

# Improving Metallurgical Performance: Advances in Operations and Production Management

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## ABSTRACT

Profitability of mining/metallurgical operations is less than other industries despite the technical advances in the recent years. The lack of integration of mining and metallurgical information at sufficient detail to act is a problem. Without such data, mine cut-off grade can not be optimized on a per grade basis. It is difficult to determine economics without integration of mine transactions, stockpile inventories, process flows and assays. Actions also require real time information from manufacturing assets, but corrected for gross errors from trucks, shovels, conveyors, faulty sensors, bad instrument calibration. Validation methods must include process models to identify corrupt actionable information. This paper presents new tools that use the model the process to sift through available data, identify and eliminate gross errors, and use statistical data reconciliation to create material balanced, internally consistent values. Uses of models allow data to be unified for use by both monitoring and decision making processes.

An agreed set of data from individual measurements is created by using material balances. Redundant mass flow information is inferred from changes in shipments, receipts and inventories obtained from the transactional records of a facility such as bills of lading, pipeline transfers, and inventory observations. This redundant information is analyzed using statistical techniques and the plant topology model. On-line gross error detection and elimination methods are required to ensure efficient evaluation of process performance. Unified data is only the top level – detailed information a click away is fundamental for finding of the root cause of problems and to reduce overall operating costs.

A Real Time Performance Management (RtPM) uses unifying analysis methods to empower everyone in the organization with unparalleled real-time intelligence, enabling them to continuously improve performance.

## **BACKGROUND**

Extraction of metals has become a global business; new economic and environmental forcing factors are present today which were unheard a couple of years ago that are causing companies to focus on plant operations. High ROI actions can be achieved internally which will increase mining and metallurgical processing unit efficiency and reducing operating costs if the proper information is provided those in the complex that can act. Large changes are possible with many of these small steps if the barriers for action are removed. The chief impediments are lack of infrastructure including the data, computing tools and essential data and bad information.

Increased demands will be placed on the types, quantity and priority of information. Metallurgical complexes are attempting to become better neighbors, increase productivity, improve customer service, and satisfy the regulators and compliance groups -- all with fewer people and less costs.

Enterprises have invested enormous time, resources and money to implement a wide range of systems to manage their operations, from Enterprise Resource Planning (ERP), to Supply Chain Management (SCM) with great promise. Some of these systems showed strong early results but all had a plateau effect. Extracting incremental value from is difficult as they automated the business processes and made them rigid, changes require additional consulting cost.

Companies have also refined, tweaked, and upgraded their Distributed Control System (DCS) and Programmable Logic Controllers (PLC'S) to maximize throughput and deliver products according to their master schedules. Many systems have been integrated and networked, enabling a step up in manufacturing metrics to be reported back to the enterprise systems.

As a result, an enormous amount of data has been warehoused. Most companies have considered data mining and business reporting solutions that would enable executives to be more effective in their roles. The return on these projects also has tended to flatten out over time.

The system in the middle, a plant information system, automates the collection and archiving of information from the controls systems, departmental systems and ERP systems and collects data from the mine to the tailing pond and also the common systems (power plants, water plants and environmental systems). With consistent information access from all areas an organization can enable collaboration between all employees to develop a responsive, aware company required for global competition.

This collaboration supports key business opportunities such as faster decision making, improving plant understanding, empowering individuals, stimulating innovation, and linking operational data and business systems. Observations become actions and these can improve operating efficiency, increase generation revenue, improve manpower productivity, optimize maintenance strategy, and improve compliance with production

constraints without required a new project or more consultants, but as people become removed from the source, better data validation is mandatory.

This paper highlights current information technologies that are being applied in the development of enhanced dynamic performance monitoring systems and integrated workflow systems with emphasis on ways to improve the quality of the data without losing the ability to “drill down” to the raw information.

## **REAL TIME PERFORMANCE MANAGEMENT PLATFORM**

Operations have endeavored to improve aspects of their businesses for years. ISO 9000/14000 is a standard for changing business processes specifically to improve quality; Process Safety Management (29CFR1910.119) is a congressional requirement specifying how a company processing highly hazardous materials can install a system to change their business processes specifically to improve process safety. These are both continuous improvement standards and represent a commitment not a project. RtPM is that same technique but designed to change business processes to increase profits.

