this information to improve or optimize plant performance.

Plant improvement or optimization starts with a plant audit. If one believes there is room for improvement, the benefits for plant auditing can be significant and are often measurable in terms of improved recovery, grade, or throughput and decreased operating cost.

The formal plant audit as a recognized engineering function is still in its infancy. It has been and will continue to be used informally by metallurgists to improve operations. Management wants to know how to quantify the potential benefits of this approach. In that regard, plant auditing today is in a similar position as process control was in the 1970s.

*The plant audit can be a management tool that identifies the strengths and weaknesses of the current operation and provides a road map to future improvements. In fact, an audit should be mandatory for management seeking improved profitability.*

The reality of market conditions (of low metal prices on a cyclical basis) has caused mining company management to severely cut the technical staff at mining properties. Plant metallurgists and superintendents must devote all their working time toward meeting production goals. There is little or no time for reflection nor a moment to ask the question: “Are we doing as well as we can?” Plant audits undertaken by persons outside the local management offer an independent and unbiased review of current plant practice.
DEFINITION OF AUDIT

Audit is a very commonly used word in the English language. Although it is a well-respected activity in the accounting profession, it has a negative connotation for most people. The unpleasant association is due to the abuse of the audit process. It has frequently been used for assigning blame. Audits should not threaten local management staff. All operations can be improved. Senior management should not use results of an audit to punish the plant management.

Metallurgists have raised their concerns regarding use of the word audit. Several suggestions for use of alternative wording have been made: diagnosis, evaluation, review, appraisal, and so on. Do these words change the primary objective of the task? This author believes they do not. Therefore, it is appropriate that the formal definition of audit be reviewed to understand the nature of what is implied.

Audit has a myriad of meanings, depending on the use and the application involved (Mills 1989). Several definitions include the following:

- A human evaluation process to determine the degree of adherence to prescribed norms (criteria, standards) and resulting in a judgment.
- A formal, often periodic examination and checking of accounts or final records to verify their correctness or any thorough examination and evaluation of a problem (Merriam-Webster Dictionary 2003).
- A formal examination of accounts with verification by reference to witnesses and vouchers or to make an official systematic examination of accounts (The Oxford English Dictionary 1989).

These definitions contain several key words and/or phrases including formal, verify, and norms. There are implications associated with them.

The word formal or official implies that the audit function must have a recognized position in the hierarchy of the organization. The audit must also be systematic. Hence, it should be a well-planned and organized activity.

The second key phrase is “checking of accounts or final records to verify their correctness” or “verification by reference to witnesses and vouchers.” This implies that both people and records must be involved. The word verified requires that findings must be based on factual information and not hearsay evidence or assumptions.
The third phrase, “prescribed norms,” implies that criteria must be available to which findings can be compared. How can one make a judgment if criteria and/or standards have not been predetermined?

Based on these definitions and implications of key phrases, it is reasonable to conclude that an audit is concerned with the methodology as well as the results of that methodology. The output of an audit is a report giving observations and, very often, recommendations for specific corrective action.

A properly planned and conducted audit should be a positive and constructive process. It is a management tool, not a weapon, and should be used to determine where a plant is with respect to standard norms.
AN AUDIT CAN BE USED WITH A LARGE NUMBER OF MODIFIERS OR PREFIXES like financial, analytical, geological, environmental, mining, quality, plant, and so forth. Hence, depending on the application and user, the word audit has a myriad of meanings. For example, to an accountant, an audit means a review of financial accounts to verify their correctness with respect to established norms; to a geologist, it means investigating proven and probable ore reserves, cut-off grades, and so forth.

The types of audits generally associated with the mining industry are shown in FIGURE 2.1. A property audit encompasses one or more of these areas, depending on the objectives of the study. Several elements have to be addressed under each category. TABLE 2.1 lists some of the important factors for each category. This list is for illustrative purposes only and does not include all the factors that should be addressed in each area (Malhotra and Baltich 1989a, 1989b).

One of the commonly used and very effective methodologies for audit is the function-tree approach where the major components of the audit are broken down into various subsections, as illustrated in FIGURE 2.2 for a processing plant. A component of the processing plant, namely process metallurgy, can again be subdivided into various components as illustrated in FIGURE 2.3. The process parameters can be further subdivided if it can be beneficial to the audit.

The discussions in this document are restricted to the processing plant since the main objective is to provide a systematic approach to plant auditing for enhanced metallurgical performance. The approach is generic in nature and can also be used for other categories of auditing.
Geological/Resource Audit
Mining Audit
Processing Plant Audit
Environmental Audit
Safety and Health Audit
Marketing Audit
Economics or Accounting Audit
Quality Control Audit

FIGURE 2.1 Categories of a property audit
### AUDIT CATEGORIES

**TABLE 2.1 Elements of a property audit**

<table>
<thead>
<tr>
<th>Category</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geological/Resource</td>
<td>Ore reserves, Ore grade, Cut-off grade, Major impurity, Mineralogy and mineral associations</td>
</tr>
<tr>
<td>Mining</td>
<td>Mining methods, Overburden ratio, Mining capacity, Dilution</td>
</tr>
<tr>
<td>Processing Plant</td>
<td>Plant capacity, Work index of ore, Product yield or recovery, Product quality, Chemical reagents, Equipment efficiency, Tailings characterization</td>
</tr>
<tr>
<td>Environmental</td>
<td>Dust control, Working environment, Hazardous chemicals, Guards on equipment, Water seepage, Emissions, Air pollutants, Water pollutants</td>
</tr>
<tr>
<td>Safety and Health</td>
<td>Training, Hazardous chemicals, Tailings disposal</td>
</tr>
<tr>
<td>Marketing</td>
<td>Transportation to market, Product markets, Specifications, Substitutes</td>
</tr>
<tr>
<td>Economics or Accounting</td>
<td>Operating cost factors, Revenue, Profits, Sensitivity analyses</td>
</tr>
<tr>
<td>Quality Control</td>
<td>Product specifications, Feed specifications, Process specifications</td>
</tr>
</tbody>
</table>
FIGURE 2.2 Elements of a metallurgical processing plant audit

FIGURE 2.3 Elements of process metallurgy
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