All business processes and the software that supports them must incorporate continuous improvement capabilities. This is a key differentiation between the traditional Process Information Systems (PIMS) and the much less common Process Management Systems. A traditional PIMS is open loop. Information is gathered into databases and disseminated as reports and on-line inquiries to all requesters, and the system’s responsibilities end. This system has not looked at the sharing the information to transform its knowledge **for action** and could not support this more aggressive approach. The industrial desktop based on a graphical programmable interface is central to the development environment. A Process Management system is closed loop. It encourages people to take reasoning based actions and provides the tools for action changing the individual from a fire fighter to a proactive worker that can analyze, make discoveries about the plant and business processes and, most importantly, implement his/her findings.

Real Time Performance Management is the system that supports continuous improvement of profits. This is quite different than Enterprise Performance Management (e.g. balanced scorecard) which is also targeted at continuous improvement of margins but is driven from transactions instead of real time events.

The business drivers for performance management are compelling. Among them:

- Collaboration throughout the extended enterprise, including global resources, suppliers and customers
- Empowering individuals to make profit-contributing decisions at all levels of the organization
- Closing the loop between active planning and goal setting, and actual execution in real time
- Bridge centralized and decentralized organizational structures

Integral to a modern implementation is dependent upon informed and enabled workers and management of the continuous improvement process. These require applications that gather, analyze and deliver timely and appropriate information to individuals throughout the organization either on the LAN or on the Internet (or both) as a real time portal.

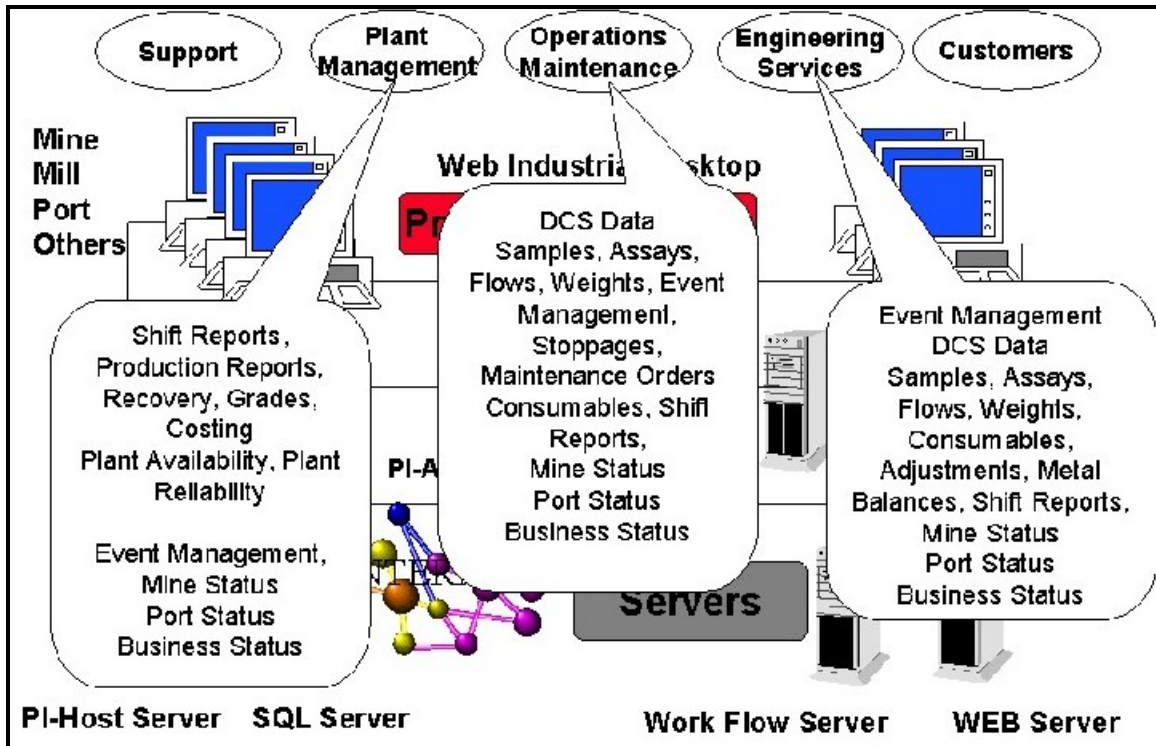


Figure 1. Empowering People to Access their Information According to their Roles and Responsibilities.

Figure 1 shows the typical types of information required by the plant people and executives. Each of them requires a different context on the data requirements, but until recently, engineering, operations / maintenance, management and others could access the information only in one direction (vertical) and in one way. The key is to enable an organization to manage processes with multifunction access (horizontal) as defined by Bascur and Kennedy (2).

A user needs access to the content but both in an overall or aggregated view and a detailed view in order to create the desired user experience. The “dashboard” must also be able to disseminate information securely to those that need it at the time they need it regardless as to its source. In all industry, information is held in a many disconnected systems instead of a single, monolithic system and these systems also must expose services in order to effect performance management. Integration that uses only data links to gather their information and events for the portal are view only and not complete performance management.

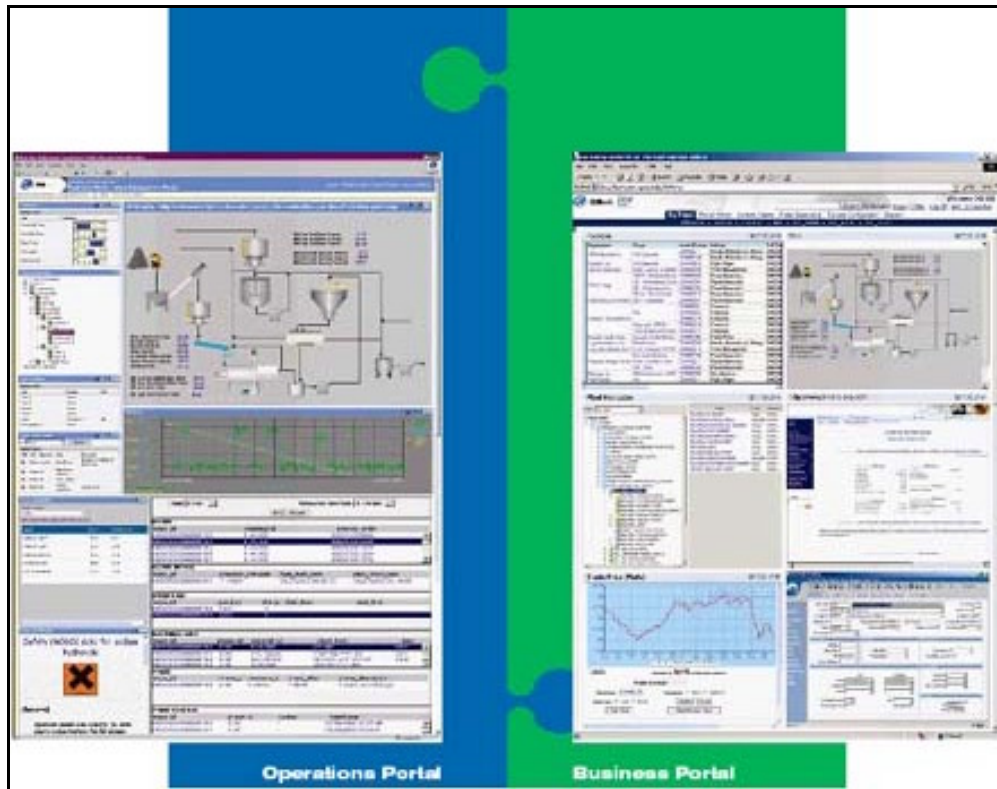


Figure 2. Example of an Operational and a Business Portals

RtPM is an events-driven platform that delivers unified, role based portal views across the enterprise for executive, management, engineering, operations and business administration. By tying together manufacturing and corporate system, the RtPM Platform unearths the buried knowledge that's to empower better, immediate decisions that can significantly impact the bottom line.

RtPM is a real time portal and a platform for software applications that gathers and transforms the real time and enterprise data and events, through a series of contextual and analytical tools, and presents it timely, relevant information to individuals to make decisions. It also must have access to services from the departmental systems that can effect actions.

The main aggregation of information is in the form of Key Performance Indicators (KPI'), which are used as a measure of the overall performance. When those KPI's embody real time manufacturing events and data, individuals from line operations, supervisors, plant managers and executives can collaborate to evaluate the actual performance either by actions or additional programs. This enables and empowers individuals to make role-based decisions; the collection of these decisions will return large benefits over time. This is the true power of continuous improvements.

The portal strategy allows executives and business managers to participate in the evaluation of the plant KPI's via the Enterprise Portal, while operations personnel

evaluate them through the Operational Portal. Figure 2 shows two typical portals for operations and for management. Information is presented based on their roles and adapted by their functions.

The implementation of RtPM, the transformation of raw data and events to actionable information, is depicted in Figure 3 below, called the Implementation Pyramid as described by Kennedy (5). The process begins with a large amount of data and ends with visualization and a call to action.



Figure 3. Implementation Pyramid

Gather Data and Events from disparate sources. The data-gathering problem is driven by the scope of the optimization. Connectivity to ERP (Enterprise Resource Planning) and other structured and unstructured data sources provides context for grouping and aggregation of raw business data using the OSIsoft RLINK. It supports the integration of PP-PI, PM, QM, and MM for the operations people while providing SAP applications access to the plant data via PP-PI and the Generalized Message. Besides the ERP data, there are multiple DCS and SCADA systems, PLC's and handheld terminals; there is also information from train and truck scales, vehicles, pipelines, blenders, and other plants. To complete the picture, the systems need information external to the plant such as energy and raw material pricing information, weather, and other data sources from the web, data from Laboratory Information System (LIMS), Computerized Maintenance Systems (CMMS), ERP Systems and Process Information Systems (PIMS).

Putting Data into a Contextual Frame of Reference. Information as it comes from the DCS or SCADA is unintelligible to management and must be put into their frame of reference. This involves building hierarchical data structures, i.e. arranging data by areas, units, equipment, or by feeds/products types, so that people can easily find the required related information. Other context that may be considered might include: campaigns, benches, seams, heats, batch, lot, run, material transfers.

Analysis. There are many forms of analysis ranging from real time calculations to aggregations (e.g. daily, monthly), to complex model based computations (e.g., material balances, reconciliation). Analyzing tens thousands of data points in real time is quite required. For example, trucks, compressors, belt conveyors, turbines, heaters and other

rotating equipment might need calculations running on a one second basis to assess performance and insipient or actual failure. As we bring the data up to the management level in real time, the data must be validated so people can trust the information they receive and can make profitable decisions.

Distribution. Once data has been put into context, validated and analyzed, the resulting information must be distributed to those that need it in a timely fashion. For example, as soon as a non compliance event is detected it has to be disseminated to the responsible personnel in order to minimize the problem.

Visualization. Visualization includes graphical representations, trending, charts, and the ability to drill down to find root cause and data at the original resolution. OSIsoft delivers this visualization across the Internet via PI Interactive Configurable Environment and on the LAN via ProcessBook.

Action. Actions are needed at all levels, not just the operator at the plant floor or the senior management. All people are empowered by tailoring the visualizations to their roles and responsibilities. These actions are aligned with the business structures and rules defined by the strategic plan of the enterprise.

## **BOTTOM LINE, YIELDS AND INVENTORY MANAGEMENT**

This section provides details of the Contextual Frame of Reference and the Analysis steps of the Implementation Pyramid. It also discusses the distributions and presentation of the results to a large audience via the Web. One of the biggest challenges to process plant management is the accumulation of accurate information on process operations. This information is necessary for any analysis and decision-making within the plant and enterprise. Therefore, there is a requirement for meaningful, accurate and consistent data.

Material balances calculated from data measured at various locations around process units, tanks inventories, stockpiles, silos, bins, and assays are useful for many purposes, such as yield accounting, on-line control, and process optimization (catalyst selections, reagent schemes, liner replacements, water management, utilities management). To achieve material balances, gross errors or anomalies in the production data must first be classified, detected, and the source of the data examined.

Often, it is possible to calculate material balances by several independent procedures when excess measurement information, i.e., redundant data, is available. Clearly, if the data were collected without measurement errors (a theoretical condition never found in practice) all material balances calculated from redundant data would be in agreement. The real situation is that errors exist in practical measurements, so that the results of material balances determined from available optional procedures differ. Consequently, best-fit computational procedures to adjust the material balances by taking measurement errors into account can be implemented as suggested by Bascur and Soudek (3, 4).

In this case, the application framework is used to develop a process flow diagram connecting flow meters, tank inventories, stockpiles and composition analysis for the

defined streams. A plug-in for data reconciliation and gross error is used to perform the calculations.

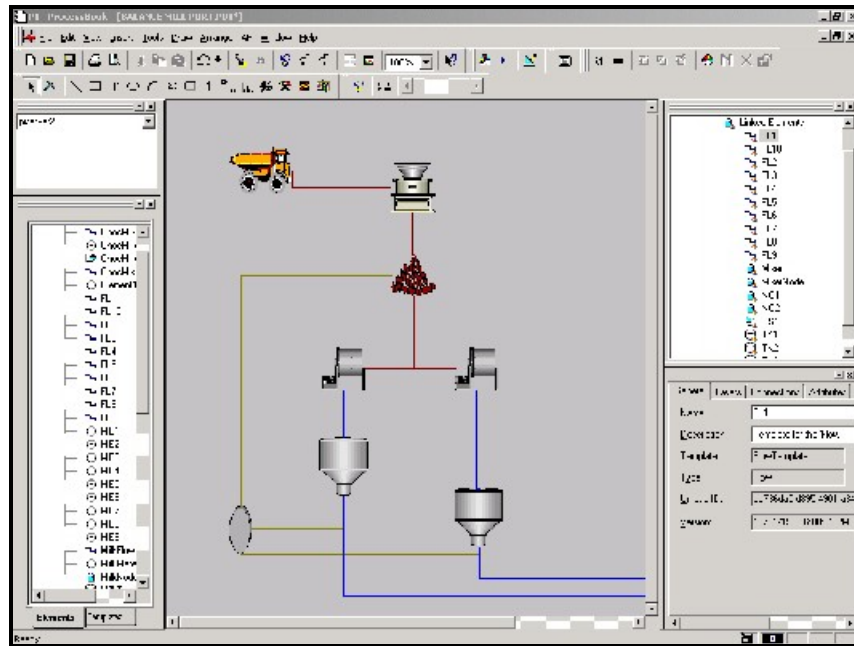


Figure 4. The Application Framework using PI Modeler Add-in.

Figure 4 shows the process flow diagram a mineral processing plant. The PI Application Framework and PI Advanced Calculation Engine assists in organizing and formulating the analysis requirements. Once the process topology is defined, the Sigmafine plug in can be used to reconcile the data from inventories, flows, and compositions. New advances in technology enable to perform metallurgical balances of integrated industrial plants. As such, Mine, Concentrator, Smelter, Refineries and Special Treatment Plants can be solved simultaneously to track metal values. The metal losses in tails, slag, and dumps can be calculated.

Figure 5 shows the results in a WEB environment for access by management, personnel and external resources. A thin client called PI Internet Configurable Environment (PI-ICE) enables any one with a browser and a security password to access the information in real time. These mine/mill/port metallurgical balances are performed interactively by process, accounting and metallurgical personnel. In these applications considerable conventional errors has been detected savings metal losses and optimizing the metal recovery process.

In addition to the unified yields and inventories, the total variable costs associated with the processing of the ore for a certain block can also be included. The real time information will access the associated consumables during the period of time when this ore type was processed. Analysis of the metallurgical performance can be performed linking the grade/recovery with the grinding/blast strategies. At the same time equipment downtime and equipment availability can be incorporated for the assets. Real time based

costing emerges as a reporting exercise when the proper application framework for real time information management is used. This integrated approach enables collaboration between operations, engineering, accounting and management to drive the organization's bottom line according to their business strategy. At the same time personnel can look for opportunities using alternative processing methods and strategies (grinding efficiency, reagents, and blasting methods) to adapt to the changes in ore type to produce the least cost concentrates.

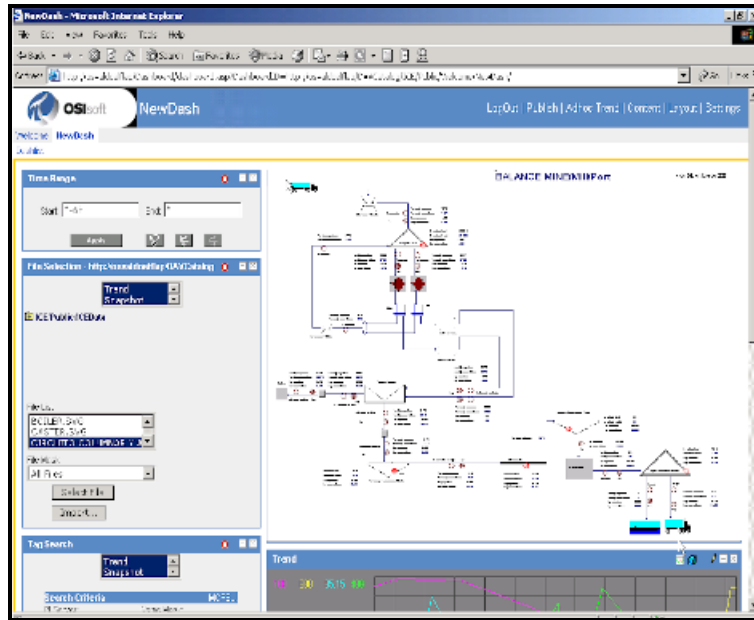


Figure 5. Web browser showing real time performance indicators such as yields, inventories, asset availability.

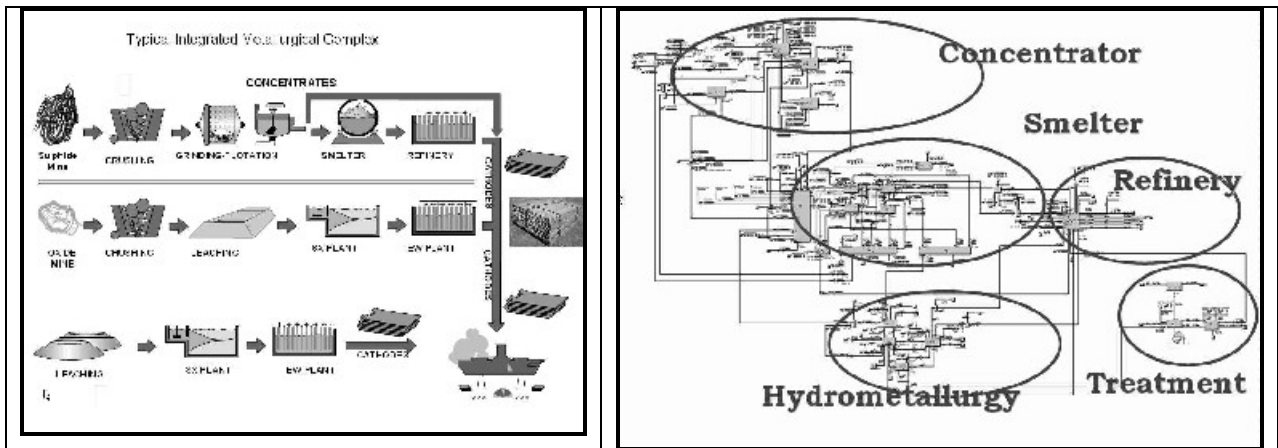


Figure 6. A Typical Integrated Metallurgical Complex Model using Sigmapine

Figure 6 shows a typical integrated metallurgical complex. Several plants are integrated from the mine, concentrator, smelter, refineries and other treatment facilities. The data analysis tool is used to validate the set of inventories, flows, compositions and transactions using Sigmapine. Gross errors are identified. These events require the

collaboration of process engineers, accountants and plant managers to identify the sources of errors or correct operational problems. Recoveries and grades are obtained as well as the consumption of materials used in production. Metal losses are calculated based on the set of data provided. The people integration with their system was described by Bascur and Kennedy (1, 2).

## **CONNECTIVITY TO ERP SYSTEMS**

The SAP-certified RLINK gateway to R/3's PP-PI, QM and PM modules reduces enterprise integration costs. The result is a standard R/3 configuration that enables process engineers and management to leverage production information. RLINK supports Microsoft and SAP standards to provide organizations with all the information needed to make profitable business decisions:

- Asset Efficiency—operating to capacity and maximizing equipment uptime with timely, condition-based maintenance using operating hours, number of starts, and alarms (e.g., temperature, pressure, vibration) to trigger maintenance
- Increase Profits—plant control systems don't have access to data required to optimize profits like material costs, energy costs, market demand and prices for finished products
- Enhance the level of coordination and collaboration between manufacturing, maintenance and logistics business functions
- Analyze tradeoffs to satisfy business objectives of reducing operational costs and inventory, improving delivery reliability and response time, and service to the customer
- Cycle Time—reduce time from product order placement to customer delivery
- Available-To-Promise—provide reliable delivery date to customer (i.e., when order is taken) based on real-time view of finished goods inventory, production plan, raw materials, etc.
- Reduce magnitude and complexity of production management reporting
- Overcome problems associated with manual entry: data entry is slow and error prone, manual calculations are often required, limited volume of data that can be handled

R/3 must be notified when problems occur in manufacturing as described by Stengl and Ematinger (9). Without a real time connection, R/3 may only recognize a problem when it's too late (i.e., if product is not shipping). Reacting to problems is inefficient, so critical plant events must be escalated to R/3. As companies move to an E-Business environment integrating suppliers and customers over the web, greater demands will be placed on internal coordination between manufacturing and sales. RLINK enables companies to react to unplanned manufacturing events. Therefore, companies will be required to provide a more timely and accurate view of manufacturing to the ERP system to compete in the E-Business world.

## **PM Module**

The R/3 PM (Plant Maintenance) module tracks maintenance history and schedules maintenance activities. PM supports measurement points and counters for each piece of equipment that will be maintained based on actual data from the plant. That equipment is also monitored in PI and RLINK to calculate the runtime (measurement counter) or determine alarm conditions (measurement point) that should be sent to R/3. The PI-Alarm subsystem detects that an alarm (e.g., high temperature) has occurred and RLINK passes the alarm to SAP. This creates a measurement document and an optional maintenance notification. The measurement document and the notification number are returned to RLINK and sent to PI for analysis with production data.

The information collected in the substation operator's weekly inspection is a critical component of the maintenance decision-making process. Abnormal values or conditions found during the weekly inspection are used to create a maintenance notification in SAP for follow up via a corrective maintenance work order. Counter readings on transformer tap changers and circuit breakers are used to trigger preventive maintenance activities in SAP. This enables a company to move from a calendar based maintenance program (such as maintain every 4 years) on circuit breakers and tap changers to an operations based maintenance trigger (such as maintain every 10,000 operations for transformer tap changes). PM notifications are also generated based on rate of change conditions for the tap changers (i.e., too many or not enough in a given period). For circuit breakers, if the quantity of gas added is more than 5 lbs and less than 10 lbs per month on average over a 6 month rolling period, then an outage is scheduled to repair the seals. Transformer temperature readings on top oil and hot spot are used (along with other information) to assess the transformers ability to carry rated load.

## **REAL TIME INFORMATION MANAGEMENT INFRASTRUCTURE CASE STUDIES**

There are many examples where the requirements for process, laboratory, maintenance and business systems have driven the decision for data integration to empower the work force. Many simple projects are generated with high return on investment rather than a few isolated traditional projects. A few selected cases are described in the following paragraphs (6, 7). These were selected because of their objective to reduce maintenance costs and increase overall process effectiveness. In all cases, the customers integrated to their current maintenance system with the PI System (i.e., SAP PM, J.D. Edwards, Maximo, MIMS).

### **Situation 1: Large South American Mine/Mill/Pipeline/Port**

Critical Issues:

- Decreasing Ore Grades
- Operating costs 30% due to maintenance costs
- Compliance with Production and External Constraints
- Management concerns with existing systems

Capabilities needed:

- Integration to all existing DCS, MMI's and PLC's and business systems
- Engineers should have data for fast process troubleshooting and root cause detection
- Remote view of key performance indices
- Access to process data by all personnel (operations, maintenance, engineers, planning, and managers)
- Easy access to historical information using MS Office

Capabilities Provided:

- Integration of Mine/Mill/Port real time data with SAP PM module
- PI data is available at all locations
- PI linked to SAP PM using RLINK gateway
- Integration of operational data from Mill/Concentrators DCS, PLCs, Analyzers,

Lab Systems

Results:

RLINK PM has been operating since July 2001. They have installed RLINK PM to integrate these systems to pass equipment maintenance parameters between the new business system, the mine and the processing plants. This integration provides the ability to generate maintenance notifications from any of these systems manually or automatically.

Currently, 180 pieces of equipment from the mine and 500 pieces of equipment from the ore processing plant are configured in RLINK. Notifications are created in PM based on asset hours, failure codes, and GPS positions. In addition, RLINK provides valuable maintenance parameters for equipment failure assessment and maintenance planning. This was critical since maintenance is normally 30% of the annual cost in an asset intensive industry like mining. Any percentage savings has significant economic implications.

## **Situation 2 Large Copper/Gold Metallurgical operation**

Critical Issues:

- Green field site
- Reduce Production Costs
- High Variability of ore characteristics
- Remote site

Capabilities needed:

- Integration of Mine System, Concentrator DCS/PLC's, Maintenance and Production Systems
- Fast track implementation of performance monitoring and analysis
- Real time information access of mine, concentrator, pipeline at the desktop for all functions

Capabilities Provided:

- Total hours and tonnages are automatically sent to maintenance system.
- Automatic generation of work orders for predictive maintenance is based on asset conditions.

Critical asset lubrication planning and control using real time information  
Integration with Mining System providing critical ore data for each truck  
dumping ore at the stockpile. Information is used for real time metallurgical  
planning based on ore characteristics.  
Simplified metallurgical statistics providing production, chemical analysis, size  
analysis, yields and inventories  
Equipment and Process Control Event State Management

Results:

Increased nominal production rates by more than 20%  
Increased equipment availability  
Enabled Mine/Mill optimization  
Cost management. Tracking grinding mill relining and ball consumption  
No need for specialized programming to generate real time graphical displays or  
reports  
Implemented a real time plant wide water management  
Implemented a real time reagent inventory and purchasing system. Automatic  
purchase order and shipments

## CONCLUSIONS

Companies are using information architecture as a strategic weapon enabling agile operations. Microsoft servers and desktops with the .NET framework create a familiar base on which web services can be implemented and consumed in heterogeneous computing environments. Having robust and extensible PIMS, ERP and CMMS are necessary to run behind the Portal and other integrated applications.

Making profitable, intelligent business decisions is complex process, made easier through RtPM strategy. A robust environment provides with real time, historical process/equipment information and business information for all functions in Metallurgical Complexes. This environment enables users to build, construct and maintain their views of their business operations for simplified performance management, process and equipment troubleshooting, continuous improvement and innovation.

A methodology based on adding the process structure (plant topology) and knowledge of the measurement system and its strategic locations will minimize the global error based on satisfying the material balance constraints. Process topology is the key for implementation of variable costs management; yield accounting; dynamic process and equipment performance monitoring, downtime analysis and asset monitoring.

In general the results can be summarized as follows:

Improved quality and speed of plant monitoring and diagnosis  
Optimizing plant efficiency performance (by continuous improvement and innovations)  
Condition based maintenance  
Improved production and regulatory information

Consistent and comparable information across the enterprise (benchmarking).

Companies have produced a suite of applications to bridge the gap between plant control systems and company business systems. The enabling information management systems are used throughout the company to provide the platform on which these applications rest.

## GLOSSARY

CMMS – Computerized Maintenance Management System  
COM – Microsoft Component Object Model  
DCS – Distributed Control System  
DNA – Microsoft Digital interNet Architecture  
ERP – Enterprise Resource Planning  
KPI – Key Performance Indicator  
LAN – Local Area Network  
LIMS – Laboratory Information System  
MMI – Man Machine Interfaces for Control  
PLC - Programmable Logic Controllers  
RDBMS – Relational Data Base Management System  
SCADA – Supervisory Computer and Data Acquisition System  
WAN – Wide Area Network, Enterprise Network  
WWW – World Wide Web

## REFERENCES

1. Bascur, O.A. and J. P. Kennedy, “Industrial desktop - information technologies in metallurgical plants,” Mining Engineering, 1996, September.
2. Bascur, O.A. and J.P. Kennedy, 1995, “Measuring, Managing and Maximizing Performance in Industrial Plants,” XIX IMPC Proceedings, SME, Littleton, CO.
3. Bascur, O.A, and Soudek, A., “Improving Metallurgical Performance: Data Unification and Measurement Management”, Proceedings VI SHMT, Rio de Janeiro, 2001, pp. 748-755.
4. Bascur, O.A, and Soudek, A.,”Integration of Mineral Processing Operations via Data Unification and Gross Error Detection”, International Autogenous and Semiautogenous Grinding Technology 2001, Editors Barratt, D., Allan, M. and Mular, A., IV-34-47, 2001.
5. Kennedy, J.P., “Web Services and Enterprise Performance Management (EPM)”, NPRA Conference, San Antonio, TX., 2003.
6. Llao, M, “ PI Uso y Expectativas en la Industria Minera”, OSIsoft Technical Users Seminar, Buenos Aires, Argentina, 2001.

7. Luyt, C., "BHP-Billiton RLINK Plant Maintenance Implementation," OSISOFT Users Conference, Monterrey, CA, 2002.
8. Rojas, H., and H.M. Valenzuela, "Strategic Plan for Automation and Process Management at the Chuquicamata Mine," Latin American Perspectives: Exploration, Mining and Processing, Bascur, O.A., Ed., SME, Littleton, CO, 1998, pp281-292.
9. Stengl, B and R. Ematinger, SAP R/3 Plant Maintenance, Addison Wesley, New York. 2001.

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